West Lothian Geodiversity

Volumes 1 – 3

Geology and Landscape North Programme
Commissioned Report CR/06/008N

SCOTTISH EXECUTIVE

Lothian and Borders RIGS Group

SCOTTISH NATURAL HERITAGE

West Lothian Council

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

West Lothian Geodiversity

Volume 1 – Report

Geology and Landscape North Programme
Commissioned Report CR/06/008N

SCOTTISH EXECUTIVE

Lothian and Borders RIGS Group

SCOTTISH NATURAL HERITAGE

West Lothian Council

BRITISH GEOLOGICAL SURVEY

GEOLOGY AND LANDSCAPE NORTH PROGRAMME

COMMISSIONED REPORT CR/06/008N

West Lothian Geodiversity

Volume 1 – Report

H F Barron, M A E Browne and A Finlayson

Contributors

S L B Arkley, S M Clarke, A Matthewson, A Pickering ,

K I G Lawrie and E K Hyslop

Editor

D J D Lawrence

Keywords

Geodiversity; West Lothian.

Front cover

Five Sisters Bing, West Calder

Bibliographical reference

BARRON, H F, BROWNE, M A E, AND FINLAYSON, A. 2005. West Lothian Geodiversity. *British Geological Survey Commissioned Report*, CR/06/008N8N. 190pp.

Keyworth, Nottingham British Geological Survey 2006

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desks at Nottingham, Edinburgh and London; see contact details below or shop online at www.geologyshop.com

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

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

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

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

British Geological Survey offices

Keyworth, Nottingham NG12 5GG
☎ 0115-936 3241 Fax 0115-936 3488
e-mail: sales@bgs.ac.uk
www.bgs.ac.uk
Shop online at: www.geologyshop.com

Murchison House, West Mains Road, Edinburgh EH9 3LA
☎ 0131-667 1000 Fax 0131-668 2683
e-mail: scotsales@bgs.ac.uk

London Information Office at the Natural History Museum (Earth Galleries), Exhibition Road, South Kensington, London SW7 2DE
☎ 020-7589 4090 Fax 020-7584 8270
☎ 020-7942 5344/45 email: bgslondon@bgs.ac.uk

Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU
☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast BT9 5BF
☎ 028-9038 8462 Fax 028-9038 8461

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB
☎ 01491-838800 Fax 01491-692345

Columbus House, Greenmeadow Springs, Tongwynlais, Cardiff, CF15 7NE
☎ 029–2052 1962 Fax 029–2052 1963

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU
☎ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

Foreword

Increasing pressure on land and the environment demands a greater awareness and understanding of the dynamics of our natural world in order to deliver a sustainable environment for the future. Biodiversity and the need for the Government to recognise, audit and plan for habitat and ecology is widely accepted and enshrined in UK legislation. However the importance of the complementary concept of Geodiversity is only now gaining recognition, despite providing the foundations for habitats and species.

Geodiversity has a vital role in all aspects of the natural heritage and impacts on many sectors in economic development and historical and cultural heritage. For example, in the development of sustainable eco or geo-tourism (North West Highlands and other UK UNESCO Global Geoparks), Strategic Environmental Assessment, local authority structure and mineral plans, building stone resources, education and art.

Nationally important geological sites have been assessed and are protected by statutory measures, but there is little systematic inventory and evaluation of local sites or development of management measures for these sites.

A first step in addressing these issues is to conduct geodiversity audits. This report documents the first geodiversity audit of a local authority area conducted in Scotland and provides a foundation for developing a West Lothian Geodiversity Action Plan (WLGAP).

Acknowledgements

The authors wish to express their thanks to John Sheldon of West Lothian Council, John Gordon and Rachel Wignall of Scottish Natural Heritage and David McAdam of Lothian and Borders RIGS Group for support and advice throughout the project.

Particular thanks are offered to the Scottish Executive Sustainable Development Directorate for funding most of the project with a grant from the Aggregates Levy Fund. Martin Smith is thanked for co-funding the project from the BGS Geology and Landscape North Programme.

Sarah Arkley and Stu Clarke are thanked for their contribution to field work, Alastair Matthewson for data compilation, Ken Lawrie for database design, Amelia Pickering for supporting the GIS work, Ewan Hyslop for information on the built heritage and Dave Lawrence for advice on geodiversity, report editing and general encouragement.

The field work could not have taken place without the co-operation of a large number of farmers and landowners; their permission is gratefully acknowledged.

Contents

TABLES

Summary

For its size, Scotland has the most varied geology, natural landscapes and landforms of any country on the planet. This variety, or geodiversity, has resulted in the dramatically different landscapes we see in Scotland today. Although not as striking as some of the iconic landscapes in other parts of Scotland, West Lothian's Carboniferous bedrock and cover of glacial deposits nevertheless exhibit a large variety of rock types, structures, fossils, processes, soils and landforms set within a varied landscape.

This report describes a geodiversity audit of West Lothian – the first to be conducted in Scotland. It was undertaken as a means of informing the framing of recommendations and action points designed to guide the sustainable management, planning, conservation and interpretation of all aspects of the Earth heritage of West Lothian. The audit was not intended to be comprehensive survey of all potential geodiversity sites in West Lothian, but rather an evaluation of a representative selection of sites and features of geological and landscape importance. The audit was conducted by the British Geological Survey (BGS) in partnership with West Lothian Council (WLC), Scottish Natural Heritage (SNH) and Lothian and Borders RIGS Group (LaBRIGS).

A database of 204 potential geodiversity sites for the West Lothian area was compiled from the geological literature, BGS staff expertise and information from LaBRIGS Group. This database was used to target sites for geodiversity field auditing, which took place between August and December 2005.

Information on soils was obtained from the Macaulay 1:25,000 digital soil data and the joint WLC and SNH document on Soil sustainability in West Lothian. Data on designated sites was obtained from SNH, JNCC and Lothian Wildlife Information Centre; habitats and landscape data from WLC; archaeology from Historic Scotland and West of Scotland Archaeology Service.

During the field work, 86 sites were visited and information recorded on site ownership, access, fragility, geological merit, potential use and relevance to other interests, at local, regional, national and international level. This information was then entered in the BGS GeoDiversitY database, designed specifically for geodiversity auditing. Details of a further 36 sites which were not visited, but are potentially significant, were also added, giving a total of 122 sites and features of potential geological and landscape importance in West Lothian.

From this list of 122 sites, 51 were selected as being representative of particular geodiversity features in the context of West Lothian and are classed as West Lothian Geodiversity Sites (WLGSs). Of these 51 sites, four are currently protected nationally as SSSIs and six protected locally as RIGS. The new WLGSs expand this list of important sites to provide much better geodiversity coverage at the local level.

A draft West Lothian Geodiversity Action Plan (WLGAP) is presented. The main objectives of this plan are: to 'embed' geodiversity into future planning, management and interpretation policies; to recommend strategies for continued monitoring of WLGSs; and to increase overall awareness, understanding and appreciation of West Lothian's geodiversity.

1 Introduction

1.1 PROJECT AIMS

Geodiversity, or the variety of rocks, minerals, fossils, landforms, sediments and soils, together with the natural processes which form and alter them, is becoming an increasingly important topic when planning for sustainable development within Scotland. In seeking to take account of geodiversity in the Local Plan and planning applications, planners require baseline information in a readily accessible format to allow the sustainable management of West Lothian's natural heritage.

This pilot project aims to:

- initiate the process of geodiversity auditing and action planning in Scotland and act as a guide to further work in other areas of the country;
- review the component elements of West Lothian's geodiversity, and its relevance to other interests;
- allow incorporation of geodiversity into the planning system through integration with the Local Biodiversity Action Plan (LBAP) process.

The audit was not intended to be a comprehensive survey of all potential geodiversity sites in West Lothian, but rather an evaluation of a representative selection of sites and features of geological and landscape importance. Four sites in West Lothian currently enjoy national recognition and protection as Sites of Special Scientific Interest (SSSIs) for their geological importance and six are non-statutory Regionally Important Geological and Geomorphological Sites (RIGS). Existing conservation designations in West Lothian are listed in Appendix 1.

The study has shown that, whereas the existing network of such sites reflects the most significant elements of the area's Earth heritage in a national or regional context, there is considerable scope to expand the network to provide better coverage at the local level.

1.2 PROJECT BACKGROUND

This project was instigated by the British Geological Survey (BGS) Geology and Landscape North (GLN) programme, based in Edinburgh. A BGS-led bid in 2003 to the Forward Scotland Community Environmental Renewal Scheme (CERS) for a geodiversity audit of the Lothians had been rejected for lack of community involvement, but GLN remained convinced of the merit of geodiversity auditing in Scotland. Other partners in this CERS bid included Lothian and Borders RIGS Group (LaBRIGS) and the four Lothian councils.

The GLN programme has carried out several Geodiversity audits and assisted in the preparation of Local Geodiversity Action Plans (LGAPs) in northern England and, along with LaBRIGS and UKRIGS saw a need to begin this process in Scotland. Scottish Natural Heritage (SNH) were consulted in late 2004 and it was agreed that West Lothian would be a suitable area for a Scottish geodiversity pilot project, particularly as West Lothian Council (WLC) had identified a need for a geodiversity plan in their document *'Planning for Biodiversity Action 2005 – 2009'*.

A proposal for a collaborative project between the BGS, SNH, WLC and LaBRIGS was submitted by the four partners to the Scottish Executive Sustainable Development Directorate in December 2004. A positive response was received, including personal support from Lewis Macdonald MSP, the then Deputy Environment Minister. Funding was awarded from the Scottish Executive Aggregates Levy Fund, with co-funding from the BGS GLN programme and staff-in-kind support from SNH, WLC and LaBRIGS.

The main purpose of the project was to conduct a geodiversity audit in order to provide a resource for the planning process in West Lothian, with the secondary aim of assisting WLC and LaBRIGS designate additional RIGS in West Lothian. A draft West Lothian Geodiversity Action Plan (WLGAP) would be prepared, but completion of a comprehensive plan and the wider stakeholder consultation required was outside the timeframe and resources of the project.

Key project deliverables were agreed as:

1. Geodiversity data as GIS layers
2. Geodiversity database
3. Project report, including site photographs

Main contacts for the partners in this project are:

- British Geological Survey, Edinburgh (Hugh Barron)
- Scottish Natural Heritage, Edinburgh (John Gordon)
- West Lothian Council (John Sheldon)
- Lothian and Borders RIGS Group (David McAdam)

1.3 LEGISLATIVE AND POLICY CONTEXT

The introduction of Planning Policy Statement 9 (PPS9): *Biodiversity and Geological Conservation* by the Office of the Deputy Prime Minister (ODPM) has elevated the importance of geodiversity to a new level in England and Wales. In PPS9, the Government's objectives for planning include:

- **to promote sustainable development** by ensuring that biological and geological diversity are conserved and enhanced as an integral part of social, environmental and economic development, so that policies and decisions about the development and use of land integrate biodiversity and geological diversity with other considerations.
- **to conserve, enhance and restore the diversity of England's wildlife and geology** by sustaining, and where possible improving, the quality and extent of natural habitat and geological and geomorphological sites; the natural physical processes on which they depend; and the populations of naturally occurring species which they support.

The first of six key principles in the document states:

- Development plan policies and planning decisions should be based upon up-to-date information about the environmental characteristics of their areas. These characteristics should include the relevant biodiversity and geological resources of the area. In reviewing environmental characteristics local authorities should assess the potential to sustain and enhance those resources.

No equivalent Scottish Planning Policy (SPP) covering geodiversity yet exists; however, three recent developments present opportunities to raise awareness of geodiversity within Scotland:

- The Nature Conservation (Scotland) Act 2004
- Modernising the Planning System White Paper
- Strategic Environmental Assessment (SEA)

1.3.1 Nature Conservation (Scotland) Act 2004

This Act provides the legislative components of a new integrated system for nature conservation in Scotland. It sets out a series of measures which are designed to conserve biodiversity and to protect and enhance the biological and geological natural heritage of Scotland.

The Act supersedes the SSSI provisions of the Wildlife and Countryside Act 1981, providing for the enhanced protection and management of SSSIs. The provisions place a duty on public bodies to further the conservation and enhancement of SSSIs, provide a new offence whereby third parties can be convicted for damaging SSSIs, and enable the making of byelaws for the protection of SSSIs. It also enables Scottish Ministers to make a Nature Conservation Order to protect a nature conservation feature which is of special interest, or which is contiguous with land containing such a feature, to ensure its protection.

In an effort to limit the damage inflicted on Scotland's fossil resources, the Act also requires SNH to prepare and issue a Scottish Fossil Code setting out recommendations, advice and information relating to fossils. The production of this code is progressing and should be launched in early 2007.

1.3.2 Modernising the Planning System

A key theme in the Scottish Executive's recent White Paper *Modernising the Planning System* is the role of planning in delivering sustainable development. The modernised system will use the new SEA regime to help deliver sustainable development and will give environmental considerations the attention they deserve. In the current system, 70% of local plans are over 5 years old and around 20% are more than 15 years old. The new system will require all plans to be updated every 5 years. This more regular updating should allow greater attention to be paid to geodiversity.

1.3.3 Strategic Environmental Assessment

In heralding the new Strategic Environmental Assessment (SEA) regime for Scotland, Environment and Rural Development Minister Ross Finnie MSP stated in October 2003 that:

> *'At a minimum SEA will mean that every public official preparing a strategy, plan or programme will have to think about its environmental effects. If these are significant, the plan will have to undergo an Assessment. This will highlight both the negative and positive environmental impacts across the full range from water, land and air quality, biodiversity and human health to the built and archaeological heritage of Scotland.'*

The Environmental Assessment (Scotland) Act 2005 came into force on 20 February 2006. The Scottish Executive states that 'SEA is a key component of sustainable development establishing important new methods for protecting the environment and extending opportunities for participation in public policy decision making. SEA achieves this by:

- systematically assessing and monitoring the significant environmental effects of public sector strategies, plans and programmes;
- ensuring that expertise and views are sought at various points in the process from SNH, SEPA, Historic Scotland and the public; and
- requiring a public statement as to how opinions have been taken into account.'

SNH has a statutory role as an SEA Consultation Authority. It can provide advice on a wide range of topics in relation to the natural environment and will normally give particular attention to biodiversity, landscape and geological features (indicating if appropriate where these are the subject of national or international protection), access and recreational use of the natural heritage and where relevant, the soil, water, and material assets that are necessary to support these environmental features.

BGS is the United Kingdom's premier centre for earth science information and expertise, and as such, BGS can assist SNH by providing authoritative advice on the geology and geomorphology of Scotland, particularly in relation to sites that are not existing SSSIs or included in the Geological Conservation Review (GCR).

1.3.4 West Lothian Local Plan

The 2005 West Lothian Local Plan (WLLP) commits WLC *to producing a geodiversity plan to address the planning and conservation needs of geology and geomorphology* (see WLLP section 3.20). The plan also includes a strategy to protect and enhance the built and natural heritage of West Lothian by:

a. *conserving and enhancing green spaces, rivers, the coastline and water features and promoting the principles of biodiversity;*
b. *protecting habitats, landscapes, archaeological features and the built heritage from damaging development;*
c. *rehabilitating the environment where it has been scarred by previous industrial and development activities;*
d. *improving and, where appropriate, managing native and mixed woodlands; and*
e. *improving public access to the countryside, coastline and heritage features, in a manner that preserves the quality of those features.*

WLC will subject any proposals which affect the integrity or quality of any designated site (including non-statutory sites such as RIGS) to particular scrutiny. There is a presumption against development which could affect any such designated site and in determining such planning applications; WLC will use the precautionary principle where there is uncertainty of the environmental impact.

1.3.5 West Lothian Biodiversity Action Plan

West Lothian Council adopted its first Local Biodiversity Action Plan (LBAP) in 1998 and a revised version was published in 2005. A section on geology, landforms and soils is included in both these documents; the latter refers to the need to prepare a geodiversity plan for West Lothian.

1.3.6 West Lothian Soil Sustainability Report

As part of the review of the West Lothian Biodiversity Action Plan, WLC and SNH commissioned the Scottish Agricultural College (SAC) to prepare a report on the soils of West Lothian. The report provided a number of recommendations, in consultation with WLC and SNH, on the sustainable use of soil in West Lothian. These included:

Local Plan: WLC to implement a policy towards soil sustainability.

Development Control: WLC to initiate a procedure for soil management and sustainability prior to specific devopments as part of the Developmenr Control process.

Open Space: soil management plans recommended for new and existing sites.

Environment: encourage buffer zones close to environmentally significant area, prevention of soil pest and weed movement during soil movement.

Biodiversity: LBAP group should consider developing a soil action plan.

Climate Change: as policies on climate change develop the effects on soil should be considered and updated.

Monitoring: establish baseline data on organic matter, pH, P and K levels, topsoil soil structure, topsoil water-holding capacity and earthworm numbers

Raising Awareness: general awareness raising on the value and good management of soil should be undertaken to ensure sustainability in the short and long term.

1.3.7 EU Soil Directive

The EC Soil Thematic Strategy aims to support the evaluation of Community policy and legislation in relation to soil, its functions and related environmental compartments. Through the EU Soil Directive, it will drive well-informed soil protection and soil management activities across all Member States, to provide explicit protection for soils in relation to existing environmental protection legislation. This process is already acting as a stimulus for the development of national soil protection strategies and their evaluation.

1.3.8 Guidance note on Geodiversity to Biodiversity Groups

The Scottish Biodiversity Group (now the Scottish Biodiversity Forum) published a guidance note in 2000 on geodiversity. This is intended to inform local biodiversity groups about the importance of geodiversity and the necessity of linking the two together (Appendix 2).

1.3.9 Guidance on Local Nature Conservation Site Systems in Scotland

A working group, convened and chaired by SNH, comprising BGS, COSLA, Scottish Environment LINK, RTPI, SNH, SWT and UKRIGS has prepared the document *Guidance on Establishing and Managing Local Nature Conservation Site Systems in Scotland.* This document, published by SNH in March 2006, includes the following recommendations:

- Local Nature Conservation Sites (LNCS) should form part of an overall approach to delivering the Local Biodiversity or Local Geodiversity Action Plan, with the following purpose: To identify biodiversity and geodiversity of at least local importance and to assist efforts to protect and enhance these interests (Para. 3.4).
- Responsibility for introducing, reviewing and managing local biodiversity sites and local geodiversity sites should be taken by the local authority, although this may be delegated. Either way, the work should be carried out with the help of a panel of advisors comprising relevant interests and expertise (Para. 4.3).
- The Local Plan should include an explanation of the purpose of the LNCS designation. It should set this in the context of other nature conservation policies, including statutory designations, the Local Biodiversity Action Plan, and Local Geodiversity Action Plan (as and when developed). The Local Plan should make available full details of the process followed in selecting sites. Ensuring that LNCS are an effective mechanism requires good communication between development control officers and officers dealing with LNCS. The presence of LNCS should be included early in discussions about the location of development, and planning authorities should consider opportunities to enhance LNCS during development (Para. 5.3).
- Planning policies for the protection of LNCS should be distinct from policies relating to statutory designations, and should be set out in the context of these policies. Where a planning application concerns land selected as a LNCS, the developer should carry out an assessment of the impact of the proposal on the nature conservation interest of the site. Where it is decided, for significant reasons of social and economic importance, that development should go ahead, there should be provision as far as possible for retention

of nature conservation interest through planning conditions. Where this is not possible, the loss should be compensated for by habitat creation or site enhancement elsewhere through planning agreements or conditions (Para. 5.4).

- The location of LNCS should be clearly identified on the Local Plan proposals map, and boundaries shown where scale allows. A formal record of the evaluation of the site should also be readily available within the planning process. To this end, Site Statements should be made available as supplementary planning guidance within the Local Plan, and included in the consultation process for the Local Plan (Para. 5.5).
- LNCS may be selected in places where there is already a national or international nature conservation designation. If the local interest for which the LNCS is designated is different to the national interest for which the statutory designation is made, the LNCS should exist alongside the statutory designation. If the interests are the same, there is no need to incorporate the site as part of the LNCS system (Para. 5.14).
- Within Scotland's National Parks, the policies and procedures developed by the Park Authority set out how biodiversity and geodiversity will be protected and enhanced across the Park area. Through the Park Plan, the Park Authority may decide that an approach equivalent to a LNCS system will help prioritise action and assist in decision-making (Para. 5.15).

2 Geodiversity and its importance

International recognition of the need to conserve biological diversity led to the UN Convention on Biodiversity agreed at the Rio Earth Summit in 1992 and the subsequent signing by over 160 countries. Since the UK government published 'Meeting the Rio Challenge' in 1995, most local authorities or regions in the UK have prepared and implemented Biodiversity Action Plans (BAPs) for their areas, and biodiversity is now accepted as an essential element in sustainable development planning and management strategies. SNH define biodiversity as:

> *'the variety of life, protecting and enhancing a diverse range of plants, birds, animals and the habitats upon which they rely'*

Until relatively recently the parallel concept of geodiversity had attracted little interest, despite its fundamental importance in underpinning biodiversity by providing the substrates. SNH define geodiversity as:

> *"the variety of rocks, minerals, fossils, landforms, sediments and soils, together with the natural processes which form and alter them"*

An alternative definition given by Murray Gray (the author of the first geodiversity textbook) is:

> *'the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (land-form, processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems'*

Geological and landscape features, other than those already afforded some measure of protection such as SSSIs, are often seen as sufficiently robust not to require active management or action planning. All geological features are potentially vulnerable. In addition to threats posed by inappropriate site development and the infilling of quarries, the encroachment of vegetation, natural weathering and general deterioration with time may threaten to damage or obliterate important geological features. This situation would not be tolerated in wildlife or archaeological sites of comparable scientific or educational value.

The geodiversity of an area may be considered as one of its chief natural resources. A key starting point is an appreciation of the most up to date available understanding of the area's geology, landforms and soils, together with the processes and phenomena which have formed them and continue to influence them. An area's geodiversity thus encompasses:

- sites or natural features which are deemed worthy of some form of designation or protection for the quality of Earth heritage features displayed
- sites or natural features at which representative examples of the area's Earth heritage may be seen
- sites and natural features currently employed in interpreting Earth science
- resource potential for geotourism
- the whereabouts and nature of past and present working of mineral products
- the influence of earth science in shaping the man-made environment, urban landscapes and architectural heritage
- natural hazard management
- the inter-relationship and inter-dependence between Earth heritage and other interests

Documentation of an areas' geodiversity may include:

- materials collections and site and other records
- published literature and maps
- the historical legacy of research within the area

2.1 GEODIVERSITY – WHY IS IT IMPORTANT?

Geodiversity is fundamental to almost every aspect of life – all raw materials that cannot be grown and all energy that cannot be generated by renewables have to be found using geological science.

A clear understanding of geology is also vital to the design and location of buildings, roads, railways and airports as well as to the safe control of waste disposal, and the management of a wide range of natural and man-made natural hazards. All are aspects of geodiversity.

An awareness of geodiversity helps us to understand our environment and predict environmental change in the future. Geological research demonstrates that surface environments are continually evolving through natural self-regulating systems involving the Earth's crust and mantle, oceans, atmospheric processes and life forms. Human activity imposes further pressures and changes to these natural cycles which pose great challenges to modern society. Exhaustion of finite resources such as fossil fuel and global climate change are two of the most pressing. Only by studying the geological record can we hope to predict the earth's response to these changing conditions.

The recognition of natural and cultural heritage features and their sustainable management are today accepted as important functions within a civilised society. The importance of the range and diversity of Earth heritage features – the 'geodiversity' - of any area is as important a facet of its natural heritage as its wildlife interests. Conservation, sustainable management, educational use and interpretation of geodiversity are thus as important as that of biodiversity or archaeology.

However, geodiversity is not, or should not be regarded merely as concerned with conservation of Earth heritage sites or features – it has a vital place in all aspects of natural heritage and impacts in fields as varied as economic development (for example, supporting the development of geotourism in the new UNESCO European Geopark Network; the North West Highlands Geopark is the first Scottish member), building stone resource development, education and lifelong learning, archaeology, art and wildlife. Geodiversity may be one of the most significant areas of heritage interest in areas of high landscape value, or areas previously or currently affected by significant mineral extraction.

Geodiversity interests need to be integrated into other policies and processess relating to sustainable development including:

- Strategic Environmental Assessment
- local authority local, structure and mineral plans
- the Water Framework Directive
- the forthcoming Soils Directive
- Local Biodiversity Action Plans

An appreciation of geodiversity is important to a comprehensive understanding of many aspects of biodiversity. It also offers substantial opportunities to enhance the conservation, management, educational use and interpretation of such related features. Because it has hitherto received little serious consideration, geodiversity needs to be addressed and evaluated by expert earth scientists.

2.2 GEODIVERSITY – LINKING WITH BIODIVERSITY

It has long been known that there are strong ties between geodiversity and biodiversity. Recent ecological work has highlighted the complexity of these relationships and the large number of factors that come in to play.

At the physical level, geological processes such as glacial erosion and properties such as the relative resistance to erosion of different rock types, produce varying landforms and relief features within a landscape. These landscape features in turn provide diversity in physical conditions that support plant and animal communities, at all scales from small outcrops through to mountain ranges.

At the larger scale tectonic processes create pronounced relief which has a direct influence on regional and local climate, and in turn, on the ecosystems that develop. This also works at smaller scales, for example, microclimate differences between the top and base of a cliff.

Landscape variety is continually modified by geomorphological processes acting at a variety of scales. Glacial, fluvial and other processes such as slope failure produce new habitats that promote ecological succession and cyclicity and increase overall biodiversity.

In locations where climate, relief and human management are constant, the variation in rock type can strongly influence vegetation distribution. The way in which a rock weathers and acts as parent material for soil development is the most obvious mechanism for influencing floral characteristics. The main factors that rock type influence are soil chemistry, grain size, texture, porosity and permeability. Exceptional soil conditions, such as the high calcium carbonate content in shell sands on the west coast of the Western Isles, together with the low-intensity, traditional agricultural management, have created the unique flora of the machair.

Differences in pH have a major impact on the uptake of various minerals by plants − this is probably the key factor in differentiating the floras from calcareous and non-calcareous rocks. Specific plant-rock associations do occur with rocks of a very distinct chemistry such as serpentine (for example Calaminarian grasslands of the *Violetalia calaminariae)*. Rock type also influences chemistry of both ground and surface waters which give rise to differing aquatic communities.

In summary, the very diversity of rock types and geomorphological processes creates and leads to further diversity in their interaction with other processes. Ultimately biodiversity is a direct function of geological form and process.

2.3 SCOTLAND’S GEODIVERSITY

For its size Scotland has the most varied Earth heritage, natural landscapes, landforms and soils of any country on the planet. This variety has resulted in dramatically different landscapes and coastlines, such as the machair and beaches of the Western Isles, the fjords and mountains of the western Highlands, the Arctic plateau of the Cairngorms, the plains of Strathmore and East Lothian, to the rolling hills of the Southern Uplands.

The rocks that fashioned Scotland’s landscapes have formed over millions of years. Some of the oldest rocks in the Highlands and the Western Isles were formed about 3 billion years ago. Scotland was once part of North America and for much of the Earth’s history was separated from England by a large ocean, closure of which did not take place until Mid-Silurian times (Figure 1A). Over the last 600 Ma (million years), the Scottish landmass has drifted slowly from south to north across the equator with the successive deposition of various rock types (see Figure 1A for geological timescale), including: limestones and quartzites of the North West Highlands (Cambrian and Ordovician); greywackes of the Southern Uplands (Ordovician and Silurian); Old Red Sandstone of Orkney, Caithness and the Moray Firth (Devonian).

The Midland Valley's coal reserves formed during the Carboniferous (around 300 Ma), when Scotland was sitting at the equator, covered in tropical forests. As Scotland 'drifted' northwards and passed through the northern desert belt, red sandstone rocks were formed. The dynamic earth forces that drove Scotland north across the globe produced heat and pressure and caused earthquakes and volcanic eruptions. These forces folded, faulted and heated rocks, producing volcanoes such as Edinburgh's Arthur's Seat. Many of the rocks altered or produced by these forces are hard and resistant to erosion. They thus have a strong influence on the landscape.

The rocks that underlie the surface are sometimes exposed on hillsides, in coastal cliffs, in river banks and in artificial excavations such as quarries and road cuttings. Rocks can also be seen in building stones, giving areas their own local architectural distinctiveness. The effects of past land-uses such as mining or quarrying can be seen as an eyesore, but may provide excellent habitats especially for pioneer species, and have good restoration potential. Quarries also provide excellent locations for recreation and Earth heritage interpretation, and oil-shale bings can provide distinctive habitats in which orchids, *lycopodium* and staghorn mosses can thrive.

Scotland has been covered by ice sheets many times in its history. Moving ice rounded the hills and scratched and polished the rocks. It also created the wide straths and glens that today have small 'misfit' streams within them. As ice shaped the existing rocks, it left behind the eroded material (i.e. 'subsoils') as mounds of sand and gravel on the floodplains. These deposits often have distinctive terraced or mound shapes and can be very important for habitat. They are also an important economic resource. However, because the processes that formed them are no longer active, they are a finite resource that cannot be re-created (unless Scotland is once again covered by ice-sheets). When the ice sheets melted, the resultant rise in sea level of up to 45 m left old shorelines and raised beaches around the Scottish coast.

Soils are also an important component of the natural heritage. They are an integral part of the landscape, reflecting not only the natural processes from which they have been formed, but also the influences of human activities present and past. In Scotland, all the soils we see today have formed since the last glaciers melted around 10,000 years ago. The ever-evolving nature of soils, however, means that they are being continually formed and modified both by natural processes and by human activities. These interactions are responsible for the wide range of soils which exist in Scotland today.

3 The Geodiversity of West Lothian

3.1 GEOLOGICAL BACKGROUND

West Lothian's geodiversity is typical of much of the Midland Valley, though older rocks from the Silurian and Devonian geological time periods seen elsewhere are not present at surface – rocks from the Carboniferous time period comprise the entire bedrock surface area of West Lothian (see Figure 1A for geological column). This does not necessarily lead to low geodiversity as they comprise a wide variety of rock types including oil-shale, limestone, sandstone and dolerite, which demonstrate a wide range of geological processes and structures. Nearly 92% of this bedrock is covered by a variety of glacial deposits; both these deposits and the underlying bedrock have been sculpted into an array of landforms. A detailed account of the bedrock geology of West Lothian can be found in Appendix 3.

3.1.1 Geological history

West Lothian lies in the Midland Valley of Scotland between the Highland Boundary Fault to the north and the Southern Upland Fault to the south. The Midland Valley is considered to be a displaced 'terrane' – a north-east to south-west-orientated sedimentary basin emplaced in its present relationship with the Highlands and Southern Uplands by large-scale horizontal fault movement (strike-slip) during the end-Silurian to mid-Devonian times.

The nature of the basement rocks in the Midland Valley is known only from indirect evidence. Geophysical studies indicate that a metamorphic basement lies at a depth of between 7 and 9 km. The basement is 20 to 25 km thick and the base of the crust is at a depth of about 33 km. The composition of the basement is indicated by the occurrence of metamorphic rocks carried to the surface as exotic fragments (xenoliths) in volcanic vents.

The Carboniferous of West Lothian comprises both sedimentary and igneous rocks. Geologists have classified the sedimentary and extrusive igneous rocks into five main groups (Figures 1B, 2). The sedimentary rocks are divided by age, from the oldest to youngest the groups are:

1. Inverclyde Group
2. Strathclyde Group
3. Bathgate Group
4. Clackmannan Group
5. Coal Measures (Scotland) Group

These groups are subdivided further into formations (See Figure 1B).

The three groups of intrusive rocks are divided by origins and compositions. (Figures 1A, 2):

1. Volcanic Vents and Plugs
2. Alkali-dolerite sills
3. Quartz-dolerite sills and dykes

Subaerial volcanic activity was widespread in the Midland Valley in Lower Carboniferous times. Eruption of volcanic rocks in the east ceased sometime in the Viséan, but persisted in the west well into the Namurian (Figure 1).

The sedimentary strata consist principally of sandstones and mudstones with relatively minor proportions of limestone, coal and oil-shale. They were deposited as part of an extensive fluviodeltaic system which occupied most of north-west Europe during the Carboniferous Period. Sediment was carried from Caledonian mountains to the north and deposited at or near sea level in a differentially subsiding basin. Early Carboniferous strata were deposited, in part at least, under lagoonal conditions and the strata include seams of oil-shale. Cyclic sedimentation, including the deposition of seams of economically valuable coal, lasted from the Viséan to the late Carboniferous.

Periodic marine incursions brought about the deposition of thin but widespread limestones mainly in the late-Viséan Lower Limestone Formation and in the Namurian Upper Limestone Formation. In the area of the Bathgate Hills, marine limestones were deposited fringing volcanic islands. An unusual fauna has recently been recovered from one of the associated nonmarine limestones which included possibly one of the world's earliest known reptiles, amphibians and various terrestrial invertebrates. A period of uplift and erosion in the Highland High to the north and within the Midland Valley brought about mainly fluvial deposition during late-Namurian Passage Formation times, temporarily replacing the fluviodeltaic processes. Marine incursions were brief and largely confined to the lower part of the formation.

Two episodes of basaltic intrusion are known in the district. Most of the intrusive igneous rocks are quartz-dolerites which occur as east-west dykes and sills. They are of late-Carboniferous age. Alkali-dolerite sills, probably of contemporaneous in age to Viséan and Namurian volcanic rocks, are present. After deposition of the Carboniferous, the strata were folded to form the Falkirk-Stane Syncline. Faulting took place on east-west trending faults.

There is no evidence of the interval between Carboniferous times and the Quaternary preserved in West Lothian. During the Quaternary the entire region was overwhelmed by glaciers, on more than one occasion. The last widespread glaciation in Great Britain was the Main Late Devensian, during which the ice reached its maximum extent between 18,000 and 22,000 years ago. The Main Late Devensian ice sheet was less extensive than earlier glaciations, but it still covered much of Britain, stretching as far south as Bristol Channel (Figure 3). In the mountainous source regions of Scotland, Wales and Northern England, erosional processes dominated as ice carved out the deep corries and U-shaped valleys we associate with those areas today. In lower lying areas, such as that occupied by present-day West Lothian, depositional processes were more dominant releasing thick blankets of till from beneath the ice (Figure 4). Where ice flow was particularly fast, streamlining of the landscape occurred with the underlying terrain being shaped into a series of longitudinal landforms parallel to the direction of ice flow (Figure 10).

As climate warmed towards the end of the Main Late Devensian glaciation, meltwater from the retreating ice sheet laid down vast belts of sand and gravel along the major drainage pathways. The weight of the Main Late Devensian Ice Sheet depressed the earth's crust beneath it (a process known as isostatic depression). When the ice sheets melted, releasing water back in to the oceans, sea-level rapidly increased (glacio-eustatic sea-level rise). The depressed land, however, took a longer time to rebound after the removal of ice, allowing the sea to reach higher levels than today. Continued uplift has now elevated the shorelines from this period, so that today raised beach and estuarine clay deposits can be seen in the north-east of the district, bordering the Firth of Forth. Even now, 11,500 years after the final disappearance of ice in Britain, much of Scotland continues to rebound from the ice overburden. In parts of the Highlands uplift presently occurs at about 3 mm per year, while rates in West Lothian are around 1−2 mm per year.

Soils began forming in West Lothian after the retreat of the last ice sheet. Parent material for soil formation is predominantly glacial or periglacial in origin, mainly till with minor areas of glaciofluvial sand and gravel, stony drift (frost-shattered rock or local thin glacial material or solifluction sheets) and raised beach deposits. The predominant soil association (Figure 5) in West Lothian is Rowanhill (glacial till parent material); others include Hobkirk (drifts of soft red sandstone parent material), Darleith (drift from basaltic rock parent material) and Darvel (glaciofluvial sand and gravel parent materials). The other main soil classification used is that of sub-group – a diverse range are present in West Lothian (Figure 6). The main sub-groups present are non-calcareous gleys, peaty gleys, peaty podzols, peat, brown forest soils with gleying, brown forest soils.

Some of the geological process that formed the geodiversity of West Lothian are still active in the area today: mechanical and chemical weathering of rocks is ongoing; slope processes – debris flows may occur during very heavy rainfall, particularly on steep slopes; river erosion and deposition (see Figure 161); coastal erosion and sedimentation.

3.2 USE OF GEOLOGICAL RESOURCES

3.2.1 Mineral resources and extraction

West Lothian has a long history of mineral production. A wide range of products have been worked within the county and mining and related industries have had an impact on its character.

3.2.1.1 COAL

The majority of formerly economic coal seams occur in the Limestone Coal Formation and Lower Coal Measures (Figures 1, 2). Several seams exceed 1 m in thickness. A limited number of coals in the Upper Limestone Formation and the Passage Formation have also been exploited along with others such as the Hurlet Coal at the base of the Lower Limestone Formation and the Houston Coal in the West Lothian Oil-shale Formation. Deep (longwall) mining ceased with the closure of the Polkemmet Colliery in 1985. The most recent coal working in West Lothian has been restricted to licensed opencast mines which have concentrated on seams in the Coal Measures and Limestone Coal Formation. The largest opencast coal sites in the district have been located on the outcrop of the basal Coal Measures, where 'fireclay' and 'brickclay' have been extracted in addition to coal. Coal can be worked economically by opencast methods only where the ratio of coal to overburden is favourable. Past extraction of coal in shallow mines commonly used `stoop and room' methods whereby only about half the coal was taken, the remainder serving as pillars to support the roof. Despite the practice of `stooping' and `stoop-splitting', that is, of robbing all or part of the coal pillars when mining was coming to an end, sufficient reserves can nevertheless remain in the pillars to justify opencast working. On a small scale, ground which has been affected by shallow stoop and room mining can be stabilised prior to construction, by working the coal opencast, the value of the coal recovered partly offsetting the excavation costs.

Coal is being extracted following granting of planning permission for the extraction of opencast coal and fireclay at the former Polkemmet Colliery site. Owing to the paucity of geodiversity sites within the Coal Measures of West Lothian (see section 3.4.6), development or extraction activities that exposed and allowed the preservation of representative Coal Measures sections would be a valuable addition to the geodiversity of the district.

3.2.1.2 OIL SHALE

West Lothian is unusual for the British Isles in having oil-shale seams that are thick and widely developed. The first plant in Britain to process mineral oil commercially, producing "Paraffin Oil", was set up in Bathgate in 1851, utilising a cannel coal known as Boghead Coal or Torbanite which occurred at the base of the Coal Measures over a small area on the Torbanehill Estate south-west of Bathgate. It gave an oil yield of 535 to 580 litres/tonne, but the deposit was exhausted within 12 years. Around the same time oil-shale was discovered in West Lothian and identified as a raw material suitable for the production of shale-oil and, in due course, replaced cannel coal in the retorting and refining processes. It was mined in the district from then until 1962. Although oil-shales are developed at over a dozen horizons within the West Lothian Oil-shale Formation (Strathclyde Group, Figure 2), three multiple, thick shales produced the bulk of the oil-shale mined: the Broxburn Shale, Dunnet Shale and Pumpherston Shale.

The oil-shale industry, which was situated very largely in West Lothian in the country between Cobbinshaw, Blackness and Dalmeny, with small outlying centres at Straiton and Carlops in Midlothian, reached its maximum productivity in the early years of the twentieth century with outputs of more than three million tons of oil-shale. It declined to 740,943 tons in 1950, produced at half a dozen mines and three opencast sites, of which three of the former and one of the latter were in the south of the West Lothian area near West Calder. By 1959, the workings were only in the Dunnet and Broxburn shales.

Retorting crude oil from oil-bearing shale resulted in a vast amount of waste. This waste was stored in large heaps, the red shale bings of West Lothian (Figures 26–30; 157–159). These bings are of considerable historical and social importance – two are currently protected as scheduled historical monuments (Five Sisters and Greendykes). Bings are significant landmarks in the general low-lying landscape of West Lothian and give a sense of community identity, particularly the unique Five Sisters Bing which features on the West Lothian Council logo. They also provide well used open spaces for recreation in an increasingly urbanised part of West Lothian, and form an important resource for education.

The survival of 19 oil-shale bings in West Lothian is largely due to the economic value of waste shale; it is used as hard-core for roads, footpaths and foundation material for buildings. This value saved the bings from reclamation during the 1970's and 80's. Several bings are being currently worked for hard-core, including Drumshoreland north and south, Clapperton and Niddry.

Oil-shale bings also make a major contribution to local biodiversity. Their unique physical and chemical structure provide a unique habitat, not found elsewhere in Britain or Western Europe, that hosts several nationally (UK) rare plant and animal species. They also play a major role in the success of 15 of the 45 West Lothian habitat indicator species. More than 350 plant species have been recorded on the Addiewell North Bing, which is also a Scottish Wildlife Trust Reserve.

3.2.1.3 Hydrocarbons

Natural gas and oil have their origin in organic-rich rocks which are common in the Carboniferous sedimentary sequence. Exploitable accumulations of oil and gas may be found where the rocks are folded and faulted to provide traps for the hydrocarbons. Within each trap, open-textured reservoir rocks are needed to hold the oil or gas. The Carboniferous rocks of the Livingston district include source rocks and reservoir rocks but the latter are probably too fractured to have retained significant quantities of oil or gas. There have been several reported occurrences of oil-impregnated sandstone and natural oil-seepages in the district and a deep oil-well was sunk unsuccessfully at West Calder between 1919 and 1921.

3.2.1.4 Limestone

Almost all the limestones that have been worked in the district occur within the Upper and Lower Limestone formations and in the West Lothian Oil-shale Formation. However, one of the limestones in the Ballagan Formation was quarried at Selms [NT 084 661]. Some of these limestones were quarried and mined underground for agricultural and industrial uses. North-east of Bathgate, the East Kirkton and West Kirkton (Hurlet) limestones have both been quarried on a small scale near Limefield [NS 988 694], and the latter also at Addiewell [NS 994 624]. The overlying Petershill (Hillhouse) Limestone is up to 18m thick and has been quarried and mined almost continuously along its outcrop between Glenbare Quarry [NS 985 690] and Craigmailing [NS 994 722]. Small quarries in the thinner Blackhall Limestone were at Whitebaulks [NT 008 747] and Tartraven [NT 006 725] for example. The Burdiehouse Limestone at the base of the Hopetoun Member was quarried extensively along its irregular outcrop between Abercorn and Newton. Smaller quarries occur elsewhere along its extensive outcrop. In the Upper Limestone

Formation, the Calmy Limestone has been mined in Carribber Glen [NS 969 752], and quarried near Leven Seat [NS 946 576]. The Castlecary Limestone was formerly mined beneath Bowden Hill [NS 977 747], at Standhill [NS 968 673], near Longridge [NS 961 621] and at Leven Seat where limestone quarrying then mining lasted almost 200 years, before terminating in 1900. The Castlecary Limestone was the most extensively worked in the district, probably owing to its reputation for producing excellent lime.

There are currently no active limestone quarries in the county, but a number of disused quarries provide some of the most important, and in one case unique, sites at which certain rock units may be seen. They contribute greatly to the area's geodiversity.

3.2.1.5 FIRECLAY AND SHALE FOR BRICKMAKING

In the neighbourhood of Winchburgh and East Calder old small brickworks gave place to large works at Winchburgh, Camps and Ecclesmachan where 'blaes' and 'boulder-clay' (till) were excavated and mixed, but these long since ceased working. Passage Formation strata, which include the most valuable refractory fireclays in the United Kingdom, crop out widely around the rim of the Central Coalfield syncline, and underlie much of the district. Fireclays occur principally near the top and bottom of the Passage Formation and throughout much of the Lower Coal Measures.

The Glenboig Lower and Upper Fireclays of the Passage Formation, because of their high alumina content, were economically the most important. They are thought to be overbank deposits of a meandering river system, and are thus not true seatclays as they are not associated with coals. They were mined initially along the western outcrop of the Central Coalfield, but latterly the industry concentrated on the eastern outcrop where the quality was found to be better; a total of 12 mines were located between Birkhill near Linlithgow and Leven Seat, with the Ballencrieff Mine [NS 964 695] being the last to close in 1985.

Fireclays associated with coal seams belonging to the Lower Coal Measures, have also been mined throughout the district around Armadale. Latterly, fireclay production has been confined to a number of opencast coal sites located within the outcrop of the Lower Coal Measures where it was extracted in conjunction with coal.

3.2.1.6 SANDSTONE

Sandstone occurs in thick beds throughout the Carboniferous sequence of West Lothian and in the past considerable quantities of freestone was quarried for use in construction. Many of Edinburgh's buildings erected before the 20th century owe their character principally to the sandstone from which they were constructed. West Lothian quarries provided sandstone for a number of these; examples include the Bank of Scotland, the National Gallery on the Mound and Daniel Stewart's and Melville College (Binny Quarry). Active in the 18th and 19th centuries, the quarries are all long-since disused and mostly filled in. Most of West Lothian's historic buildings were also contructed from local stone (see 3.2.2).

The main beds that provided high quality sandstone were the Binny Sandstone and the Dunnet Sandstone in the middle of the West Lothian Oil-shale Formation. The most important quarries in the Binny Sandstone were at Binny; others were at Cockmuir, Craigton, Hermand, Hopetoun White and Humbie (Figure 7). The only quarry in the Dunnet Sandstone was Hopetoun Obelisk, although the sandstone is thought to be extensively developed in the Livingston area. Other sandstones have been quarried locally.

Certain sandstones of the Passage Formation are typically soft, friable, open-textured and are composed predominantly of quartz. Although the outcrop of the Passage Formation is extensive in the district, it is commonly concealed by superficial deposits. Silica sand is produced from one quarry located at Leven Seat, where sandstone production has continued for over 70 years. The iron oxide content of the sandstone precludes its use for most types of glass manufacture, though recent exploration at Levenseat Quarry indicates some sandstone of glass-making quality may be present. It is not known whether purer sandstone, suitable for colourless glass manufacture, occurs elsewhere in the district.

Although sandstone is not extracted for building stone within West Lothian at the moment, sandstone quarries are being opened up in adjacent districts. The Sir Walter Scott Monument in Edinburgh was recently repaired by 'snatch' quarrying at Binny. Sections can still be seen in some of the ancient quarries and are valuable both as geological sections in their own right and as a link to the built heritage of the region. Some stone quarries offer the potential to be re-opened as a resource for repairs and conservation work.

3.2.1.7 Metalliferous minerals

The district has limited occurrences of economic metalliferous minerals. The ironstone industry of West Lothian was represented for example by furnaces operated at Causewayend [NS 961 760] beside the Union Canal during the latter half of the 19th century, coinciding with the peak in local ironstone mining. Blackband and clayband ironstones were formerly mined extensively throughout the district with the principal centre at Armadale. Bedded ironstones were the main source of iron ore during the industrial revolution in Scotland, but production declined rapidly around the end of the 19th century. Among the ironstones exploited were the Curdly Ironstone and Crofthead Slatyband (Passage Formation).

The discovery of native silver in vein mineralisation associated with faulting and emplacement of a quartz-dolerite dyke at Hilderston [NS 990 715] in 1606 resulted in intermittent mining activity for silver, lead and nickel between 1607 and 1898. The silver lode, which unusually included native silver, was exhausted within a few years and the presence of nickel ore in the vein mineralisation was not recognised until about 1870. The mineral suite included niccolite, bravoite, annabergite, erythrite, native silver and galena, in a gangue comprising baryte, calcite and dolomite. Minor stratabound lead-zinc mineralisation has also been discovered in the same neighbourhood in the lower, argillaceous part of the Petershill Limestone.

3.2.2 Built heritage

West Lothian has a rich and varied built heritage, much of which reflects the underlying geodiversity. The earliest example is the outstanding prehistoric monuments of Cairnpapple Hill; later historic buildings include, Hopetoun House, the House of the Binns, Blackness Castle and Dalmeny.

Other notable buildings include St Michael's Parish Church, one of Scotland's finest parish churches, and Torphichen Preceptory – the tower and transepts of a 13th century church built by the Knights of St. John of Jerusalem.

West Lothian has a rich resource of good quality building stone and, as well as supplying stone for some of Edinburgh's finest buildings (see 3.2.1.6), most of West Lothian's historic buildings and all older buildings in the towns and villages are built from stone sourced within the area; two examples are given below:

3.2.2.1 Linlithgow Palace

Construction of Linlithgow Palace (Figure 155), the birthplace of Mary Queen of Scots, began in 1424 under James 1 and was completed by James VI in 1624. It is largely built from thinly bedded or laminated sandstone which weathers to a distinctive variable orange and cream colour. Historical records indicate that the stone used to build Linlithgow Palace was obtained from Kingscavil Quarry, situated a few kilometres to the east of the town. The quarry is now infilled and long disused.

The older parts of the external walls, on the east, north and parts of the west side, are composed of random-sized, roughly squared blocks built into rough courses. Parts of the later south range, particularly near the entrance, are constructed from the same type of sandstone, but used in a more formal way with squared blocks of uniform size built into regular courses.

In contrast, the King's Fountain situated within the Palace was made from a different sandstone type. This has a more uniform nature, and is finer grained and slightly softer, making it easier to carve and produce the sculptural detail seen on the fountain. The stone may also have been obtained locally, but from a different quarry.

As there are no building stone quarries operating in West Lothian today, all the stone used for repairs to the Palace have to be imported from other parts of the United Kingdom. The stone used for the recent major repairs to the King's Fountain was obtained from a quarry in Yorkshire.

3.2.2.2 Blackburn House

Blackburn House, located between Blackburn and Seafield, was constructed around 1760 with some later additions. It was built using locally-sourced sandstone, limestone and dolerite. The portico was added some time later and is made from Binny Sandstone (see 3.2.1.6) from Binny Quarry near Broxburn.

Blackburn House is about to be renovated at a cost of £3.4 million to create a bespoke centre for the Creative Industries in West Lothian, with funding from the Heritage Lottery Fund, the European Union, Historic Scotland and West Lothian Council. Like Linlithgow Palace, stone for this renovation will be obtained from Yorkshire.

3.3 EVALUATING THE GEODIVERSITY OF WEST LOTHIAN

3.3.1 Site desk study

The first stage of the project involved compiling a database of potential geodiversity sites for the West Lothian area. This was done by utilising the geological literature (much of it is over 50 years old), BGS staff expertise and additional local knowledge afforded by the LaBRIGS Group on the key geological localities of West Lothian. A preliminary list of 204 potential sites was drawn up and used to target sites for the field audit. The locations of these sites are plotted in Figure 8 and details presented in Appendix 4. The list could be used to augment the audit in the future.

3.3.2 Field audit

Field work was carried out between August and December 2005. Of the 204 potential geodiversity sites, 86 were visited during the course of the audit. Data was recorded in BGS notebook record cards or recorded directly on to forms designed for use with the BGS GeoDiversitY database (see Appendix 5 for examples). Digital cameras were used to record the site locality, features and general site condition (see Volume 2, Figures). Garmin 12XL handheld GPS units were used for site positional referencing.

As far as possible landowners and farmers were contacted prior to visiting or accessing sites, but ownership was not established for every site visited. Most landowners or farmers were helpful and allowed access, a few allowed access reluctantly, and access permission was denied by one large estate, on the grounds that any site designation arising out of the work would interfere with 'lawful estate business'.

3.3.3 Project database (GeoDiversitY)

A corporate database had been designed for previous geodiversity work in northern England (North Pennines AONB, County Durham and Northumberland National Park). This GeoDiversitY database consists of a number of tables stored in the BGS corporate Oracle database with front-end data entry and browsing capability implemented in Microsoft Access. To accommodate the different natural heritage designations used in Scotland, the database structure and entry forms were re-built.

Data from the 86 sites visited were entered into the database. Details of a further 36 sites were added – these were sites where the geodiversity was likely to be important but:

- ownership could not be determined;
- access was denied during the audit visit;
- no time was available for visiting.

This gave a total of 122 sites, which form 122 records in the GeoDiversitY database (see Appendix 5 for sample records). This data was then exported as a DBF file to allowing building of ArcGIS shape files.

3.3.4 Project GIS

A project GIS was established to display the location of geodiversity information and to enable it to be examined in relation to existing scientific, historical and cultural designations. A wide range of digital data were acquired (Figures 9–13) and the datasets translated to a suitable format for display in ESRI ArcGIS (Table 1).

Most of these datasets were available under licence for no cost from their owners, but fees were payable in order to licence the 1:25,000-scale soils data from the Macaulay Institute and the West Lothian wildlife site data from the Lothian Wildlife Information Centre. Both these datasets were licenced for one year. Use of Ordnance Survey mapping in the project was covered by BGS membership of the OS Pan Government Agreement, Licence Number: 100017897.

Dataset	Figure No.	Format	Supplier	Licence req. for BGS use	Licence fee
Earth science					
1:50k Digital Geology (DiGMapGB-50)	2, 4	ESRI shape files	BGS	No	No
Geological Conservation Review sites (GCR)	9	Web table	JNCC	No	No
Sites of Special Scientific Interest (SSSI)	9	ESRI shape files	SNH	Yes	No
1:25k soil classification	5, 6	ESRI shape files	Macaulay	Yes	Yes
Regionally Important Geological and Geomorphological Sites (RIGS)	9	Excel table	LaBRIGS	No	No
Topography and landscape					
NEXTMap Britain DSM from radar altimetry	10	Raster images	Intermap	Yes	Yes
1:250k, 1:50k, 1:25k, 1:10k topography, National Grid, Admin Meridian		Raster and vector	OS	Yes, PGA	Yes
Landscape Character Assessment	11	ESRI shape files	SNH	Yes	No
Habitats, ecology and biodiversity					
Country Parks, Historic gardens and Designed Landscapes	12	ESRI shape files	SNH	Yes	No
Areas of Great Landscape Value	9	ESRI shape files	WLC	No	No
Habitat mapping		ESRI shape files	WLC	No	No
Special Protection Areas (SPAs)	12	ESRI shape files	JNCC	No	No
Special Areas of Conservation (cSACs)	12	ESRI shape files	JNCC	No	No
Ramsar sites	12	ESRI shape files	JNCC	No	No
Sites of Special Scientific Interest (SSSI)	12	ESRI shape files	SNH	Yes	No
National Nature Reserves (NNR)	12	ESRI shape files	SNH	Yes	No
Ancient and semi-natural woodland inventory	12	ESRI shape files	SNH	Yes	No
Raised and intermediate bog inventories	12	ESRI shape files	SNH	Yes	No
Great Crested Newt Sites (Scotland)	12	ESRI shape files	SNH	Yes	No
Listed Wildlife Sites & Wildlife Sites (1993)	12	ESRI shape files	LWIC	Yes	Yes
Archaeology					
Sites and Monument Records	13	ESRI shape files	WOSAS	No	No
Scheduled Ancient Monuments	13	ESRI shape files	Historic Scotland	Yes	No

Table 1 Digital datasets used in the project GIS.

3.4 THE GEODIVERSITY RESOURCE

3.4.1 Geodiversity site review

The 122 geodiversity sites are separated into four classes for GIS display based on the values assigned to the various citeria in the Geological Scientific Merit fields in the GeoDiversitY database (see Appendix 5, main database entry window). Table 2 lists the ranking criteria applied to these fields in the database. The GeoDiversitY database and its ranking criteria were designed by BGS to applicable to all parts of Britain and have the potential to become the national standard for geodiversity databasing.

LOCAL GEODIVERSITY ACTION PLAN (LGAP)
ASSESSMENT OF GEOLOGICAL SITES - RANKING CRITERIA

RARITY	The abundance or significance of the feature of the site in the global context. *Is the rarity such that the feature is one of only a few in the world, in the UK or in the regional area or is it one of many examples and only of reference or educational significance (because it is on the doorstep)?*	10	WORLD
		8	UK
		6	REGIONAL
		4	LOCAL (LGAP)
		2	EDUCATIONAL / REFERENCE
		0	NOT PRESENT / RELEVANT
QUALITY	The extent to which a feature is typical or demonstrates 'text-book' features. *World class specimen or cruddy example?*	10	WORLD CLASS
		8	UK
		6	REGIONAL
		4	LOCAL (LGAP)
		2	EDUCATIONAL / REFERENCE
		0	NOT PRESENT / RELEVANT
LITERATURE & DATA	The detail of written literature or material collections relating to the feature.	10	DETAILED STUDIES
		8	INTERPRETATIONS
		6	DESCRIPTIONS
		4	COLLECTED MATERIAL
		2	REFERENCED
		0	NO DATA
EDUCATIONAL VALUE	The value of the site feature for educational fieldwork (including school, degree and adult education courses). Including 'relief sites' that may relieve pressure on other popular sites. *Is it visited by UK-wide groups or local schools only?*	10	UK EDUCATIONAL
		8	REGIONAL
		6	LGAP AREA SCHOOLS / HE
		4	LOCAL (WALKING DIST.) GROUPS
		2	LITTLE VALUE
		0	NO VALUE
COMMUNITY VALUE	The value of the site to local people as a local amenity including historical or cultural associations outside the geological significance. 'Local is defined as within walking or 10 min drive distance. *Is the feature of the site used daily as common ground or rarely visited by the local community?*	10	DAILY LOCAL USE
		8	WEEKLY USE
		6	MONTHLY USE
		4	YEARLY USE
		2	INFREQUENT USE
		0	NO LOCAL USE

Table 2 Ranking criteria for BGS geodiversity audits.

The four classes applied are:

3: Geological features of great value, worthy of interpretation & conservation – 34 sites

2: Geological features of some value, may be worthy of interpretation & conservation – 33 sites

1: Geological features of limited value – 34 sites

0: Geological features destroyed, no longer visible, or of no value – 21 sites

Although the Geological Scientific Merit (GSM) scores were taken into account when applying these four classes to the sites, other factors such as the number of other natural heritage designations were also considered. Also the WLGS list includes a few sites that were not visited and thus not scored for GSM.

The 67 class 3 and class 2 sites are considered to be representative of particular geodiversity features in the context of West Lothian and classed here as West Lothian Geodiversity Sites (WLGS). For numbering and description purposes, a number of these localities have been considered together to give a total of 51 WLGSs (Table 3, Figure 14).

Of these 51 WLGS sites, four have statutory protection as geological or mixed geological and biological SSSIs (4−East Kirkton, 25−Skolie Burn, 26−Petershill Quarries and 27−Rifle Ranges Quarries). The remaining 47 WLGSs form a reservoir of non-statutory, but significant geodiversity sites. Five of these 47 sites are existing RIGS and LaBRIGS have a further 16 localities on a 'proposed' RIGS list for possible future designation.

WL GS No.	Site name	Geology Class		Geol Theme	WLGS class	Other Designation	Site Potential / Issues / Management
		Group	Formation				
1	Baad Park Burn	Inverclyde Quaternary	Ballagan	LthSt Sed Struc GDep	2	PHRP AGLV	Potential interpretation leaflet for Pentlands walk. Good viewpoint
2	West Cairn Hill, East Burn	Inverclyde	Kinnesswood	LthSt Sed	2	PHRP AGLV	Potential interpretation leaflet for Pentlands walk. Good viewpoint
3	Linhouse Water - Above Carstairs Viaduct	Inverclyde	Ballagan	LthSt Sed	2	B-SSSI SWTR AGLV (LWS SW)	Potential for Linhouse Water geotrail
4	East Kirkton Quarry	Strathclyde	West Lothian Oil-shale	Pal Sed	3	G-SSSI, GCR RIGS AGLV	Potential for on-site interpretation board and/or part of a Bathgate Hills geotrail. Rubbish dumping, burning, and overgrowing
5	Five Sisters	Strathclyde	West Lothian Oil-shale	MnHe	2	SAM	Potential for on-site interpretation, oil-shale mining heritage
6	Seafield Law	Strathclyde	West Lothian Oil-shale	MnHe	3	P-RIGS	RIGS, potential for on-site interpretation − artificial Crag and Tail, interpretation leaflet
7	Greendykes	Strathclyde	West Lothian Oil-shale	MnHe	3	SAM P-RIGS	RIGS, interpretation leaflet, oil-shale mining heritage
8	Almond Valley Heritage Centre	Strathclyde	West Lothian Oil-shale	MnHe	2	(LWS)	Current museum displays on the oil shale industry, geology, mining, oil refining and social history
9	Murieston Water 2	Strathclyde	Gullane	Struc	3	B-SSSI, CP LWS, AGLV AWI SNWI	Potential for on-site interpretation or leaflet on faulting
10	Almondell and Calder Wood	Strathclyde	West Lothian Oil-shale	LthSt MnHe	3	RIGS LWS, WS AWI SNWI AGLV, CP	Potential for on-site interpretation
11	Upper Uphall	Strathclyde	West Lothian Oil-shale	MnHe	3	P-RIGS	RIGS, potential for on-site interpretation board and / or leaflet on stoop and room mining
12	Union Canal, Winchburgh	Strathclyde	West Lothian Oil-shale	LthSt	3	SAM P-RIGS LWS	RIGS, potential for interpretation leaflet
13	Hopetoun Obelisk Quarry	Strathclyde	West Lothian Oil-shale	Sed LthSt BSt	3	HGDL (LWS) AGLV	Potential for on-site interpretation Soil dumping

WL GS No.	Site name	Geology Class		Geol Theme	WLGS class	Other Designation	Site Potential / Issues / Management
		Group	Formation				
14	Society East Shore	Strathclyde SSDPV	West Lothian Oil-shale SSDLO	Sed LthSt Ign GDep	2	AGLV (LWS) (HGDL) (AWI)	Potential for Society East Shore to Abercorn Point geotrail, interpretation leaflet and/or on-site interpretation board
15	Society Point	Strathclyde	West Lothian Oil-shale	Sed LthSt Struc	3	AGLV (HGDL) (AWI)	RIGS, potential for Society East Shore to Abercorn Point geotrail, interpretation leaflet and/or on-site interpretation board
16	Society Shore	Strathclyde	West Lothian Oil-shale	LthSt Pal	2	AGLV (HGDL) (AWI) (LWS)	Potential for Society East Shore to Abercorn Point geotrail, interpretation leaflet and/or on-site interpretation board
17	Hopetoun Shore	Strathclyde MCPAS	West Lothian Oil-shale LAFAS	Sed LthSt Struc Ign, Pal	3	AGLV P-RIGS (HGDL) (AWI), (LWS)	Potential for Society East Shore to Abercorn Point geotrail, interpretation leaflet and/or on-site interpretation board.
18	Abercorn Point	Strathclyde Quaternary	West Lothian Oil-shale	Sed LthSt Struc PGDep	3	AGLV (M-SSSI) (HGDL) (LWS)	Potential for Society East Shore to Abercorn Point geotrail, interpretation leaflet and/or on-site interpretation board.
19	Midhope Burn	Strathclyde	West Lothian Oil-shale	LthSt	2	AWI SNWI HGDL	Potential to extend Society East Shore to Abercorn Point geotrail?
20	Cairnpapple Hill	Bathgate	Bathgate Hills Volcanic	BtHe Ign	3	SAM P-RIGS AGLV HPWG	RIGS, interpretation leaflet, good viewpoint
21	Wairdlaw Quarry	Bathgate LCTS	Bathgate Hills Volcanic MVSC	Pal BtHe	3	AGLV P-RIGS (CP), (AWI)	RIGS, interpretation leaflet, Wairdlaw Limestone
22	Union Canal Museum	Bathgate	Bathgate Hills Volcanic	BtHe	2	SAM LWS	Potential for museum exhibit, geology of Union Canal
23	Levenseat working quarry	Clackmannan	Passage	Sed LthSt	3	P-RIGS	Potential for excellent sections in Passage Formation once quarry ceases operation
24	Levenseat quarries & mines	Clackmannan	Passage	LthSt MnHe	3		Potential for interpretation leaflet on limestone mines, Levenseat to Fauldhouse walk, but marred by windblown rubbish from landfill site. Good viewpoint.
25	Skolie Burn	Clackmannan	Lower Limestone Limestone Coal	LthSt Sed Ign, Pal	3	M-SSSI GCR, LWS P-RIGS	RIGS, prone to rubbish dumping and vegetation overgrowth
26	Petershill Quarries	Clackmannan	Lower Limestone Limestone Coal	Pal Sed LthSt Ign	3	M-SSSI GCR, RIGS WS, SWTR AGLV	Interpretation board vandalised, vegetation overgrowth
27	Rifle Range Quarries	Clackmannan	Lower Limestone	Pal Sed LthSt MnHe	3	M-SSSI P-RIGS GCR HPWG AGLV	Vegetation overgrowth
28	Hilderston Silver Mine Quarry	Clackmannan	Lower Limestone	Sed	3	P-RIGS HPWG, WS AGLV	RIGS, potential interpretation leaflet, vegetation overgrowth
29	Hilderston Silver Mine	Clackmannan	Lower Limestone	MnHe Min	3	P-RIGS HPWG AGLV	RIGS, potential interpretation leaflet, vegetation overgrowth and flooding

WL GS No.	Site name	Geology Class		Geol Theme	WLGS class	Other Designation	Site Potential / Issues / Management
		Group	Formation				
30	Hillhouse Quarry and Mine	Clackmannan MCPAS	Lower Limestone LAFAS	LthSt Ign MnHe	2	AGLV P-RIGS (CP)	RIGS, potential interpretation leaflet on stoop and room workings, but subsidence problems
31	Muiravonside, Carribber Glen	Clackmannan	Upper Limestone	LthSt MnHe	3	B-SSSI P-RIGS, LWS AWI SNWI AGLV	RIGS, potential interpretation leaflet and/or geotrail
32	Wallace's Arch	Clackmannan	Passage	GeoM	2	P-RIGS LWS AWI SNWI AGLV	Potential interpretation leaflet and/or geotrail
33	Barbauchlaw Quarries	Coal Measures (Scotland)	Lower Coal Measures (Scotland)	LthSt	2	LWS WS	Perhaps the only Coal Measures exposures in West Lothian? Visit required to determine potential
34	Barbauchlaw Burn Quarries	Coal Measures (Scotland)	Lower Coal Measures (Scotland)	LthSt	2	WS	Perhaps the only Coal Measures exposures in West Lothian? Visit required to determine potential
35	Carsie Hill	SSDPV Clackmannan Quaternary	SSDLO Lower Limestone	Ign GeoM	2	AGLV	Volcanic vent sculpted into Crag and Tail, potential interpretation leaflet, small exposures, vegetation overgrowth
36	Auchinoon Quarry	MCPAS Strathclyde	LAFAS Gullane	Ign Meta LthSt	3	P-RIGS AGLV	RIGS, potential interpretation leaflet and/or on-site interpretation board, good viewpoint for Pentland Hills
37	Linhouse Water - Glasgow Viaduct 2	MCPAS	LAFAS	Ign	2	AGLV AWI SNWI LWS	Potential for Linhouse Water geotrail
38	The Knock	LCTS Quaternary	MVSC	Ign GeoM	3	AGLV P-RIGS (WS) (HPWG)	Potential to include on Bathgate Hills geotrail, interpretation leaflet, good viewpoint
39	Witch Craig Viewpoint	LCTS Bathgate Quaternary	MVSC Bathgate Hills Volcanic	Ign GeoM	3	AGLV RIGS WS AWI SNWI (CP)	Existing stone shelter with 43 rocks from the Midland Valley. Potential to include on Bathgate Hills geotrail
40	Cockleroy	LCTS Bathgate Quaternary	MVSC Bathgate Hills Volcanic	Ign GeoM	3	AGLV P-RIGS LWS AWI SNWI SAM	RIGS. Potential to include on Bathgate Hills geotrail, on-site interpretation/ interpretation leaflet. Good viewpoint across the whole of the Midland Valley
41	Beecraigs Quarry	LCTS	MVSC	Ign	3	AGLV CP P-RIGS (LWS)	RIGS, potential to include on Bathgate Hills geotrail, interpretation leaflet
42	Binny Craig	LCTS Quaternary	MVSC	Ign GeoM	3	RIGS AGLV AWI (WS)	Potential to include on Bathgate Hills geotrail. Good viewpoint
43	Kildimmery Fishery Quarry	LCTS	MVSC	Ign	2	AGLV	Potential to include on Bathgate Hills geotrail.
44	Craigton (Hill) Quarry	LCTS	MVSC	Ign Struc	3	(HGDL) (LWS) (AWI) (SAM) (SNWI)	Best example of quartz-dolerite sill, but access problems

WL GS No.	Site name	Geology Class		Geol Theme	WLGS class	Other Designation	Site Potential / Issues / Management
		Group	Formation				
45	Linhouse Water - Calderwood 1	LCTS	MVSC	Ign Struc LthSt	2	AGLV LWS B-SSSI AWI SNWI	Potential for interpretation leaflet and/or on-site interpretation board
46	Tophichen HIll	LCTS Quaternary	MVSC	GeoM Ign	2	SAM AGLV	Potential to include on Bathgate Hills geotrail
47	Linlithgow Loch	Quaternary		GeoM BtHe	2	B-SSSI AGLV SAM	Existing on-site board at the west end of the loch could be up-dated to include some info on the landforms and glaciofluvial deposits
48	Tailend Moss	Quaternary		Soil	3	B-SSSI P-RIGS WS RBI SWTR	RIGS, potential for interpretation leaflet and/or on-site interpretation board
49	Longridge Moss	Quaternary		Soil	3	B-SSSI P-RIGS WS RBI SWTR	RIGS, potential for interpretation leaflet and/or on-site interpretation board
50	Easter Inch Moss	Quaternary		Soil	2	WS GCNS	Potential to combine with proposed RIGS at Seafield Law (see 6 above). Interpretation leaflet and/or on-site interpretation board
51	Calder Wood	Quaternary		PGDep ActPr	3	RIGS AGLV LWS B-SSSI AWI SNWI	Potential for on-site interpretation

Abbrev.	Explanation	Abbrev.	Explanation
SSDPV	Southern Scotland Dinantian Plugs and Vents Suite	AGLV	Area of Great Landscape Value
SSDLO	Southern Scotland Dinantian Plugs and Vents Suite, Lothian Subsuite	AWI	Ancient Woodland Inventory
MCPAS	Midland Valley Carboniferous to Early Permian Basic Alkaline Sill Suite	B-SSSI	Site of Special Scientific Interest (Biological)
LAFAS	Dinantian to Westphalian Sills of Lothians and Fife	CP	Country Park
MVSC	Midland Valley sill complex	GCNS	Great Crested Newt Site (Scotland)
LCTS	North Britain Late Carboniferous Tholeiitic Suite	GCR	Geological Conservation Review Site
LthSt	Lithostratigraphy	G-SSSI	Site of Special Scientific Interest (Geological)
Sed	Sedimentology	LWS	Listed Wildlife Site
Struc	Structural geology	HGDL	Historic Garden & Designed Landscape
Ign	Igneous geology	HPWG	High Priority Wildflower Grasslands
Pal	Palaeontology	M-SSSI	Site of Special Scientific Interest (Mixed geological and biological)
Meta	Metamorphic geology	PHRP	Pentland Hills Regional Park
Min	Minerals	P-RIGS	Proposed Regionally Important Geological and Geomorphological Site
GDep	Glacial deposits	RBI	Raised Bog Inventory
PGDep	Post-glacial deposits	RIGS	Regionally Important Geological and Geomorphological Site
GeoM	Geomorphology	SAM	Scheduled Ancient Monument
ActPr	Active processes	SNWII	Semi-Natural Woodland Inventory
MnHe	Mining Heritage	SWTR	Scottish Wildlife Trust Reserve
BtHe	Built Heritage	WS	Wildlife Site (1993)
(CP)	Designations in brackets indicate that geodiversity site is adjacent or close to designated site		

Table 3 West Lothian Geodiversity Sites (WLGS) and explanation of abbreviations.

Sections 3.4.2 to 3.4.9 describe the WLGSs within their component geological groups and themes. Further details on the site access, site fragility and the importance of the geological features are available in the GeoDiversitY database.

The sections on soil, habitat and land use and biodiversity are not intended to be comprehensive, but give an indication on their relationship with the geodiversity. Possible future work could include expansion of these sections by further collaboration with SNH and possibly the Macaulay Institute.

3.4.2 Inverclyde Group rocks

The oldest Carboniferous rocks in the Midland Valley of Scotland belong to the Inverclyde Group (Figures 1B, 2). In West Lothian the group comprises the Kinnesswood and Ballagan formations

Outcrops of Inverclyde Group rocks comprise approximately 3,300 hectares, or 7.7% of the surface area of West Lothian. They crop out in a strip south-east of the A70 between East Cairn Hill and Henshaw Hill, forming the high ground of the Pentland Hills, and a smaller area to the south-east of Livingston between Linhouse Water and Kirknewton (Figure 15).

The Inverclyde Group was laid down between 345 m and 355 million years ago (Ma) whilst Scotland lay in low latitudes south of the Equator. At this time, the climate was generally considered to be semi-arid and seasonally wet. A rather discontinuous vegetational cover of the land surface was probably the norm. Locally in the Pentlands, the base of the group is taken at an unconformity on Lower Devonian and older strata. It is because of the semi-arid climate that the sandstone-dominated **Kinnesswood Formation** contains calcareous and dolomitic pedogenic (soil profile) horizons (calcrete) and the overlying **Ballagan Formation** is characterised by grey mudstone and siltstone with nodules and beds of ferroan dolostone (cementstone), and evaporite (mainly gypsum). The group is also characterised by an absence of carbonaceous rocks, especially coal seams and oil shales, in comparison with overlying rocks.

3.4.2.1 SOILS, HABITATS AND LAND USE

The hard resistant and largely glacial till-free Kinnesswood Formation sandstones that form the Cairn Hills have favoured the development of freely-draining humus-iron podzol and blanket peat soils (Figure 6); these support mainly dry and wet dwarf shrub heath. On the lower ground at the foot of the hills, the softer Ballagan Formation is mostly till-covered and gives rise to very poorly-drained blanket peat or peaty podzols (Figure 6) which support wet heath, acid grassland, marshy grassland and mire, used mainly for rough grazing. The mostly till-covered Ballagan Formation in the area to the south-east of Livingston has developed mostly poor to imperfectly-drained gley soils (Figure 6) used mainly for ley grassland and plantation forestry.

3.4.2.2 BIODIVERSITY

The till-free sandstone slopes and summit of East Cairn Hill (Figures 16, 19) have been designated as a Listed Wildlife Site [NT 12 59]. Species present at East Cairn Hill include Clustered Dock, cloudberry and Common Cow-wheat. Listed Wildlife Sites also occur at Middlemuir [NT 06 55] and Kirknewton Estate [NT 11 66], with a Wildlife site at Harperrig Moss [NT 11 61] (Figure 16), but as these are situated on glacial till there is little direct influence of the bedrock on the biodiversity. The mixed till and peat covered area to the west of Craigengar [NT 091 551] is a biological SSSI and hosts three characteristic upland habitats – dry upland heath, blanket bog and flush communities within hill cleughs. It is of international importance for its dry upland heath, species-rich grassland and its marsh saxifrage and is a candidate Special Area of Conservation (cSAC). Templehill [NT 113 614] east of Harperrig

Reservoir is listed on the Raised Bog Inventory. Inverclyde Group rocks also host several areas of Ancient Woodland, the largest being Selm Muir Wood and Overton Wood/Green Burn Wood south-east of East Calder.

3.4.2.3 WEST LOTHIAN GEODIVERSITY SITES

Given the limited coverage of Inverclyde Group rocks, the four sites described below are considered to adequately represent the group (Figure 15).

WLGS 1 BAAD PARK BURN 1 & 2 [NT 1125 6014 AND NT 1103 6037] (FIGURES 16 TO 20)

Other Designations: Pentland Hills Regional Park; AGLV

These two sites are on the Baad Park Burn to the south-east of Harperrig Reservoir (Figure 13). They are within the Pentland Hills Regional Park and close to a popular walking route following an old drove road over the Pentland Hills (Figure 14) from Little Vantage on the A70 to West Linton. At Baad Park Burn [NT 1125 6014] (Figure 15) a section of the lower part of the Ballagan Formation is exposed. This location also gives views of the Cairn Hills (Figures 16, 17). At Baad Park Burn 2 [NT 1103 6037] (Figure 18) good sedimentary structures are present in red sandstone outcrops), the former demonstrating good small-scale scarp featuring.

WLGS 2 WEST CAIRN HILL [NT 1042 5832] (FIGURE 18)

Other Designations: Pentland Hills Regional Park; AGLV

Although not visited during the audit, the BGS 1:10,000 map (surveyed in 1995) shows an outcrop of pink Kinnesswood Formation sandstone with sedimentary structures in the East Burn on the north-west slopes of West Cairn Hill (Figure 18).

WLGS 3 LINHOUSE WATER [NT 0730 6425]

Other Designations: B-SSSI (Linhouse Valley); LWS (Linhouse Water); WS (Linhouse Valley; SWTR (Linhouse Glen); AGLV

The Linhouse Water (above Carstairs Viaduct) site is a useful site for demonstrating the upper part of the Ballagan Formation and the overlying Corston Hill lavas (Arthur's Seat Volcanic Formation).

3.4.3 Strathclyde Group rocks

The Strathclyde Group is a varied sequence of rocks, sedimentary and volcanic, characterised by the presence of carbonaceous beds, including coal, oil-shale and limestone. The local Strathclyde Group strata are assigned to the Arthur's Seat Volcanic, Gullane and West Lothian Oil-shale formations (Figure 1B, 2).

Outcrops of Strathclyde Group rocks comprise approximately 19,966 hectares, or 46.3% of the surface area of West Lothian. They crop out in a broad area covering most of the eastern half of West Lothian, from the coast at Abercorn – Society to the southern slopes of the Pentland Hills at Colzium and Crosswood (Figure 21).

The Arthur's Seat Volcanic Formation, at the base of the group in the Lothians, is 342 Ma old. The sedimentary rocks were laid down between 345 Ma and 326 Ma. Deposition of the Strathclyde Group marks a lithological change from concretionary limestone and dolostone-bearing strata typical of the Inverclyde Group to a coal-bearing sequence in which volcanic rocks may be common.

The group is largely fluviatile and lacustrine in origin, with a few marine incursions from time to time. The palaeoclimate during deposition of the Strathclyde Group was mainly humid (coals, oil-shales and sideritic mud grade palaeosols) but the presence of calcretes and calcareous mudstones ('marls') in the West Lothian Oil-shale Formation point to periods of semi-arid climatic conditions.

The **Arthur's Seat Volcanic Formation** consists of extrusive igneous rocks belonging to a suite of mildly alkaline basaltic lavas which is recognised across the Midland Valley and is chemically distinct from the Lower Devonian igneous rocks of the Pentlands. Volcaniclastic rocks known as tuffs and lapilli-tuffs also occur; these may be air-fall or water-lain in origin. The formation is up to 200 m thick in this area and absent in places.

The **Gullane Formation** consists of a cyclical sequence predominantly of pale-coloured, fine- to coarse-grained sandstones interbedded with grey mudstones and siltstones. Subordinate lithologies are coal, seatearth, ostracod-rich limestone and dolostone, sideritic ironstone and, rarely, marine beds with low diversity faunas lacking for example corals. The depositional environment was predominantly fluviodeltaic, into lakes that only occasionally became marine. Desiccation cracks, soft sediment deformation textures and bioturbation are sedimentological features typical of this formation.

The **West Lothian Oil-shale Formation** is characterised by several, well-developed distinctive seams of oil-shale (see section 3.2.1.2 for historical significance) within a cyclical sequence dominated by pale-coloured sandstones interbedded with grey siltstones and mudstones. Sections in most parts of the formation can be seen on the coast from South Queensferry to Blackness. Subordinate lithologies are coal, ostracod-rich limestone (see section 3.2.1.4 for economic geology) and dolostone, sideritic ironstone and beds of fossiliferous mudstone deposited in a marine environment, including limestones with rich and relatively diverse faunas. Thick, pale green-grey or grey argillaceous, calcareous beds containing supposed volcaniclastic detritus described as 'marl' are also present and may have formed on extensive semi-arid plains. The 'marl' can rest directly on the mud-cracked top of an oil shale. The maximum thickness of the formation is in excess of 1120 m in West Lothian.

The environment of deposition was of fluviolacustrine deltas, subject to periodic inundation by incursions of marine water, with large freshwater lagoons rich in algae and other organic matter in which accumulated oil-shales and, less commonly, but significantly, limestones. The East Kirkton Limestone represents a world famous, development of non-marine limestone

3.4.3.1 Soils, habitats and land use

Compared to the Kinnesswood Formation sandstone of the Inverclyde Group, the relatively soft rocks of the Strathclyde Group rock have been easily eroded by the successive Quaternary ice-sheets leaving thick deposits of glacial till. Most soils are thus derived from this glacial till parent material with the dominant soil types being imperfect to poorly-drained non-calcareous gleys and brown forest soils with gleying. Extensive blanket Peat is developed in the south between Cobbingshaw and Harperrig reservoirs and soil complexes are common in the north, around East Calder and north-west of Winchburgh (Figure 6). The midlle of the outcrop is extensively urbanised with major population centres at Livingston and Broxburn. North of Broxburn mixed arable and ley grassland predominate, while to the south of Livingston, the land use is a mix of plantation forestry, ley grassland and rough pasture.

3.4.3.2 Biodiversity

Conservation biodiversity interest is concentrated in the biological SSSIs (Figure 12) at: the intermediate bog at Cobbinshaw Moss [NT 03 57]; Hermand Birchwood [NT 031 618]; Herman Quarry [NT 028 635]; Linhouse Valley [NT 07 64]; Calderwood [NT 07 66]; the raised bog at Tailend Moss [NT 00 67] (see section 3.4.10.10) and Philpstoun Muir [NT 06 76].

The foreshore between the mouth of the Midhope Burn [NT 080 793] at the West Lothian boundary just east of Blackness [NT 056 798] is part of the mixed geological and biological

Firth of Forth SSSI. The biodiversity interest comprises an extensive mosaic of intertidal and coastal habitats. Extensive mudflats make up much of the intertidal area, with areas of sand, shingle, rock and boulders. Associated coastal habitats include saltmarsh, grassland and sand dunes. The mudflats are invertebrate rich and form important feeding grounds for the abundant waders and wildfowl in the Forth. Mussel beds occur on the lower shores in some areas and marine algae such as *Fucus*, *Ascophyllum* and *Enteromorpha* species, and eelgrass *Zostera* species are supported on these mudflats. The site is also a Ramsar site and an SPA .

Great Crested Newt (Scotland) sites also occur at: Easter Inch Moss [NT 003 664] and Almondell and Calder Wood [NT 077 675, NT 078 674].

There are also a number of Listed Wildlife Sites (Figure 12): The River Almond and its tributaries Breich Water, Harwood Water, Murieston Water and Linhouse Water; The Union Canal; Old Philpstoun Bing [NT 054 770]; Hopetoun Estate [NT 088 789].

The following are also Wildlife Sites (Figure 12): Addiewell Ponds [NT 003 626]; Almond Pools [NT 021 663]; Almondell Country Park [NT 089 689]; Bangour Reservoir [NT 012 719]; Bellsquarry Wood [NT 050 652]; Canal Wood [NT 079 761]; Cobbingshaw Main Reservoir [NT 019 583]; Crosswood Reservoir [NT 060 575]; Easter Inch Moss [NT 003 664]; Faucheldean Bing [NT 084 742]; Harperrig Reservoir [NT 092 610]; Hermand Birchwood [NT 032 618]; Linhouse Valley [NT 072 643]; Mains Burn [NT 033 735]; North Addiewell Bing [NT 001 630]; Pumpherston Pond [NT 071 692]; Roman Camp Meadows [NT 071 706]; Skivo Quarry [NT 051 640]; Tailend Moss [NT 009 678].

Strathclyde Group rocks also host the following Scottish Wildlife Reserves: Addiewell Bing [NT 001 630]; Hermand Birchwood [NT 031 618]; Linhouse Glen [NT 072 643]. There are also numerous areas of Ancient and Semi-Natural Woodland (Figure 12).

High Priority Wildflower Grasslands (Figure 12) are present at: Hermand Quarry [NT 028 636]; Linhouse Water [NT 066 643]; Muriestone Estate [NT 059 646]; Ochiltree Place [NT 042 750]; Parkhead [NT 085 781]; Seafield [NT 004 664]; Uphall Station [NT 066 702].

3.4.3.3 WEST LOTHIAN GEODIVERSITY SITES

The Strathclyde Group is well represented by geodiversity sites, though the best of these are located in the centre and north of the outcrop (Figure 21).

WLGS 4 East Kirkton Quarry (GCR, Geological SSSI, RIGS) [NS 9901 6913] (Figures 22–25)

Other Designations: AGLV

East Kirkton Quarry exposes the Upper Viséan East Kirkton Limestone, a laterally impersistent sedimentary sequence within a thick succession of basaltic lavas and tuffs. The succession consists of limestones overlain by black mudstones. Within the limestones are contorted horizons with common spherulitic structures and chert nodules – these are interpreted as having formed in a hot spring environment. The site has yielded the world's earliest known terrestrial tetrapods. Specimens include the first complete articulated amphibians found in the Scottish Carboniferous this century − seven species have been recognised so far, with the commonest a form of primitive temnospondyl (ancestors of modern frogs and toads). Two or possibly three species of anthracosaur have been found including the first articulated anthracosaur skeleton from the Scottish Lower Carboniferous. Anthracosaurs are known from both aquatic and terrestrial forms and recent work suggests a link between these amphibians, early reptiles and amniotes. Another new species is the earliest known loxommatid. This group are poorly known, and there is an important possibility of finding the first ever articulated skeleton at this site during future research. Recent research has also revealed a wealth superbly preserved arthropods, particularly scorpions and eurypterids. New eurypterid material from East Kirkton is also under study, as are superb scorpion remains. By far the best complete Lower Carboniferous scorpions (internationally) are currently being studied. The oldest harvestman (opilionid) known was found here. East Kirkton Quarry is a Geological Conservation Review (GCR) (Arthropoda and Carboniferous–Permian Fish/Amphibians) site.

WLGS 5 FIVE SISTERS OIL-SHALE BINGS [NT 009 641] (Figures 26–27)

Other Designations: SAM (Five Sisters shale bing, SE of Mid Breich)

The oil-shale bings are unique in Britain and north-west Europe and form a significant part of the industrial heritage of West Lothian. The Five Sisters are a distinctive and well known landmark. Oil-shale waste is non toxic, alkaline and free-draining, unlike acidic coal spoil. The shale particles in oil-shale bings are more cohesive than in coal waste, and allow stable steep bing sides which are not prone to slippage. Burnt oil-shale is initially dark blue-grey (“blaes”), but rapidly oxidises to a characteristic red colour in contact with the elements (Figure 28). Variations in the chemical composition at the different bings produce a wide range of habitats and new niches for plants and animals and are a wildlife haven in a primarily agricultural and urban landscape.

WLGS 6 SEAFIELD LAW (P-RIGS) [NT 005 667] (Figures 29–30)

Other Designations: WS (Easter Inch Moss)

Seafield Law is unique in that it has been re-profiled to replicate one of the most distinctive natural landforms of West Lothian – a ‘crag and tail’ feature sculpted by the erosive power of successive glaciations during the Quaternary.

WLGS 7 GREENDYKES (P-RIGS) [NT 087 736] (Figure 28)

Other Designations: SAM (Greendykes shale bing, Broxburn)

Greendykes is the largest of West Lothian’s oil-shale bings and towers nearly 100 m above the town of Broxburn. The bing is protected as a scheduled monument and provides habitats for a wide range of locally threatened flora and fauna, such as wormwood, hares, red grouse and sky larks and badgers

WLGS 8 ALMOND VALLEY HERITAGE CENTRE [NT 0325 6689] (FIGURE 31)

Other Designations: LWS (River Almond)

The Almond Valley Heritage Centre Museum has an “oilshale adventure zone” display on the oil shale industry in West Lothian. Geological, mining, oil refining and the social history aspects of the oil shale industry are covered. The AVHC web pages also have a link to the “Secrets of the Bathgate Hills” leaflet and board game (www.almondvalley.co.uk/secrets/secrets.htm).

WLGS 9 MURIESTON WATER 2 [NT 0733 6658] (FIGURE 32)

Other Designations: B-SSSI (Calderwood); Almondell & Calder Country Park; LWS (Murieston Water); AGLV; AWI (Calder Wood); SNWI

The Calder Fault is exposed at this locality on the Murieston Water. Thin (1–10 cm) beds of Gullane Formation sandstone and siltstone are exposed in the hanging-wall of the fault with a steep (~40°) dip to the north. The beds exhibit much fault-related deformation. The Footwall strata are largely overgrown and poorly exposed.

WLGS 10 ALMONDELL (RIGS) [NT 0908 6918] & RIVER ALMOND [NT 0859 6836] (FIGURES 33–35)

Other Designations: Almondell & Calder Country Park; LWS (River Almond); WS (Almondell Country Park); AGLV; AWI (Almondell Plantations, Strathbrock & Kirkhill Woods); SNWI

Almondell and Calderwood Country Park is a 90-hectare Country Park in Mid Calder, offering woodland and riverside walks, picnic areas and barbecue facilities. The Park's Visitor Centre has leaflets on the Oakbank oil-shale bing and on the rocks found within the park. In the past they have had geological displays. The West Lothian Ranger Service based at the park arranges talks, school visits and summer events. A good example of a *Stigmaria* tree root fossil in the Calders Member (West Lothian Oil-shale Formation) can be seen in the bank of the river at NT 0887 6885 (Figure 33). At the River Almond site the Burdiehouse Limestone (Hopetoun Member, West Lothian Oil-shale Formation) can be seen in the bed of the river (Figure 34). For the Calder Wood RIGS see WLGS 51 (section 3.4.10.10).

A good example of an overfold occurs in the Broxburn Shale (West Lothian Oil-shale Formation) on the west bank of the Linhouse Water in Calder Wood [NT 0790 6710] (Figure 35). This locality is about 50 m downstream (north) of WLGS 45.

WLGS 11 UPPER UPHALL (PROPOSED RIGS) [NT 0550 7225] (FIGURES 36–38)

Other Designations: None

This site displays excellent examples of the features typically seen as a result of worked ground. There is a small oil-shale bing, sitts (areas of surface collapse) from underground stoop and room workings, uneven/low ground from quarrying and nearby remains of a dismantled railway. The site is currently used for cattle grazing, although is located on the outskirts of Uphall and could therefore be under threat from residential development in the future.

WLGS 12 UNION CANAL WINCHBURGH (PROPOSED RIGS) [NT 0868 7510]

Other Designations: LWS (Union Canal); SAM (Union Canal, River Almond to River Avon)

Exposures of sandstones, siltstones and mudstones of the Hopetoun Member (West Lothian Oil-shale Formation) can be seen in canal bank. This site was not visited.

WLGS 13 HOPETOUN OBELISK QUARRY [NT 0942 7859] (FIGURES 39–42)

Other Designations: HGDL (Hopetoun House); LWS (adjacent to Hopetoun Estate); adjacent to AWI woods

This disused quarry in the Dunnet Sandstone (Hopetoun Member, West Lothian Oil-shale Formation) was worked to provide the building stone for Hopetoun House. At the south-west corner of the quarry [NT 0942 7859] there is good face approximately 5–6 m high displaying (Figure 40) grey to pale brown, fine grained sandstone, with interbeds of very fine grained sandstone and laminated carbonaceous siltstone ("tiger-stripe") Cross bedding and cross laminations are also evident at this locality. Since the audit visit in November 2005, large quantities of soil have been tipped into the southern part of the quarry. The largest worked faces can be seen at the north-east corner of the quarry, though at the present time (March 2006) are inaccessible due to waterlogging at the base. The most accessible face is located at the north-west corner of the quarry beside some small stables [NT 0942 7871].

WLGS 14 SOCIETY EAST SHORE [NT 107 788] – [NT 102 789] (FIGURES 43–46)

Other Designations: HGDL (Hopetoun House); LWS (adjacent to Hopetoun Estate); adjacent to AWI woods

The shoreline from Society East Shore to Abercorn Point displays a reasonably well-exposed, gently-folded section through the Calders and Hopetoun Members of the West Lothian Oil-shale Formation. Sixteen individual localities within this formation were recorded along this shore section.

At Society East Shore 1 a sandstone dyke cuts across the Burdiehouse Limestone and the Camps Shale. Within the Dunnet Sandstone of the Hopetoun Member, sandstone can be seen overlying a thin oil-shale (Society East Shore 2 [NT 1058 7879], Figure 43), a limestone and sandstone with carbonate nodules (Society East Shore 3) [NT 10538 78805], Figure 44), and cross-bedded sandstone (Society East Shore 4 [NT 1052 7882], Figure 45).

WLGS 15 SOCIETY POINT [NT 1009 7902] (FIGURES 47–50)

Other Designations: *HGDL (Hopetoun House); LWS (adjacent to Hopetoun Estate); adjacent to AWI woods; AGLV*

The large outcrop of Binny Sandstone at Society Point is an excellent locality with sedimentological features such as trough cross-bedding and pebbly and carbonaceous lags. There is also a good example of a sandstone dyke-injection (Figure 49). Some damage to the outcrop has been caused by core-cutting in the sandstone (Figure 50A).

WLGS 16 SOCIETY SHORE [NT 0967 7910 – NT 0954 7913] (FIGURES 51–52)

Other Designations: *HGDL (Hopetoun House); LWS (adjacent to Hopetoun Estate); adjacent to AWI (Bog Wood); AGLV*

At Society Shore [NT 0967 7910] (Figure 51), a *Stigmaria* root fossil can be seen in a beach outcrop of the Barracks Limestone (Hopetoun Member, West Lothian Oil-shale Formation). A good example of the use of local stone can be seen at Society Shore 2 [NT 0954 7913] (Figure 52).

WLGS 17 HOPETOUN SHORE (PROPOSED RIGS) [NT 1009 7902] (FIGURES 53–57)

Other Designations: *HGDL (Hopetoun House); LWS (adjacent to Hopetoun Estate); adjacent to AWI (Bog Wood); AGLV*

On the foreshore opposite Hopetoun House and its grounds, both limbs of the Hopetoun anticline can be seen (Figures 53, 55). Ripple-marked sandstone bedding planes can be seen at Hopetoun Shore 1 [NT 0935 7919] (Figure 54). Small-scale folding and faulting are visible in the Burdiehouse Limestone on the west limb [NT 0894 7935] (Figures 56, 57).

WLGS 18 ABERCORN POINT [NT 0827 7954] (FIGURES 58–60)

Other Designations: *HGDL (Hopetoun House); LWS (adjacent to Hopetoun Estate); adjacent to AWI (The Wilderness); SAM (close to remains of Abercorn Castle); AGLV; close to M-SSSI (Firth of Forth) which is also a Ramsar site and an SPA*

At Abercorn Point 3 (WLGS 18), the Binny Sandstone is well-exposed [NT 0843 7950] (Figure 58) and good examples of cross-bedded sandstone (Hopetoun Member, West Lothian Oil-shale Formation) can be seen on the foreshore [NT 0827 7954] (Figure 59). See section 3.4.3.2 for details of Firth of Forth mixed SSSI.

WLGS 19 MIDHOPE BURN [NT 0787 7898 – NT 0784 7981] (FIGURES 61–63)

Other Designations: *HGDL (Hopetoun House); AWI (Wester Shore Wood); SAM (close to remains of Abercorn Castle); AGLV; close to M-SSSI (Firth of Forth) which is also a Ramsar site and an SPA*

Along the Midhope Burn to the south-west of Abercorn Point, a small quarry beside a footpath exposes a coarsening-up sequence of siltstones and sandstones within the Hopetoun Member of the West Lothian Oil-shale Formation (Midhope Burn 2 [NT 0784 78918] (Figures 59, 60). Further downstream, the Broxburn Shale can be seen beside the footpath about 30 m upstream from a small bridge at Midhope Burn 1 [NT 0787 7898] (Figure 61). See section 3.4.3.2 for details of Firth of Forth mixed SSSI.

3.4.4 Bathgate Group rocks

The Bathgate Group is a persistent group of volcanic rocks which interdigitate with the sedimentary rocks of the upper part of the Strathclyde Group and the larger part of the Clackmannan Group (Figure 1B). In West Lothian the group comprises the Bathgate Hills Volcanic Formation.

Outcrops of Bathgate Group rocks comprise approximately 3,185 hectares, or 7.4% of the surface area of West Lothian. They crop out in a north–south strip from north of Linlithgow to just south of Bathgate (Figure 64).

The **Bathgate Hills Volcanic Formation** occurs in the north-western part of the district where it is intercalated with and replaces sedimentary formations. It is up to 600 m thick. The basal beds of the formation are tuffs which lie at a widespread horizon just above the Two Foot Coal in the Hopetoun Member. Towards the top of the volcanic pile, olivine-basalt lava becomes predominant, occurring in layers or flows with vesicular or rubbly tops. The central parts of lava flows are commonly hard, compact and very fresh, hence well exposed at outcrop. The top and base of flows are typically amygdaloidal and/or scoriaceous with much hydrothermal alteration and are consequently less well exposed, giving rise to a conspicuous ridged topography (trap featuring) in places which reflects the alternating hard and 'soft' parts of the flows. The hard lavas and tuffs of the Bathgate Hills Volcanic Formation have resisted glacial erosion better than the softer sedimentary rocks of the Strathclyde, Clackmannan and Coal Measures Groups, resulting in the uplands of the Bathgate Hills, which reach an altitude of 312 m at Cairnpapple.

Coals and seatclays with rootlets are commonly developed directly on top of lava flows and fragments of fossil wood have been found incorporated in the base of flows, including some 'trunks' in apparent position of growth recorded at Grangepans by Cadell in ‘The Story of the Forth’ in 1925. In the northern part of the outcrop, between Linlithgow and Bo'ness, there is evidence to suggest that magma was erupted on to, or even intruded into, wet unconsolidated sediments. Irregular blocks of lava and rounded pillow-like masses are wrapped in a matrix of disturbed sediment, and sediment infills cavities or occurs as clasts within the lavas. Petrographically the lavas are remarkably uniform. Large areas of basalt are exposed in a belt running through the Riccarton Hills but this belt dies out to the north. A more widespread belt of basaltic rocks lies to the west and is exposed on the hills to the north and south of Linlithgow. The basalts and tuffs are thought to have erupted from local volcanic vents, such as those now exposed to the south-east of the extrusive rocks at Tar Hill and The Binns. These vents are now filled with volcaniclastic rocks (agglomerate).

The overall regional setting of the Bathgate Hills volcanicity has been described and a detailed account given of the interaction between eruption, erosion, clastic deposition and carbonate precipitation in Lower Limestone Formation time. Jameson envisaged the volcanic rocks accumulating above sea level to form islands surrounded by coastal plains, restricted lagoons and a variety of carbonate reef facies, which accumulated during longer periods of volcanic quiescence. This succession was terminated by subaerial exposure and erosion followed by renewed volcanic activity.

3.4.4.1 SOILS, HABITATS AND LAND USE

Bedrock with brown forest soils occurs on most of the hill tops, though most of the lower ground and the lee slopes of the crags are till covered with non-calcareous gleys and brown forest soils with gleying present (Figure 6). The hilly topography with its variable microclimate and the greater variety of soil types and drainage status has probably resulted in a wider variety of habitats than any other part of West Lothian. Ley grassland, rough grazing, plantation forestry and the urban area of Linlithgow are the dominant land uses.

3.4.4.2 BIODIVERSITY

Conservation biodiversity interest is concentrated in: the biological SSSIs at (Figure 12) Linlithgow Loch [NS 995 774 – NT 009 778] (Figure 155) and part of Lochcote Marsh [NS 981 742]; the mixed biological and geological SSSIs at Firth of Forth (also a Ramsar site and SPA) and Petershill [NS 985 693 – NS 990 710]; several areas of Ancient and Semi-Natural Woodland, the largest being Beecraigs Wood [NS 993 741].

There are also a number of Listed Wildlife Sites (Figure 12): Beecraigs Reservoir [NT 010 744]; Cockleroy Hill [NS 987 747]; Cockleroy Reservoir [NS 995 749]; the River Almond and its tributaries Breich Water, Harwood Water, Murieston Water and Linhouse Water; The Union Canal; Old Philpstoun Bing [NT 054 770]; Hopetoun Estate [NT 088 789].

The following are also Wildlife Sites (Figure 12): Balvormie Meadow [NS 997 738]; Bangour Reservoir [NT 012 719]; Bogburn Flood Lagoons [NS 977 677]; Cockleroy Wood [NS 984 748]; Easter Inch Moss [NT 003 664]; Linlithgow Marsh [NS 982 768]; Lochcote Reservoir [NS 978 737]; Petershill [NS 986 695]; Silvermines Quarry [NS 991 714]; Witch Craig Meadow [NS 988 725].

High Priority Wildflower Grasslands (Figure 12) are present at Cairnpapple Hill [NS 987 717] (Figure 65) and Knock [NS 988 715, NS 992 715] (Figure 125).

3.4.4.3 WEST LOTHIAN GEODIVERSITY SITES

Although the coverage of Bathgate Group rocks is limited, three sites described below are considered to be just about adequate to represent the group. Further quality sites may not exist.

WLGS 20 CAIRNPAPPLE HILL (PROPOSED RIGS) [NS 9872 7174] (FIGURES 65–68)

Other Designations: SAM (Cairnpapple Hill); AGLV; HPWG (unimproved acid grassland)

Cairnpapple Hill is one of the best known and most important pre-historic sites on the mainland of Scotland. The site consists of both ceremonial and burial monuments. Human activity on Cairnpapple dates back 5,500 years to the Neolithic period. During the Bronze Age the site was used as a burial site. Burials were placed under cairns, in shallow graves and in unlined pits. The site builders used the local rock types – basalt from the Bathgate Hills Volcanic Formation and quartz-dolerite from the dyke to the north or the sill to the east of the site.

The site offers one of the best viewpoints in central Scotland – on a clear day it stretches from Arran in the west to the Bass Rock in the east. Between the Rifle Range Quarries (WLGS 27) and the 312 m Trig point 600 m south of Cairnpapple Hill several low scarp features trending north-north-east pick out fresh, fine-grained basalt are interpreted as the central parts of lava flows.

WLGS 21 WAIRDLAW QUARRY (PROPOSED RIGS) [NS 9952 7313] (FIGURES 69–75)

Other Designations: AGLV; CP (adjacent to Beecraigs Wood); AWI (adjacent to Beecraigs Wood)

Although this locality is included with the Bathgate Group sites, the quarry at Wairdlaw (Figure 71) was formerly worked for limestone occurring in a small outcrop of the Wairdlaw Limestone (Lower Limestone Formation, Clackmannan Group) within the lavas of the Bathgate Hills Volcanic Formation. Well-preserved lime kilns can be seen near Wairdlaw Farm (Figure 69).

WLGS 22 UNION CANAL MUSEUM [NT 0036 7692]

Other Designations: LWS (Union Canal); SAM (Union Canal, River Almond to River Avon)

The Union Canal Museum in Linlithgow exhibits records, photographs and artefacts associated with the Union Canal. It is housed in a former canal stable situated on lavas and tuffs of the Bathgate Hills Volcanic Formation. Although no outcrops exist at this site, it is listed as there is potential for a museum exhibit on the geodiversity of the Union Canal.

3.4.5 Clackmannan Group rocks

The Clackmannan Group is characterised by strongly cyclical sequences of sandstone, siltstone, mudstone, limestone, coal and seatearth. It includes the Lower Limestone, Limestone Coal, Upper Limestone and Passage formations.

Outcrops of Clackmannan Group rocks comprise approximately 8,276 hectares, or 19.2% of the surface area of West Lothian. They crop out in a north–south strip from north-east of Linlithgow to the Gladsmuir Hills in the south-west corner of the district (Figure 76).

The Clackmannan Group formations are defined by the differing proportions of the main rock types. Thus, beds of limestone are more conspicuous in the Lower and Upper Limestone formations than elsewhere, coals are most common in the Limestone Coal Formation, and sandstones and seatearths are the most prominent constituents of the Passage Formation. Depositional environments, likewise, show an underlying similarity, being related to the repeated advance and retreat of fluviodeltaic systems into an embayment of varying salinity. Scotland during the Namurian and succeeding Westphalian was located more or less on the Equator. Its climate was essentially tropical with extensive swampy forests (mires and ‘mangrove’ swamps) rapidly producing large trees that subsequently died to produce great thicknesses of peat that with time and deep burial became transformed into coal. The Lower and Upper Limestone formations contain the highest proportion of marine deposits, while alluvial deposits dominate the Passage Formation; the Limestone Coal Formation occupies an intermediate position. The base of the Clackmannan Group is taken at the base of the Lower Limestone Formation, where a cyclical sequence of marine limestone-bearing strata rests conformably on the West Lothian Oil-shale Formation of the Strathclyde Group. This group is mostly Namurian in age.

The **Lower Limestone Formation** comprises repeated upward-coarsening cycles of limestone, mudstone, siltstone and sandstone. Thin beds of seatrock and coal may cap the cycles. The limestone beds are fossiliferous and pale to dark grey in colour; most were deposited in a tropical marine environment. The mudstone (which may also contain marine fossils) and siltstone are predominantly grey to black. A few non-marine faunal beds are also known. Nodular clayband ironstone and limestone are well developed in the mudstone sequences. The Hurlet Limestone defining the base of the formation, the Inchinnan Limestone, the Blackhall Limestone, the Main, Mid and Second Hosie limestones and, defining the top of the formation, the Top Hosie Limestone. The thickness of the formation is not well constrained but in the range of 100 to 200 m. In the Bathgate Hills the formation is interbedded with and replaced by basaltic tuffs and lava flows of the the Bathgate Hills Volcanic Formation and the key limestone horizons are more difficult to identify, may be undeveloped or be fused together.

The marine bioclastic limestone exposed at Wairdlaw [NS 994 731] (Figure 71, 74) appears to be isolated within the Bathgate Hills Volcanic Formation.

The **Limestone Coal Formation** comprises sandstone, siltstone and mudstone in repeated cycles. The majority coarsen upwards, but others fine upwards. The cycles are usually capped by seatearth and coal (3-10% of the total succession). The siltstone and mudstone are usually grey to black, while the sandstone is usually fine- to medium-grained and off-white to grey.

The **Upper Limestone Formation** is characterised by repeated upward-coarsening cycles comprising grey limestone overlain by grey to black mudstones and calcareous mudstones, siltstones and paler sandstones capped by seatrocks and coal. The main limestones are the Index, Orchard, Calmy and Castlecary limestones. A persistent development of lavas, up to 40 m thick, is present between Kipps Hill [NS 986 738] and Bathgate. Some of the flows on Kipps Hill are very fresh glassy basanites with well-developed columnar jointing. The youngest recorded volcanic activity in the district occurs above the Castlecary Limestone in the base of the Passage Formation.

The **Passage Formation** is characterised by an alternation of fine- to coarse-grained sandstones (with some conglomerates) and structureless clayrocks (including some high-alumina seatclay and fireclay). The petrography and provenance of the Passage Formation sandstones has been studied. These sandstones were derived from a low-grade metamorphic source intruded by acid igneous masses comparable to the Upper Dalradian rocks of the Highlands. A sandstone in the lower part of the formation at Leven Seat [NS 943 580] has been worked for many years as a silica sand and used for moulding sand and several other non-industrial uses. A thin bed of tuffaceous siltstone close above the Castlecary Limestone has been recorded north-west of Torphichen [NS 967 723]. This is believed to be the highest stratigraphical level at which the Bathgate Hills Volcanic Formation occurs.

3.4.5.1 Soils, habitats and land use

Like the Strathclyde Group, the rocks of the Clackmannan Group are predominately glacial till-covered, though a belt of glaciofluvial sand and gravel runs from the north-west around Westfield south-eastwards to Bathgate, and around Boghall in the north of the district. Also, much of the till is peat covered along the boundary with south Lanarkshire in the south-west. The resulting soils are very variable with drainage status varying from free to very poor, with non-calcareous gleys, peaty-gleys, brown forest soils with gleying and brown forest soils predominating (Figure 6). The topography is also variable with the Bathgate Hills in the north, the flatter ground of the Almond Valley in the middle and the upland fringe moorland in the south. Urban areas and ley grassland and rough grazing are the main land uses for most of the area, with plantation forestry predominating south of the A71.

3.4.5.2 Biodiversity

Conservation biodiversity interest is concentrated in: the biological SSSIs at (Figure 12) Carriber Glen [NS 968 751] and Lochcote Marsh [NS 981 742]; the mixed biological and geological SSSIs at Petershill [NS 985 693 – NS 990 710]; and Skolie Burn [NS 984 618 – NT 986 628]

There is one Listed Wildlife Site (Figure 12) – Beecraigs Reservoir [NT 010 744] and Wildlife Sites at: Bogburn Flood Lagoons [NS 977 677]; Cockleroy Wood [NS 984 748]; Easter Inch Moss [NT 003 664]; Foulshiels Bing NS 977 635]; Lochcote Reservoir [NS 978 737]; Longridge Moss [NS 956 618]; Nether Longford Moss [NS 975 613]; Petershill [NS 986 695]; Silvermines Quarry [NS 991 714]; Swinabbey Moss [NS 970 658]; Witch Craig Meadow [NS 988 725].

Over 20 areas of Ancient and Semi-Natural Woodland (Figure 12) occur and High Priority Wildflower Grasslands are present at Cairnpapple Hill [NS 987 717] (Figure 65) and Knock [NS 988 715, NS 992 715] (Figure 125). The development of the best herb species-rich grassland and species-rich limestone grasslands in West Lothian (MG3 & MG5) occurs in areas underlain by the Clackmannan Group. The limestones within the Clackmannan Group rocks also support one of the richest assemblages of bryophytes in the district.

3.4.5.3 WEST LOTHIAN GEODIVERSITY SITES

The Clackmannan Group is well represented by good-quality geodiversity sites (Figure 76).

WLGS 23 LEVENSEAT WORKING QUARRY (PROPOSED RIGS) [NS 940 575] (FIGURES 77–79)

Other Designations: None

Levenseat quarry is the last remaining full-time operating quarry in West Lothian. It is owned by WBB Minerals and produces silica sand used mainly for rootzone and top dessing material for sports fields and golf courses. Planning permission has been granted to extend the quarry by 12 hectares to the west of current operations. The quarry manager reported that the quarry faces adjacent to the access road at Levenseat working quarry and Levenseat working quarry 2 will be retained and will be available for conservation once the quarry ceases operation. The faces show excellent examples of Passage Formation stratigraphy and sedimentology.

WLGS 24 LEVENSEAT QUARRIES AND MINES [NS 9547 5799] (FIGURES 80–82)

Other Designations: None

A line of old quarries delineate the outcrop of the Castlecary Limestone (Upper Limestone Formation) a few hundred metres to the east of the current working quarry at Levenseat. Several mines entrances can be seen, just west of the public footpath between Leven Seat and Fauldhouse. Part of Levenseat Quarry immediately west of Leven Seat hill is now used as a landfill site (Figure 80) and the surrounding area is disfigured with much wind-blown plastic rubbish.

WLGS 25 SKOLIE BURN (GCR, MIXED SSSI, PROPOSED RIGS) [NS 984 619 – NS 987 624] (FIGURES 83–86)

Other Designations: LWS (Breich Water)

Skolie Burn, a tributary of the Breich Water south of Stoneyburn, provides the best section of the upper part of the Lower Limestone Formation and the basal beds of the Limestone Coal Formation on the eastern side of the central coalfield of the Midland Valley. The section lies above an intrusive picrite sill (alkali-dolerite) and the basal beds are baked at the contact with the sill (Figure 85). The 20 m thick sequence dips to the west and is and dominated by mudstone with several beds of sandstone and at least three marine limestones. The sequence is fossiliferous and these fossils are of vital stratigraphical importance in correlating late Dinantian and early Silesian rocks of the Midland Valley. Skolie Burn is a GCR (Dinantian of Scotland) site.

The site is a mixed SSSI designated for one of the largest areas of herb rich unimproved grassland in West Lothian, supporting over a hundred plant species. Species-rich grassland of this type is an unusual habitat in the Lothians. The site supports regionally uncommon plants, including the Greater Butterfly Orchid; scrub and marsh vegetation add diversity to the area.

WLGS 26 PETERSHILL QUARRIES (MIXED SSSI – PETERSHILL, RIGS) [NS 9849 6952] (FIGURES 87–90)

Other Designations: WS (Petershill); SWTR (Petershill); AGLV

Petershill Quarries are located in the Bathgate Hills about 1 km north-east of Bathgate and show a sequence of bedded and slightly argillaceous limestones through the Petershill Limestone of the Lower Limestone Formation. The limestone is a classic locality famous for its well-preserved marine fossils including corals, brachiopods, bivalves and echinoids. These faunas are of immense taxonomic significance, and many type species have been described from this location.

A quiet sedimentary environment is indicated by the good fossil preservation. The lateral and vertical facies variations of the Petershill Limestone are of great interest to carbonate sedimentologists and palaeoecologists. Massive limestones (biohermal buildup) occur at the southern end of the quarry. Petershill Quarries are well-known and a lot of material has been removed in the past by fossil collectors. The site is a GCR (Dinantian of Scotland) site.

The site is a mixed SSSI designated for the largest area of species rich limestone grassland in Lothians. Grassland of this type is a very scarce habitat in the region, and this site is the only example of any size in West Lothian. Woodland, scrub pools and marsh add to the diversity of habitat within the site. The limestone rocks support one of the richest assemblages of bryophytes in the district.

WLGS 27 RIFLE RANGE QUARRIES (MIXED SSSI – PETERSHILL, PROPOSED RIGS)
[NS 9890 7087] (FIGURES 91–94)

Other Designations: HPWG (Petershill); AGLV

These quarries are situated approximately 1 km north-north-east of Petershill Quarries and south-west of The Knock. They also expose the Petershill Limestone of the Lower Limestone Formation, though a more nearshore and turbulent environment is interpreted, as the fauna is not as well-preserved as in the Petershill Quarries. The site is a GCR (Dinantian of Scotland) site.

The site is a mixed SSSI designated for the largest area of species rich limestone grassland in Lothians. Grassland of this type is a very scarce habitat in the region, and this site is the only example of any size in West Lothian. Woodland, scrub pools and marsh add to the diversity of habitat within the site. The limestone rocks support one of the richest assemblages of bryophytes in the district.

WLGS 28 HILDERSTON SILVER MINE QUARRY (PROPOSED RIGS) [NS 9908 7135] (FIGURES 95, 96, 98, 99)

Other Designations: WS (Silvermines Quarry); HPWG (Bathgate Hills, Knock, Knock A); AGLV

Hilderston Silver Mine Quarry is located 200 m north of The Knock and approximately 500 m south-east of Cairnpapple Hill. Although the Petershill Limestone is no longer visible in the Silver Mine Quarry, a 3–4 m section through the overlying mudstones, siltstones and sandstones sediments is seen (Figure 98). These display an excellent coarsening upward sequence with good sedimentary structures, including ripples and burrowing (Figure 99).

WLGS 29 HILDERSTON SILVER MINE (PROPOSED RIGS) [NS 9917 7158] (FIGURES 95, 96, 100, 101)

Other Designations: WS (Silvermines Quarry); HPWG (Bathgate Hills, Knock); AGLV

At Hilderston Silver Mine native silver occurs in a vein on the margin of a thin east–west trending dolerite dyke which cuts sandstones and siltstones above the Petershill Limestone. The mine was in operation between 1606 and 1614, then reopened in the 18th century to work lead and zinc in a vein in the Petershill Limestone. The original workings were re-excavated during the 19th century, but no further economic deposits of silver or lead was found. There is no exposure left at the Hilderston Silver Mine site, although spoil heaps may still reveal some interesting minerals from the silver-lead-zinc mining (Figures 100, 101).

WLGS 30 HILLHOUSE QUARRY AND MINE (PROPOSED RIGS) [NT 0040 7487] (FIGURES 102–106)

Other Designations: AGLV; CP (adjacent to Beecraigs Wood)

This site is located within the Beecraigs Country Park three km south of Linlithgow. The Hillhouse Limestone (Lower Limestone Formation) has been worked by both underground and surface methods. The 9 to 12 m thick massive and fossiliferous limestone dips to the west at 30 –

40^0 with consequent steep stoop and room workings, some of which have collapsed recently leading to subsidence in the overlying road. The limestone is overlain by a sill of basalt with columnar jointing – this is the type locality of the Hillhouse type of olivine-basalt in the 1928 MacGregor basalt classification.

WLGS 31 MUIRAVONSIDE, CARRIBER GLEN (PROPOSED RIGS) [NS 9690 7518]

Other Designations: B-SSSI (Carriber Glen); AGLV; LWS (River Avon); CP (adjacent to Muiravonside); AWI (Carriber Glen); SNWI

This site was not visited, but the Calmy Limestone (Upper Limestone Formation) was formerly mined in several quarries south of the River Avon in Carriber Glen.

This site forms part of Carriber Glen Biological SSSI, one of the two largest areas of semi-natural mixed deciduous woodland in West Lothian, with a complex geology leading to a diversity of woodland types within the site. Primary woodland is a scarce habitat in West Lothian. The Calmy Limestone within the site supports ash/elm woodland. This is the largest example of this unusual type of woodland in Lothians. The woodland is relatively undisturbed and contains several plant species which are scarce in Lothians.

WLGS 32 WALLACE'S ARCH (PROPOSED RIGS) [NS 9459 7305] (FIGURES 107, 108)

Other Designations: LWS (River Avon); AGLV; AWI (The Desert); SNWI

Wallace's Arch is an excellent example of a natural arch landform, which can be walked under safely. The arch is formed from Passage Formation sandstone and is situated on the south bank of the River Avon about 2 km north-west of Torphichen. It is on the River Avon Heritage Trail.

3.4.6 Coal Measures (Scotland) Group rocks

The Coal Measures Group (Scotland) is sub-divided into three formations; Upper, Middle and Lower. Only the Lower Coal Measures and, to a minor extent, the Middle Coal Measures are represented in West Lothian. The Group comprises sandstones, siltstones and mudstones with coal and seatearth. Outcrops of Coal Measures (Scotland) Group rocks comprise approximately 5,029 hectares, or 11.7% of the surface area of West Lothian. They crop out in the westernmost part of the district from Westfield in the north to Fauldhouse in the south (Figure 109).

The Coal Measures were deposited in a warm and humid climate and palaeomagnetic evidence indicates that, at that time, the area lay in equatorial latitudes. The strata are believed to have been deposited in delta-plain and alluvial-plain environments with drainage generally from a large continental area to the north. The sediments accumulated under conditions of continuous but non-uniform subsidence modified by eustatic (ice age driven) changes in sea level. Periodic brief incursions by the sea left important marine horizons which are the basis of the subdivision of the succession. A wide range of alluvial and lacustrine environments of deposition is represented. These include tropical wetland forested mires and soils (coal and seatearth), floodplain (planty or rooted siltstone and mudstone), river and delta distributary channel (thick sandstones), prograding deltas (upward-coarsening sequences) and shallow lakes (mudstones with non-marine faunas). Marine bands are rare but provide important stratigraphical markers.

The **Lower and Middle Coal Measures** comprise sandstone, siltstone and mudstone in repeated cycles commonly 8-12 m thick which most commonly coarsen upwards, but also fine upwards, with seatearth and coal at the top. The mudstone and siltstone are usually grey to black, while the sandstone is fine- to medium-grained and off-white to grey in colour. Coal seams are common and many exceed 0.3 m in thickness amounting cumulatively to 5% – 8% of the total succession.

There are more than 11 seams that have been mined in the Lower Coal Measures. The main seams formerly mined are the Colinburn, Armadale Main, Armadale Ball, Mill, Shotts Gas, Lower Drumgray, Mid Drumgray, Upper Drumgray, Kiltongue, Ladygrange and Airdrie

Virtuewell coals. Middle Coal Measures are restricted to a small area west of Fauldhouse where the Airdrie Blackband Coal may have been mined. These seams have been exploited recently in opencast sites. The Lower Coal Measures are over 150 m thick.

3.4.6.1 Soils, habitats and land use

Coal Measures Group rocks are almost entirely covered by glacial till, though some of this has been subsequently stripped off in open-cast mined areas. In other areas the till is covered by colliery tips and by peat deposits, particularly in the south and west. The resulting soils are of variable with drainage status varying from imperfect to very poor, with non-calcareous gleys, peaty-gleys, deep peat and brown forest soils with gleying predominating (Figure 6). The topography is almost entirely lowland plateaux. Plantation forestry, ley grassland, rough grazing and urban (Armadale and Fauldhouse) are the main land uses, with forestry predominating south of the A71.

3.4.6.2 Biodiversity

Conservation biodiversity interest is concentrated in (Figure 12): Blawhorn Moss National Nature Reserve [NS 885 682]; Blawhorn Moss biological SSSI and SPA [NS 886 683]; 11 Raised Bog and two Intermediate Bog Inventory sites.

There are four Listed Wildlife Sites (Figure 12): Barbauchlaw Burn, River Almond [NS 906 641 – NS 934 655]; Half Loaf Pond [NS 960 668]; Fauldhouse Ponds [NS 921 606, NS 924 611, NS 928 610, NS 920 617, NS 934 617] and Wildlife Sites at: Barbauchlaw Burn [NS 923 686]; Colinshiel Wood [NS 950 690]; Drumbeg Moss [NS 870 683]; Easter Redburn Moss [NS 888 675]; Raizehill Moss [NS 878 663]; Mosshouse Farm Moss [NS 882 669]; Westcraigs Moss [NS 898 683].

There are also around 15 areas of Ancient Woodland and four areas of Semi-Natural Woodland (Figure 12).

3.4.6.3 WEST LOTHIAN GEODIVERSITY SITES

No geodiversity sites of significant value were found in the Coal Measures Group. Most of the sites mentioned in the earlier literature are quarries or mines that have since been infilled or are no longer accessible. BGS would welcome any development or extraction activities that exposed and allowed the preservation of representative Coal Measures sections.

Braehead Quarries [NS 9205 6055] (Figure 110)

Braehead Quarry [NS 9205 6055] west of Fauldhouse was a former building stone quarry working Lower Coal Measures sandstone. The quarry, closed in 1939 and is now filled in and partially landscaped. No rock sections are currently exposed. Stone from the quarry was used to build Edinburgh villas in Mayfield Road, Esslemont Road, Ross Road, Grange Loan, Midmar Drive and Comiston Drive. Note this locality is not a WLGS.

WLGS 33 and WLGS 34 Barbauchlaw Quarries [NS 9186 6825] and Barbauchlaw Burn Quarries [NS 9290 6907]

Other Designations: LWS (Barbauchlaw Burn); (WS (Barbauchlaw Glen); AGLV

Neither of these sites west of Armadale was visited but the Coalfield memoir indicates that a 10 m thick section of sandstones above Mill Coal (Lower Coal Measures) was formerly quarried here. It is recommended that these sites are visited when the opportunity arises.

3.4.7 Volcanic vent rocks

Outcrops of volcanic vents rocks comprise approximately 120 hectares, or 0.3% of the surface area of West Lothian. About 20 plugs and vents crop out as isolated subcircular areas in the northern part of the district (Figure 111). There are about 20 vents in West Lothian representing the subterranean plumbing of Lower Carboniferous volcanoes. These cylindrical to ellipsoidal shaped pipes are between 100 m and 1000 m across (greatest axis) and usually infilled with massive to poorly stratified, greenish-grey, coarse, basaltic volcaniclastic and sedimentary detritus (pyroclastic agglomerate) and are therefore vents. The largest vent is at The Binns and this is associated with two integral small plugs of olivine basalt. The next largest is Tar Hill and the most complex set is at Parkley Fisheries associated with two plugs of basalt and a late Carboniferous Quartz-dolerite dyke.

3.4.7.1 Soils, habitats and land use

The hard pyroclastic breccias and basalts of the volancic vents are more resistant than the surrounding sedimentary rocks of the West Lothian Oil-shale Formation and mostly form hills or prominent features in the landscape, e.g. Tar Hill [NT 061 739], Carsie Hill [NT 0150 7457], Jock’s Hill [NT 018 759], Peat Hill [NT 021 757], Pilgrim’s Hill [NT 014 771] and Binns Hill [NT 053 786]. These hills are mostly till-free and the predominant soil type is the free-draining brown forest soil (Figure 6). Land use on these hills is mostly ley grassland and rough grazing.

3.4.7.2 Biodiversity

Conservation biodiversity interest is concentrated in (Figure 12): Listed Wildlife Sites on the Union Canal at Pilgrim’s Hill [NT 014 771] and Niddry Castle [NT 095 743], and Hopetoun Estate [NT 102 789]; Ancient Woodland at Binns Hill [NT 055 786, NT 051 786] and East Shore Wood [NT 102 788].

3.4.7.3 WEST LOTHIAN GEODIVERSITY SITES

Given the very limited coverage of volcanic vents, the two sites described below are considered to adequately represent these rocks. Permission was refused to visit Tar Hill and Niddry Castle (see 4.3). Only two sites were visited – Carsie Hill and Society East Shore 8, but other potential geodiversity sites occur at Niddry Castle [NT 095 744], Tar Hill [NT 061 739], Pilgrim’s Hill [NT 014 771] and Binn’s Hill [NT 053 786].

WLGS 35 Carsie Hill [NT 0150 7547] (Figures 112, 113)

Other Designations: AGLV

Carsie Hill, 1.5 km south-east of Linlithgow, is one of the best examples of the dozen or so scattered volcanic vents in this area. The hill is also a good example of an ice-sculpted Crag and Tail landform (Figure 110). Outcrops of Pyroclastic breccia can be seen around the crag end of the hill. Further to the east small exposures of the Mid Hosie Limestone (Lower Limestone Formation) containing the coral *Siphonodendron junceum* are also seen.

WLGS 14 Society East Shore 8 [NT 1021 7886] (Figures 114, 115)

Other Designations: AGLV; LWS (Hopetoun Estate); HLDG (adjacent to Hopetoun House); AWI (adjacent to East Shore Wood)

Pyroclastic breccia from a vent centred on East Lodge outcrops just below the High Water Mark around 200 m south-east of Society Point. The vent intrudes the Binny Sandstone of the West Lothian Oil-shale Formation.

3.4.8 Alkali-dolerite sills

Alkali-dolerite sills comprise approximately 1,268 hectares, or 2.9% of the surface area of West Lothian. They outcrop principally in the east of the district and mainly intrude Strathclyde Group rocks (Figures 2, 116). They intrude the Strathclyde Group, mainly stratigraphically below the Bathgate Group volcanic rocks of the Bathgate Hills. These dolerites are generally medium to fine-grained and of olivine-basalt composition. They are similar petrographically and compositionally to the lavas of the Bathgate Hills and could be coeval with them.

3.4.8.1 SOILS, HABITATS AND LAND USE

The alkali-dolerite sills are variable in their topographic expression. Most are intruded into Strathclyde Group rocks and have little or no impact on landform and are till-covered, except the Auchnoon Sill which forms the till-free Auchinoon Hill. The sills intruding the Inverclyde Group between the Linhouse Water and Kirknewton also form positive landforms – Selms Top [NT 089 658], Hallcraigs [NT 106 667] and the Linhouse Water – Glasgow Viaduct 2 locality sill (Figure 122). These till-free soils have developed mainly brown forest, peaty gleys and peaty podzol soils with drainage varying from free to imperfect. As might be expected, the till covered sills develop mainly non-calcareous gleys and gleyed brown forest soils (Figure 6). The largest sill outcrops under the urban area of Livingston. On the other sills, land use is variable, but rough pasture predominates.

3.4.8.2 BIODIVERSITY

Conservation biodiversity interest is concentrated in: the mixed biological and geological SSSIs at Firth of Forth (also Ramsar site and SPA) and Skolie Burn [NS 984 618 – NT 986 628]; the biological SSSI at (Figure 12) Tailend Moss [NT 00 67] (see section 3.4.10.10); the Great Crested Newt (Scotland) site at Calder House [NT 071 674]. There are two Listed Wildlife Sites (Figure 12) – Hopetoun Estate [NT 088 789] and Kirknewton Estate [NT 113 663]. Wildlife Sites (Figure 12) occur at: Mains Burn [NT 033 735]; Faucheldean Bing [NT 084 742]; Tailend Moss [NT 009 678]. There are also around 20 areas of Ancient Woodland and five areas of Semi-Natural Woodland (Figure 12).

3.4.8.3 WEST LOTHIAN GEODIVERSITY SITES

Given the very limited coverage of alkali-dolerite sills, the three sites described below are considered to adequately represent these rocks.

WLGS 36 AUCHINOON QUARRY (PROPOSED RIGS) [NT 0919 6175] (FIGURES 117–121)

Other Designations: AGLV

Auchinoon Quarry is situated beside the A70 north of Harperrig Reservoir. The site is an excellent example of a dolerite sill and the best example of contact metamorphism in West Lothian. In the quarry face the sill intrudes laminated siltstones of the Gullane Formation − for approximately 2 m above the contact the siltstones have been thermally altered to calcsilicate hornfels. Unmetamorphosed siltstones can be seen above the hornfels in the east side of the quarry. The southern top of Auchinoon Hill, about 200 m north-north-west of the quarry, is a good viewpoint for Pentland Hills.

WLGS 37 LINHOUSE WATER – GLASGOW VIADUCT 2 [NT 0772 6562] (FIGURE 122)

Other Designations: AGLV; LWS (Linhouse Water); AWI (Linhouse Water); SNWI

At this locality the Dalmahoy Sill is well-exposed in the north-east bank of the Linhouse Water around 200 m upstream from the railway viaduct east of Oakbank. The sill forms a prominent cliff above the river and marked ridge in the hillside above. The base contact may be exposed but the cliff section is inaccessible and can only be viewed from the opposite river bank.

WLGS 17 HOPETOUN SHORE 2 (PROPOSED RIGS) [NT 0932 7918] (FIGURE 123)

Other Designations: AGLV; LWS (adjacent toHopetoun Estate); HLDG (adjacent to Hopetoun House); AWI (adjacent to East Shore Wood)

A teschenitic dolerite sill intruded into the Calders Member of the West Lothian Oil-shale Formation outcrops on the Hopetoun foreshore 450 m north-east of Hopetoun House [NT 0932 7918]. The Calders Member at this locality forms the core of the Hopetoun anticline (Figures 53, 55).

3.4.9 Quartz-dolerite sills and dykes

Quartz-dolerite (and Quartz-tholeiite) has been intruded into the Carboniferous sedimentary and volcanic strata of West Lothian both as sills and as dykes.

Quartz-dolerite sills and dykes comprise approximately 1,949 hectares, or 4.5% of the surface area of West Lothian. They crop out in the north and north-west part of the district (Figure 124).

The quartz-dolerite sills of West Lothian form part of the south-western margin of the Midland Valley Sill Complex. The outcrop of this major sill is imperfectly annular and characteristically dips inward towards the centre of the carboniferous sedimentary basin. It forms part of a major suite of high-level tholeiitic intrusions extending throughout Scotland and into the North Sea. On the basis of radiometric dates of 302 to 297 Ma, the suite is generally accepted as being of late Westphalian to Stephanian age (Figure 1).

3.4.9.1 SOILS, HABITATS AND LAND USE

Unlike the alkali-dolerite sills, most quartz-dolerite sills have a distinct landform expression, normally foming distinct areas of higher ground e.g. the ridge from Eastcraigs Hill [NS 904 680] to Gowanbank [NS 916 713] north-west of Armadale, Tophichen Hills [NS 975 726] (Figure 151), The Knock [NS 991 711] (Figures 125–129), Cockleroy [NS 989 744] (Figures 135–138), and Binny Craig [NT 043 735] (Figures 142–143, 150). Soil types are very variable on the sill outcrops, but poorly-drained non-calcareous gleys dominate the till covered parts and free to imperfectly-drained brown forest soils and soil complexes are most common on the till-free hill tops and slopes (Figure 6). Agriculture, particularly rough grazing is the main land use on the quartz-dolerite sill areas. Like the Bathgate Group, the hilly topography with its variable microclimate and variety of soil types and drainage status has probably resulted in a wide variety of habitats.

3.4.9.2 BIODIVERSITY

Conservation biodiversity interest is concentrated in (Figure 12) the mixed biological and geological SSSI at Petershill [NS 985 693 – NS 990 710] and the biological SSSIs at Carriber Glen [NS 968 751], the raised bog at Tailend Moss [NT 00 67] (see section 3.4.10.10) and Calderwood [NT 07 66]. At the Calderwood SSSI, the valleys of the Murieston Water and Linhouse Water merge together at the northern end of the site to enclose an area of mixed birch woodland and grassland on a plateau with a northerly slope. The sides of both river valleys contain long established mixed deciduous woodland and in the floor of the Linhouse Valley oxbow lochans have developed into rich marsh communities. There are two small ponds in the northern section with emergent plant species. The valley woodlands are dominated by deciduous trees particularly Ash and Elm but including Oak, Hazel, Rowan and Gean. The ground flora is dominated by herbs characteristic of long established woods. This habitat is restricted and declining within West Lothian. Much of the ground between the valleys has developed into

Birch Woodland with a mixture of Ferns *Dryopteris* spp. grasses *Holcus* spp. *Agrostis* spp. and Bracken *Pteridium aquilinum* underlying. The bracken cover increases in the more open areas and grades into unimproved neutral grassland rich in herbs such as Common Knapweed *Centaurea nigra*, Harebell *Campanula rotundifolia*, Lesser Stitchwort *Stellaria graminea* and Meadow Vetchling *Lathyrus pratensis*. The marsh areas in the valley floor are diverse in species. The wettest sections contain Meadowsweet *Filipendula ulmaria*, Valerian *Valeriana officinalis*, Reed Canary grass *Phalaris arundinacea* and several species of sedge. On drier ground mixed willow carr has become established. Marsh habitats of this type are localised in West Lothian and are also declining.

There is one Listed Wildlife Site (Figure 12) – Cockleroy Hill [NS 987 747] and Wildlife Sites at: Balvormie Meadow [NS 997 738]; Cockleroy Wood [NS 984 748]; Drumbeg Moss [NS 870 683]; Easter Redburn Moss [NS 888 675]; Lochcote Reservoir [NS 978 737]; Mains Burn [NT 033 735] Mosshouse Farm Moss [NS 882 669]; Silvermines Quarry [NS 991 714]; Tailend Moss [NT 009 678]; Witch Craig Meadow [NS 988 725]. There are also over 20 areas of Ancient Woodland and around 12 areas of Semi-Natural Woodland (Figure 12).

3.4.9.3 WEST LOTHIAN GEODIVERSITY SITES

Given the limited coverage of quartz-dolerite sill rocks, the sites described below are considered to well represent the geodiversity of these rocks.

WLGS 38 THE KNOCK (PROPOSED RIGS) [NS 9906 7114] (FIGURES 125–129)

Other Designations: AGLV; M-SSSI (adjacent to Petershill); WS (adjacent to Silvermines Quarry); HPWG (adjacent to Bathgate Hills, Knock, Knock A); AGLV

The rocky knoll of The Knock, 200 m south of Hilderston Silvermines quarry, is formed by a steep east-north-east dipping quartz-dolerite sill intruding basalt lavas of the Bathgate Hills Volcanic Formation and sedimentary rocks of the Lower Limestone Formation. Sphaeroidally-weathered dolerite can be seen on the slopes of hill (Figure 128). The summit of the hill (altitude 305 m) is an excellent viewpoint (Figure 125), with an indicator cairn listing the visible hills. The Knock is also a glacially-sculpted Crag and Tail.

This site lies at the end of Petershill SSSI. The site is a mixed SSSI designated for one of the largest areas of herb rich unimproved grassland in West Lothian, supporting over a hundred plant species. Species-rich grassland of this type is an unusual habitat in the Lothians. The site supports regionally uncommon plants, including the Greater Butterfly Orchid; scrub and marsh vegetation add diversity to the area.

WLGS 39 WITCH CRAIG WALL AND VIEWPOINT (RIGS) [NS 9908 7275] (FIGURES 130–134)

Other Designations: AGLV; WS (Witch Craig Meadow); CP (adjacent to Beecraigs Wood); AWI (Witch Craig Wood); SNWI

Witch Craig Viewpoint is situated above Witch Craig Wood and about 1 km north-east of Cairnpapple Hill. Access is by a path from the car park at the Scottish Korean War Memorial. On the summit a stone shelter (Figures 130, 131) incorporates 43 rock specimens from locations visible from this site, bringing the geodiversity across the Midland Valley to this one place (Figure 132). The site is a current RIGS site with a RIGS leaflet explaining the stones gathered at the shelter. There is a 'refuge stone' at [NS 9910 7273]. This is one of a number of stones that formed a circle at a distance of a mile around Torphichen Preceptory. All of the space within the circle formed by these stones formed a legal church sanctuary.

WLGS 40 COCKLEROY (PROPOSED RIGS) [NS 9894 7437] (FIGURES 135–138)

Other Designations: AGLV; LWS (Cockleroy Hill); WS (adjacent to Cockleroy Wood); CP (adjacent to Beecraigs Wood); AWI (Beecraigs Wood); SNWI; SAM (Cockleroy Fort)

Cockleroy is a well known viewpoint across the Midland Valley (Figure 137) situated immediately north-west of the Beecraigs Country Park. The hill is composed of Bathgate Hills Volcanic Formation basalts intruded by a quartz-dolerite sill. A park leaflet mentions a detour to the summit of Cockleroy but does not mention any geodiversity features. The Bronze Age hilltop fort known as Wallace's Bed is a Scheduled Ancient Monument and a stone arrowhead has been found on the summit.

WLGS 41 BEECRAIGS QUARRY (PROPOSED RIGS) [NT 0080 7390] (FIGURES 139–141)

Other Designations: AGLV; CP (Beecraigs Wood); LWS (adjacent to Beecraigs Reservoir)

Beecraigs Quarry is situated in the south-east corner of Beecraigs Country Park. It shows a good section through an east–west trending quartz-dolerite dyke displaying fresh material and horizontal columnar jointing (Figure 140). The fine-grained margin of the dyke can be seen beside the ladder. The quarry is currently used as an outdoor climbing wall and the exposures are easily accessible and safe (no loose material). Existing park leaflets do not mention geodiversity features or sites. A dry stone dyke lining the road is made of quartz-dolerite (Figure 141).

WLGS 42 BINNY CRAIG (RIGS) [NT 0432 7346] (FIGURES 142–145)

Other Designations: AGLV; AWI; WS (close to Mains Burns)

Binny Craig is a prominent landmark situated in the grounds of Oatridge Agricultural College at Ecclesmachan, north-west of Broxburn. It is best known for being a spectacular example of a Crag and Tail landform (Figure 142). The 'Crag' is formed from the Binny Craig Sill, a fine-grained quartz-dolerite (strictly basalt) sill which has intruded the West Lothian Oil-shale Formation. The sill dips at 25^0 to the east and forms the cliffs on the west side of the hill and the dip slope to the east. Outrops of the basalt are extensive and display some columnar jointing (Figure 141) and exposures of the baked oil-shales also occur (Figure 145). On a clear day the summit (altitude 220 m) affords an excellent panorama (Figure 144) from the Lammermuir Hills, Pentland Hills and Culter Fell in the south-east through to Ben Lomond and other Highland hills to the north-west.There is a RIGS leaflet which describes the landform, geology and other natural history features of the site.

WLGS 43 KILDIMMERY FISHERY QUARRY [NT 0220 7603] (FIGURES 146, 147)

Other Designations: AGLV

Good exposures of an east–west trending quartz-dolerite dyke occur in the Kildimmery Fishery Quarry, on the north side of Nancy's Hill, 2 km south-east of Linlithgow. The quarry is now flooded and used as a fishery. Floating trackway up the middle of the quarry allows good viewing of the quarry faces. The Quarry was still being worked in the 1930's. The dyke intruded a volcanic vent of pyroclastic breccia and several of the hills nearby such as Jock's Hill, Peet Hill and Carsie Hill (WLGS 35) are also vent landforms.

WLGS 44 CRAIGTON (HILL) QUARRY [NT 0761 7684]

Other Designations: AGLV; LWS (close to Union Canal); HGDL (close to Hopetoun House); AWI (close to Philpstoun Muir); SNWI; SAM (close to Union Canal)

Craigton (Hill) Quarry lies 2 km north-west of Winchburgh and adjacent to the M9 motorway. Permission to visit this site was denied by the Factor, but a previous visit indicates that it provides an excellent example of a 33 m thick quartz-dolerite sill with stepped contacts.

WLGS 45 LINHOUSE WATER – CALDERWOOD 1 [NT 0790 6705] (FIGURE 148)

Other Designations: B-SSSI (Calderwood); AGLV; LWS (Linhouse Water); CP (Almondell and Calder); AWI (Calder Wood); SNWI

At this locality in the Linhouse Water between Mid and East Calder, a quartz-dolerite dyke intruding the Gullane Formation forms a small (~1 m), but obvious waterfall in the river. For details of the Calderwood biological SSSI, see section 3.4.9.2.

3.4.10 Quaternary deposits, landscapes and soils

During the Main Late Devensian glaciation a vast stream of ice flowed in a general eastward direction through the Midland Valley and out to sea via the Forth estuary. It is believed that this ice extended as far as 60 km beyond the mouth of the Firth of Forth into the North Sea. Initially, the primary source for this stream was ice accumulation centred in the north, from which ice flowed over the Ochil Hills and into the southern Midland Valley. As the Devensian glaciation progressed, however, the Southern Uplands also became a dominant source area, and ice was pushed in a north-easterly direction into the Forth estuary. The processes that occurred during this glacial episode, and since then, have had a significant influence on shaping the character of West Lothian's landscape.

Quaternary superficial deposits cover approximately 43,098 hectares, or 91.7% of the surface area of West Lothian (Figure 4).

Using the NEXTMap Britain shaded-relief Digital Surface Model (Figure 10) and the BGS DiGMapGB-50 superficial deposits theme, West Lothian's landscape can be divided up into a series of broad domains (Figure 149):

3.4.10.1 CRAG AND TAIL TOPOGRAPHY

The crag-and-tail topography is pronounced in the vicinity of the Bathgate Hills, where outcrops of resistant igneous rocks have withstood the erosive power of successive Quaternary ice sheets. These outcrops, formed of Carboniferous basaltic lavas (Bathgate hills) and intrusive laccoliths and sills (Binny Craig, for example), have left a protected 'tail' of softer rock and sediment on their lee (down ice) side (Figures 142, 143, 150). The resulting topography is a prime indicator of the eastwards direction of ice flow in the West Lothian area during Quaternary glacial episodes.

As ice overrode this more elevated part of the landscape, pressurised subglacial meltwater was forced up and over the outcrops of igneous rocks. This is well illustrated at Torphichen Hill where meltwater has exploited weaknesses along faults in the quartz-dolerite sill, incising deep channels over the high ground (Figure 151).

3.4.10.2 TILL COVERED LOWLAND

Till is the material that is laid down beneath a glacier. It is present over much of the surface of West Lothian's lower lying terrain and in places exceeds 50 m in thickness. Tills tend to be an unstratified, heterogeneous mixture composed of a clay, silt or sand matrix supporting a variety of larger clasts ranging from pebbles to boulders. The stones contained in this mixture can give an indication of the source of the ice, and the route it took, before depositing material. In addition to local Carboniferous rocks (e.g. limestones, sandstones, siltstones, mudstones and basalts), tills in West Lothian contain porphyrites from the Ochil Hills and schists from the Grampian Mountains beyond. These exotic clasts indicate a general northern source for much of the ice that last overrode West Lothian. Clasts of red felsite derived from Tinto Hill in Lanarkshire, however, have been found near Calder House in Mid Calder, revealing the increasing influence of ice from a southern source during later stages of the Devensian glaciation.

Much of the till covered lowland in West Lothian is gently undulating. A number of dry gullies and over-deepened stream beds exist as a result of meltwater from retreating ice cutting through the till. In western West Lothian, near Blackridge, some subglacial streamlining of till is evident in the form of gentle southwest – northeast aligned ridges. These 'drumlin' features lie on the outskirts of a more pronounced drumlin zone, which lies farther to the west (Figure 152). Such elongated landforms are the result of powerful, rapidly flowing ice moving over soft deformable materials.

3.4.10.3 Glaciofluvial Sand and Gravel Belts

During deglaciation, higher ground in the district became ice-free first, leaving lobes of retreating ice in the lower lying areas. Fast flowing meltwater from this decaying ice was centred along major east – west trending belts, depositing sands and gravels while washing out finer silts and clays. The meltwater systems of this time are clearly seen to have been deflected around the Bathgate Hills. In places, moundy terrain is observed indicating the deposition of sediments into local pockets amongst the stagnating ice. Elsewhere, hollows have developed where detached blocks of ice were surrounded and buried by sands and gravels deposited by the meltwater. Subsequent melting of these ice blocks has left depressions in the land, referred to as 'kettle holes'. Linlithgow Loch (Figure 155), lying in a hollow bounded by high ground to the north and south, provides a large example of a kettle hole. While this hollow was choked by stagnating ice and glacial deposits, it is likely that meltwater was diverted northwest along the course of the present River Avon.

3.4.10.4 Upland, Streamlined

The upland, streamlined domain includes areas of higher ground that lie on the fringes of hills and plateaus to the south. When viewed from above, a degree of streamlining is evident, indicating that the overriding ice was still thick enough and moving fast enough to modify the underlying terrain. Ice moulding of bedrock is evident in areas such as Leven Seat where the underlying sedimentary rocks are shaped in alignment with ice direction (Figure 153). The streamlined upland landscape is also evident on areas underlain with harder bedrock, such as Corston and Auchinoon Hills (Figure 117).

3.4.10.5 Upland, Limited Modification

Lying at the margins of the Pentland Hills, these upland areas have experienced significantly less glacial modification than the lower lying landscape which lay within the main ice flow path. Rising up to 550 metres, the ground here will have supported a thinner, slower moving cover of ice, with a reduced capability to erode and modify the landscape. Although till is present in the Pentlands, it is thin and patchy compared to lower lying ground. Accumulations of coarse, angular clasts, derived from frost shattering and solifluction also occur here as a legacy of the cold conditions that persisted for a period following ice retreat from the Pentlands.

3.4.10.6 Raised Beach

Raised beaches comprise material, originally deposited in a coastal environment, which has since been elevated due to falling sea-level or uplifting land. In West Lothian raised beach deposits (Figure 154) occur as a result of glacio-isostatic uplift following the removal of ice overburden at the end of the Devensian glaciation. The deposits are primarily composed of sands, but also contain gravels and muds. They are found as areas of flat land or terraces bordering the Forth estuary.

3.4.10.7 Modern Beach

The modern beach can be defined as the area lying between the present low- and high-water marks, alternately covered by water and exposed to air during tidal cycles. In West Lothian the modern beach area comprises outcrops of bedrock and deposits ranging from cobbles through to silt. The most dominant deposit, however, is fine sand transported by river systems entering the Forth estuary (Figure 55).

3.4.10.8 Alluvium

Alluvium is material deposited by a river. In West Lothian it is usually occurs as relatively flat ground lying adjacent to river systems that have been operating during the Holocene. Sediments can comprise clays, silts, sands and gravels depending on the velocity of water at the time of deposition. In upland areas, where river velocity is higher, larger pebbles and cobbles may be present, however, lowland alluvial deposits tend to contain finer sediments. In West Lothian most alluvial deposits have a high sand and clay content.

3.4.10.9 Influence of Quaternary landscape on soils and vegetation in West Lothian

Because in Scotland, soils formed at the end of the last glaciation, and because soil formation is a slow and continuous process, soil properties and characteristics are influenced by the underlying material (often till or bedrock geology) and the landforms left following ice retreat.

Much of West Lothian falls within the till covered lowland domain.

The high clay content and highly consolidated nature of this deposit limit water infiltration and this will lead to formation of soil which has low permeability and is often waterlogged. Brown forest soils with gleying and peaty gleys predominate here, supporting grassland and rush pastures over undulating low ground. Where terrain is slightly higher and steeper, areas of moist Atlantic heather moor and blanket bog occur. Most of the soils developed on the till-covered lowland are capable of producing a moderate range of crops but are restricted by drainage limitations.

The crag and tail domain supports similar soils to the till covered lowland, with brown forest soils with gleying and peaty gleys commonly occurring. This is to be expected as crag and tail lee sides tend to support a till cover. The main difference between the domains is the soil parent material, with stones of basaltic rock having a greater presence in this domain.

The coarse nature of glaciofluvial sands and gravels have allowed the development of more freely draining brown forest soils and brown forest soils with gleying. Under natural conditions, such areas would have formerly supported broad leaved woodland. Soils in this domain now form prime agricultural land with few limitations to sustained agricultural use. Even under high rainfall, the soil can be readily cultivated.

Like glaciofluvial deposits, the sandy raised beach deposits lend themselves well to the development of freely draining soils. Brown forest soils and brown forest soils with gleying also occur here providing good agricultural land.

Soils in the upland areas develop on thin covers of till, or thin sandy stony slope deposits. With higher precipitation and lower temperatures, soils tend to be peaty podzols and humus-iron podzols with some gleys and peat. Hilltops and gentle slopes can carry blanket peat while gleys occupy slope bases. The uplands support a semi-natural habitat with Atlantic heather moor communities and flying bent grassland.

Alluvial soils in West Lothian tend to have high clay contents and are therefore relatively poorly drained. Soils are young and tend to be mineral alluvial soils or peaty alluvial soils where water logging occurs.

3.4.10.10 WEST LOTHIAN GEODIVERSITY SITES

WLGS 1 BAAD PARK BURN [NT 1125 6014] (FIGURE 17)

Other Designations: Pentland Hills Regional Park; AGLV

A section in the Ballagan Formation is capped by about 1 m of glacial till.

WLGS 42 BINNY CRAIG (RIGS) [NT 0432 7346] (FIGURES 142–144, 150)

Other Designations: AGLV; AWI; WS (close to Mains Burns)

See section 3.4.9.3

WLGS 46 TORPHICHEN HILLS [NS 975 725] (FIGURE 151)

Other Designations: AGLV; SAM (Castlehorn Fort and Standing Stones, Torphichen Preceptory; AWI (close to Bishopbrae Strips)

Excellent examples of glacial meltwater channels occur on the Torphichen Hill and Gormyre Hills. Glacial meltwater has exploited weaknesses along faults in the quartz-dolerite sill, incising deep channels over the high ground. The remains of a fort on the southernmost hill are a Scheduled Ancient Monument.

WLGS 47 LINLITHGOW LOCH [NT 004 776] (FIGURE 155)

Other Designations: B-SSSI (Linlithgow Loch); SAM (Linlithgow Palace, Peel and Royal Park); AGLV; LWS (close to Union Canal)

Linlithgow Loch is a very large kettle hole formed by the melting of a large detached mass of ice trapped within glacial deposits. This is part of the Linlithgow Loch SSSI (biological) – the largest natural freshwater loch in the Lothians, and the only example of a lowland mesotrophic loch in West Lothian. The loch supports representative examples of aquatic and emergent plant communities, and some of the plant species present are uncommon in the Lothians. The loch is regionally important for the number of birds it supports. Breeding birds of particular interest are Great Crested Grebe and Mute Swan, both uncommon in West Lothian. In the winter the loch has some of the largest flocks of Mallard, Coot, Tufted Duck and Pochard in West Lothian.

WLGS 18 ABERCORN POINT [NT 083 795] (FIGURE 154, 156)

Other Designations: HGDL (Hopetoun House); LWS (adjacent to Hopetoun Estate); adjacent to AWI (The Wilderness); SAM (close to remains of Abercorn Castle); AGLV; close to M-SSSI (Firth of Forth) which is also a Ramsar site and an SPA

Post-glacial cemented raised beach deposits can be seen above the modern beach at Abercorn Point 2 [NT 0835 7952]. A large glacial erratic of locally-derived dolerite resting on sandstones of the Hopetoun Member (West Lothian Oil-shale Formation) can be seen just below the High Water Mark at Abercorn Point 3 [NT 0827 7954]. Glacial erractics of a distinctive porphyritic dolerite (essexite) originating in the Campsie Fells near Lennoxtown have been found along the south shore of the Firth of Forth from Bo'ness to Hound Point east of South Queensferry. This is also located near the boundary of the Firth of Forth mixed SSSI. (See section 3.4.3.2 for details).

WLGS 48 TAILEND MOSS (PROPOSED RIGS) [NT 009 678]

Other Designations: B-SSSI (Tailend Moss); WS (Tailend Moss); RBI (Tailend Moss); SWTR (Tailend Moss)

This site on the western outskirts of Livingston is one of the few remaining examples of raised bogs in West Lothian, though it has suffered damage by peat cutting and mining subsidence. The main geodiversity interest is the peat soil; there is also potential for pollen records to help elucidate the depostional and climatic history of the area after the last glaciation.

Tailend Moss is a raised bog on low lying ground, bordered by acid grassland, scrub and fen communities. The Moss consists of a complex of extensive wet peatland communities, dry heath and in the low lying sections, open water pools and swamp vegetation. Tailend Moss is one of the few examples of this type of habitat in the Lothians and is of value for breeding heathland birds and several locally rare plants such as Alternate Water-milfoil *Myriophylum alterniflorum*, Bog Asphodel *Narthecium ossifragum*, Greater Bladderwort *Utricularia vulgaris* and Lesser Pond Sedge *Carex acutiformis*. It is a Scottish Wildlife Trust (SWT) Reserve and home to one of the few remaining populations of Water Voles in West Lothian.

WLGS 49 LONGRIDGE MOSS (PROPOSED RIGS) [NS 958 620]

Other Designations: B-SSSI (Longridge Moss and Farm); WS (Longridge Moss); RBI (Longridge Moss); SWTR (Longridge Moss)

This relatively large raised bog is surrounded by many wildlife-rich habitats. It is a SWT Reserve and also home to one of the few remaining populations of Water Voles in West Lothian. The main geodiversity interest is the peat soil; there is also potential for pollen records to help elucidate the depostional and climatic history of the area after the last glaciation.

WLGS 50 EASTER INCH MOSS [NT 001 667] (FIGURES 157–160)

Other Designations: WS (Easter Inch Moss Moss); GCNS (Easter Inch A & B)

This site 3 km south-east of Bathgate and adjacent to Seafield Law is a good example of a lowland raised bog. There is some evidence of damage from past domestic peat cutting. Easter Inch Moss is 500 m west of Seafield Law (WLGS 6) [NT 005 667]. The main geodiversity interest is the peat soil; there is also potential for pollen records to help elucidate the depostional and climatic history of the area after the last glaciation.

WLGS 51 CALDER WOOD (RIGS) [NT 076 664] (FIGURE 161)

Other Designations: B-SSSI (Calderwood); LWS (Linhouse Water); AGLV; CP (Almondell and Calder); AWI (Calder Wood); SNWI

Active landslip activity in glacial till can be seen at this locality on the Linhouse Water south-east of Livingston. The site is within the Almondell and Calder Country Park, is a biological SSSI, an AGLV, a Listed Wildlife Site, and has AWI and SNWI woodlands. Around 430 m upstream from this locality there is a section in the river bank [NT 0734 6613] comprising a soil profile on terraced river gravels overlying glacial till. The locality is also an area of active river erosion and depositional processes (Figures 161). For details of the Calderwood biological SSSI, see section 3.4.9.2.

4 West Lothian Geodiversity Action Plan (WLGAP)

4.1 INTRODUCTION

The Geodiversity Audit described in Chapter 3 reviewed the component elements of West Lothian's geodiversity, and its relevance to other interests, at local, regional, national and international levels. It was undertaken as a means of informing the framing of recommendations and action points designed to guide the sustainable management, planning, conservation and interpretation of all aspects of the Earth heritage of West Lothian.

The audit included evaluations of 122 sites and features of geological and landscape importance in West Lothian, four of which are currently protected nationally as geological features in SSSIs and six protected locally as RIGS. The list of 51 WLGSs (Table 2) selected expands these list of important sites to provide much better coverage at the local level.

A draft West Lothian Geodiversity Action Plan (WLGAP) has been prepared as a basis for discussion (Table 3). The WLGAP will require targeted consultation among partners to agree objectives, actions and timescales.

4.2 AIMS

The main objectives of the WLGAP may be summarised as follows:

- To promote overall awareness, understanding, enjoyment and care of West Lothian's geodiversity and its relationship with biodiversity through partnership and community involvement
- To 'embed' geodiversity into future development planning and environmental management, monitoring and interpretation policies
- To provide guidance to West Lothian planners, landowners and other individuals and organisations on sustainable management of geodiversity in the area
- To identify threats to geological sites or features and recommend strategies to conserve and protect geological features
- To indentify opportunities to enhance or restore the value of geodiversity features
- To engage industry, local communities and voluntary groups in **caring for** West Lothian's geodiversity

Objective	Action	Lead	Key Partners	Timescale
1 Geodiversity audit	1. Desk study of potential geodiversity resources.	BGS	LaBRIGS	Completed May 2005
	2. Conduct field audit of selected sites.	BGS		Completed Dec. 2005
	3. Compile geodiversity database & GIS layers.	BGS		Completed March 2006
	4. Compile detailed geodiversity report including key list of geodiversity sites (WLGS).	BGS		Completed March 2006
	5. Supply GeoDiversitY database, GIS layers and report to WLC and SNH.	BGS	BGS, SNH	March/April 2006
	6. Keep GeoDiversitY database and GIS up to date with new data and additional site information	WLC	LaBRIGS, SNH, BGS	Ongoing
	7. Publish WLC geodiversity report.	WLC	BGS, SNH, LaBRIGS	Autumn 2006
	8. Attempt to gain access to major estates geodiversity sites.	WLC	SNH, LaBRIGS, Estates, BGS	2006−2007
	9. Visit potential geodiversity sites identified in desk study, but not visited in main 2005 audit.	LaBRIGS	BGS, WLC, SNH,	2006−2008
2 Monitor condition of WLGS, SSSIs and RIGS and seek to improve where necessary, and secure long-term future	1. Note site condition from Fragility and Fragility Notes fields in GeoDiversitY database.	WLC	SNH, LaBRIGS	2006
	2. Establish a site monitoring system and secure the resources to implement it and follow up with appropriate management or restoration action	WLC, LaBRIGS	SNH, BGS	Next Local Plan review cycle
	3. Seek to retain RIGS status for existing sites and consider listing additional RIGS from WLGS list.	LaBRIGS	WLC, SNH, BGS	2006−2010
	4. Consider what protection WLGS status should provide	WLC	SNH, LaBRIGS	2006
	5. Implement a policy towards soil sustainability, soil management procedures within Development Control process, and consider developing a soil action plan	WLC	SNH	2006–2010?
3 Greater collaborative working	1. Prepare guidance on the interpretation of the geodiversity audit for development management purposes	WLC	LaBRIGS, SNH	2007
	2. Plan the integration and implementation of the GAP with the next review of the LBAP-	WL LBAP partnership	LaBRIGS, SNH	2010
	3. Seek broader local membership for the West Lothian Geodiversity Partnership (?) within LaBRIGS Group	LaBRIGS	WLC, SNH etc	2006-7
	4. Work with landowners to develop/list further RIGS in West Lothian	LaBRIGS, WLC	landowners	2006-9
	5. Work with landowners to help manage the geodiversity resource at further RIGS in West Lothian	LaBRIGS, WLC	landowners	2006-9
	6. With WLC, work to place RIGS in planning context for next Local Plan Review	WLC, LaBRIGS	SNH, BGS	2006-2010?
4 Raise awareness of geodiversity	1. Promote geodiversity and WLGSs in publications, plans and strategies	WLC	SNH, BGS	Ongoing
	2. Write/publish at least one new RIGS leaflet per year	LaBRIGS	AVHC, WLC	Ongoing
	3. If required, provide basic geological training to rangers and seek funding for this purpose	BGS	WLC, SNH	2007 –
	4. Identify needs for new RIGS posters and seek funds	LaBRIGS	AVHC, WLC	2007
	5. Attend Annual Environment Fair at AVHC	LaBRIGS	BGS	2006-2010
	6. Consult ranger services to identify interpretive leaflet support needs and seek funding if required	LaBRIGS-	WLC, SNH	2007

Objective	Action	Lead	Key Partners	Timescale
5 Education and lifelong learning	Seek funding for education development project and project officer	LaBRIGS, UKRIGS, SESEF	SNH, BGS, WLC	2006-7
	Assess RIGS in terms of School National Curriculum and develop teaching materials at appropriate levels for selected sites	LaBRIGS, UKRIGS, SESEF, SAGT, ESTA	SNH, BGS, WLC	2007-8
	Write and publish landscape leaflet based upon Union Canal tourist potential	LaBRIGS, BWS	WLC, AVHC	2007
	Collaborate with Central Scotland Forestry Trust in River Avon Walkway Trail project	CSF, WLC, FCS, LaBRIGS	SNH, BGS, landowners	2006-7
	Collaborate with Pentland Hills Ranger Service in geodiversity project in Pentland Hills	MLC, WLC, CEC, LaBRIGS	BGS, landowners	2006-7
	Collaborate with all West Lothian Ranger services (including Hopetoun House and NTS) in further geodiversity projects	WLC, LaBRIGS	BGS, landowners	ongoing

Table 4 Draft West Lothian Geodiversity Action Plan (WLGAP).

SESEF–Scottish Earth Science Education Forum, SAGT– Scottish Association of Geography Teachers, ESTA–Earth Science Teachers Association, British Waterways Scotland, CEC–City of Edinburgh Council, MLC–Midlothian Council FCS–Forestry Commission Scotland, CSF–Central Scotland Forestry Trust.

5 Bibliography

BARRON, H F. 2005. Lothian shapes up for its second first. *Earth Heritage*, Issue 24, 5.

BARRON, H F, and ARKLEY, S. 2006. West Lothian leads in Scotland. *Earth Heritage*, Issue 25, 12−13.

BRAZIER, V. 2001. Earth science and the natural heritage: developing agenda for Scotland. 305−313 in *Earth science and the natural heritage: interactions and integrated management.* GORDON, J E, and LEYS, K F, (editors). (Edinburgh: The Stationery Office.) ISBN 0 11 497283 4

BUREK, C. 2005. A tale of two sites: how RIGS can complement SSSIs. *Earth Heritage*, Issue 24, 24−25.

BUREK, C. 2006. Do we need a National GAP? *Earth Heritage*, Issue 25, 10.

BUREK, C, and POTTER, J. 2004. Local Geodiversity Action Plans: setting the context for geological conservation, *English Nature Research Report*, No. 560.

BUREK, C, and POTTER, J. 2004. Local Geodiversity Action Plans – sharing good practice workshop, Peterborough, 3 December 2003. *English Nature Research Report*, No. 601.

BENN, D I and EVANS, D J A. 1988. *Glaciers and Glaciation*. Arnold, London. ISBN 0 340 58431 9

BENTON, M J, and SPENCER, P S. 1995. Fossil reptiles of Great Britain. Geological Conservation Review Series No. 10. Joint Nature Conservation Committee. 386 pages (London: Chapman and Hall.) ISBN 0 41262 040 5

BOULTON, G S, JONES, A S, CLAYTON, K M and KENNING, M J. 1977. A British ice sheet model and patterns of glacial erosion and deposition in Britain. 231–246, in *British Quaternary studies: recent advances*. SHOTTON, F W. (editor). (Oxford: Oxford University Press.) ISBN 0 198544146

BROWN, C J and SHIPLEY, B M. 1982. *South-East Scotland: Soil and Land Capability for Agriculture.* (Aberdeen: The Macaulay Institute for Soil Research.) ISBN 0 708402259

CADELL, H M. 1913. *The story of the Forth.* (Glasgow: James Maclehose.)

CADELL, H M. 1925. *The Rocks of West Lothian.* (Edinburgh: Oliver and Boyd.)

CAMERON, I B, AITKEN, A M, BROWNE, M A E, and STEPHENSON, D. 1998. Geology of the Falkirk District. *Memoir of the British Geological Survey*, Sheet 33E (Scotland.) ISBN 0118845411

CAMERON, I B, and STEPHENSON, D. 1985. *British Regional Geology: The Midland Valley of Scotland* (3rd Edition). (London: HMSO for British Geological Survey.) ISBN 0 11 884365 6

COSSEY, P.J., ADAMS, A.E., PURNELL, M.A., WHITELEY, M.J., WHYTE, M.A. & WRIGHT, V.P., (2004), British Lower Carboniferous Stratigraphy. Geological Conservation Review Series No. 29, 617 pages, (London: Chapman and Hall.) ISBN 1 86107 499 9

COTTLE, R. 2002. Linking Geologoy and Biodiversity. *English Nature Research Report No. 562.* ISSN 0976 876X

CROFTS, R. 2001. Sustainable use of the earth's resources. 286−295 in *Earth science and the natural heritage: interactions and integrated management.* GORDON, J E, and LEYS, K F, (editors). (Edinburgh: The Stationery Office.) ISBN 0 11 497283 4

DINELEY, D and METCALF, S. 1999. Fossil Fishes of Great Britain. Geological Conservation Review Series No. 16, 675p, (London: Chapman and Hall.) ISBN 1 86107 470 0

ENGLISH NATURE. 2004. Geology and biodiversity – making the links (Peterborough: English Nature.) ISBN 1 85716 803 8

ELLIS, N V, BOWEN, D Q, CAMPBELL, S, KNILL, J L, MCKIRDY, A P, PROSSER, C D , VINCENT, M A, and WILSON, R C L. (1996) *An introduction to the Geological Conservation Review.* Geological Conservation Review Series No 1, (Peterborough: Joint Nature Conservation Committee.) ISBN 1861074034

GORDON, J E, and LEYS, K F. 2001. Earth science and the natural heritage: developing a more holistic approach. 5−18 in *Earth science and the natural heritage: interactions and integrated management.* GORDON, J E, and LEYS, K F, (editors). (Edinburgh: The Stationery Office.) ISBN 0 11 497283 4

GORDON, J E, and MACFAYDEN, C C J. 2001. Earth science conservation in Scotland: state, pressures and issues. 130−147 in *Earth science and the natural heritage: interactions and integrated management.* GORDON, J E, and LEYS, K F, (editors). (Edinburgh: The Stationery Office.) ISBN 0 11 497283 4

CARRUTHERS, R G, CALDWELL, W, BAILEY, E M, and CONACHER, H R J. 1927. The Oil-Shales of the Lothians.

(Third edition). *Memoir of the Geological Survey, Scotland*.

GRAY, M. 2004. *Geodiversity: valuing and conserving abiotic nature*. (Chichester: John Wiley & Sons.) ISBN 0 470 84896 0

GRAY, M. 2005. What's in a name? Geotope and Geodiversity? *Earth Heritage*, Issue 23, 6.

GRAY, M. 2005. Planning for geoconservation. *Earth Heritage*, Issue 23, 16–17.

HARRISON, S J, and KIRKPATRICK, A H. 2001. Climate change and its potential implications for environments in Scotland. 296–305 in *Earth science and the natural heritage: interactions and integrated management.* GORDON, J E, and LEYS, K F, (editors). (Edinburgh: The Stationery Office.) ISBN 0 11 497283 4

HARVIE, B. 2005. Oil Shale Bings. 2005. Report for West Lothian Local Biodiversity Action Plan.

HAYWARD, E, and MCDONALD, C. 2004. *West Lothian Soil sustainability report*. Report for West Lothian Council and Scottish Natural Heritage.

JAMESON, J. 1987. Carbonate sedimentation on a mid-basin high: the Petershill Formation, Midland Valley of Scotland. 309–327 in *European Dinantian environments.* MILLER, J, ADAMS, A E, AND WRIGHT, V P (editors). Geological Journal Special Issue No.12. (Chichester: John Wiley and Sons Ltd.) ISBN 0471911836

LARWOOD, J. 2004. How to mind the LGAP. *Earth Heritage*, Issue 22, 6.

LARWOOD, J. 2006. LGAPS: where are we now? *Earth Heritage*, Issue 25, 9.

LAWRENCE, D J D, VYE, C L, YOUNG, B. 2004. *Durham Geodiversity Audit.* (Durham: Durham County Council.) ISBN 0 902178 21 0

LOWE, J J, and WALKER, M J C. 1997. *Reconstructing Quaternary Environments (2nd Edition).* (Harlow: Prentice Hall.) ISBN 0582101662

MACEWEN PEACH, A. 1909. Boulder distribution from Lennoxtown, Scotland. *Geological Magazine,* Vol. VI, 26–31.

MACGREGOR, A G. 1945. The mineral resources of the Lothians. *Wartime Pamphlet of the Geological Survey of Great Britain* 45.

MACGREGOR, M, and ANDERSON, E M.. 1923. The economic geology of the Central Coalfield of Scotland, area VI, Bathgate, Wilsontown and Shotts, with Braehead, Fauldhouse, Armadale and Harthill. *Memoir of the Geological Survey, Scotland*.

MACGREGOR, M, and HALDANE, D. 1933. The economic geology of the Central Coalfield, area III, Bo'ness and Linlithgow. *Memoir of the Geological Survey, Scotland*.

MADDOX, S J, and ANDREWS, J E. 1987. Lithofacies and stratigraphy of a Dinantian non-marine dolostone from the Lower Oil-Shale Group of Fife and West Lothian. *Scottish Journal of Geology,* Vol. **23,** 129–147.

MCADAM, A D. 2003. *Edinburgh and West Lothian* (Second edition). Landscape Fashioned by Geology. (Edinburgh: Scottish Natural Heritage.) ISBN 1 853973270

MCADAM, A D, and CLARKSON, E N K. 1986. *Lothian geology: an excursion guide*. (Edinburgh: Edinburgh Geological Society.)

MCADAM, A D, SMITH, R A, and ROSS, D L. 1993. Geology for land use planning: Livingston. *British Geological Survey Technical Report* WA/92/37.

MCFAYDEN, C C J. 1992. The East Kirkton Quarry proposed site of Special Scientific Interest, West Lothian. *Earth Science Site Documentation Series.*

MCFAYDEN, C C J. 1994. The Petershill Quarry proposed site of Special Scientific Interest. *Earth Science Site Documentation Series.*

MCKIRDY A P, and CROFTS, R. 1999 *Scotland – The Creation of its Natural Landscape*. A Landscape Fashioned by Geology. (Edinburgh: Scottish Natural Heritage.) ISBN 1 853970042

MCKIRDY, A P, THREADGOLD, R, and FINLAY, J. 2001. Geotourism: an emerging rural development opportunity. 255–261 in *Earth science and the natural heritage: interactions and integrated management.* GORDON, J E, and LEYS, K F, (editors). (Edinburgh: The Stationery Office.) ISBN 0 11 497283 4

MCMILLAN, A A, GILLANDERS, R J, and FAIRHURST, J A. 1999. *Building Stones of Edinburgh.* (Second edition edition). (Edinburgh: Edinburgh Geological society.) ISBN 0 904440 04 4

MITCHELL, G H, and MYKURA, W. 1962. The geology of the neighbourhood of Edinburgh. (3rd edition). *Memoir of the Geological Survey, Scotland,* Sheet 32. ISBN 0 11887408 X

MONAGHAN, A A, PARRISH R R. 2006. Geochronology of Carboniferous–Permian magmatism in the Midland Valley of Scotland: implications for regional tectonomagmamatic evolution and the numerical time scale. Journal of the Geological Society, London, Vol. 163, 15–28.

NATURE CONSERVANCY COUNCIL. 1990. *Earth science conservation 2004in Great Britain: A strategy. (*Peterborough: Nature Conservancy Council.) ISBN 0861396898

NORTH PENNINES AONB PARTNERSHIP. 2004. *North Pennines Area of Outstanding Natural Beauty: A Geodiversity Audit and Action Plan 2004–2009.*

OFFICE OF THE DEPUTY PRIME MINISTER. 2005. *Planning Policy Statement 9: Biodiversity and Geological Conservation.* (London: HMSO.) ISBN 0 11 75394 6

OWEN, D, PRICE, W, and REID, C. 2005. *Gloucestershire Cotswolds: Geodiversity Audit & Local Geodiversity Action Plan*. (Gloucester: Gloucestershire Geoconservation Trust.) ISBN 1 904530 07 9

PALMER, D, JARZEMBOWSKI, E, SIVETER, D J. and SELDEN, P. Due 2006. Fossil Arthropods of Great Britain. Geological Conservation Review Series No. XX. Joint Nature Conservation Committee. 280p. (London: Chapman and Hall.) ISBN 1 86107 486 7

BENTON, M J, and SPENCER, P S. 1995. Fossil reptiles of Great Britain. Geological Conservation Review Series No. 10. Joint Nature Conservation Committee. 386 pages. (London: Chapman and Hall.) ISBN 0 41262 040 5

PARKES, M. 2006. Geological heritage in the Emerald Isle. *Earth Heritage,* Issue 25, 20–22.

PEACH, B N, CLOUGH, C T, HINXMAN, L W, WILSON, J S G, CRAMPTON, C B, MAUFE, H B, and BAILEY, E B. 1910. The geology of the neighbourhood of Edinburgh. (Second edition). *Memoir of the Geological Survey of Great Britain*.

PROSSER, C. 2005. New Planning Policy Statement leaves scope for more emphasis on geology. *Earth Heritage,* Issue 23, 17–18.

PROSSER, C. 2006. Massive step for geological conservation. *Earth Heritage,* Issue 25, 8–9.

PROSSER, C, MURPHY, M, and LARWOOD, J. 2006. *Geological Conservation:a guide to good practice. English Nature* 8–9. ISBN 1 85716 906 9

PURRI, G, WILLISON, T, and WOOLGAR, P. 2001. The sustainable use of soil. 190–196 in *Earth science and the natural heritage: interactions and integrated management.* GORDON, J E, and LEYS, K F, (editors). (Edinburgh: The Stationery Office.) ISBN 0 11 497283 4

ROBERTSON, T, SIMPSON, J B, and ANDERSON, J G C. 1949. The limestones of Scotland. *Special Report on the Mineral Resources of Great Britain, Memoir of the Geological Survey of Great Britain* Vol. 35 (Scotland).

ROBSON, R. 2001. Skolie Burn Site Special Scientific Interest. *Earth Science Management Brief Project.*

ROYAL SOCIETY FOR NATURE CONSERVATION. 1999. RIGS Handbook [online]. Last update 2000 [cited 20 March 2006]. Available from http://www.ukrigs.org.uk/html/ukrigs.php?page=hbcontent&menu=promo

SCOTTISH BIODIVERSITY Group. 2000. *Local Biodiversity Action Plans in Scotland: Sector Guidance Note 1 – Geodiversity.*

SCOTTISH EXECUTIVE. 2005. Choosing Our Future: Scotland's Sustainable Development Strategy. (Edinburgh: Scottish Executive.) ISBN 0 7559 4851 3. Also avaible in PDF format from http://www.scotland.gov.uk/Publications/2005/12/1493902/39032

SCOTTISH NATURAL HERITAGE. 2006. *Guidance on Establishing and Managing Local Nature Conservation Site Systems in Scotland*. 22pp.

SCOTTISH WILDLIFE TRUST. [2002]. Scottish Wildlife Trust Policy: Geodiversity [online]. Last update on 11 March 2002 [cited 20 March 2006]. Available from http://www.swt.org.uk/Downloads/03_d_Geodiversity_info.pdf.

SEYMOUR, T, and GOVAN, F. 2004. *Assessment of the Wildflower Grassland Resource of the Lothians.* Report prepared by Lothians Farming and Wildlife Advisory Group for Scottish Natural Heritage.

STANLEY, M. 2001. Welcome to the 21st century. *Geodiversity Update.* No. 1 p. 1.

SYMONDS TRAVERS MORGAN. 1998. *Environmental Geology in Land Use Planning, Case Study No. 3: Industrial Heritage and Landform Replication in West Lothian.* Report for the Department of the Environment, Transport and the Regions.

SUTHERLAND, D G. 1984. The Quaternary deposits and landforms of Scotland and neighbouring shelves. *Quaternary Science Reviews*, Vol. 3, 157–254.

THOMPSON, A, HINE, P D, POOLE, J S, and GREIG, J R. (1998). *Environmental Geology in Land Use Planning: A Guide to Good Practice.* Report to the Department of the Environment, Transport and the Regions by Symonds Travers Morgan, East Grinstead (80pp)

TREWIN, N H, (editor) 2002. *The Geology of Scotland.* (London: The Geological Society.) ISBN 1 86239 126 2

USHER, M B. 2001. Earth Science and the natural heritage: a synthesis. 314–324 in *Earth science and the natural heritage: interactions and integrated management.* GORDON, J E, and LEYS, K F, (editors). (Edinburgh: The Stationery Office.) ISBN 0 11 497283 4

VINCENT, P. 2004. What's in a name? Geotope or Geodiversity? *Earth Heritage,* Issue 23, 7.

WETHERELL, A. 2004. Linking geology and biodiversity. *Earth Heritage,* Issue 23, 20–21.

WEST LOTHIAN COUNCIL. 2005. West Lothian Local Biodiversity Action Plan: Planning for Biodiversity Action 2005 –2009.

WEST LOTHIAN COUNCIL. 2005. The Finalised West Lothian Local Plan 2005.

WILSON, R C L, DRURY, S A, and CHAPMAN, J L. 2000. *The Great Ice Age*. (London: Routledge.) ISBN 0 415 19841 0

WOODLEY-STEWART, C, and YOUNG, B. 2004. Geodiversity takes its rightful place. *Earth Heritage,* Issue 23, 10–11.

5 Glossary

Acid	Describes igneous rocks rich in silica (SiO_2 more than 63%).
Adit	Horizontal, or nearly horizontal, tunnel or mine entrance
Alkaline	Describes igneous rocks that contain more sodium and/or potassium than is required to form feldspar and hence contain, or have the potential to contain (i.e. in the norm), other alkali-bearing minerals such as feldspathoids, alkali pyroxenes and alkali amphiboles.
Alluvial	Environments, actions and products of rivers or streams
Amygdaloidal	A texture in lava consisting of spheroidal or ellipsoidal cavities formed by gas bubbles and subsequently filled with secondary minerals such as calcite, quartz or zeolites.
Annabergite	Hydrated Nickel Arsenate [Ni3(AsO4)2-8(H2O)]. A bright green mineral formed as a weathering product of nickel-containing minerals such as niccolite. The characteristic green colour is easily noticeable and was used to spot veins of nickel-bearing ore.
Anthracosaur	A order of late Palaeozoic labyrinthodont amphibians.
Anticline	An arch-shaped fold in rock in which the rock layers are upwardly convex. The oldest rock layers form the core of the fold, and outward from the core progressively younger rocks occur.
Argillaceous	Detrital sedimentary rocks composed of very fine grain silt or clay-sized particles (<0.0625 mm), usually with a high content of clay minerals
Baryte	Barium sulphate [$BaSO_4$]. A dense colourless to white mineral found in hydrothermal veins.
Basalt	A dark-coloured, fine-grained, usually extrusive, igneous rock composed of minerals rich in iron and magnesium and with a relatively low silica content.
Basanite	A dark-coloured, fine-grained, usually extrusive, igneous rock composed mainly of feldspathoid, olivine and plagioclase feldspar minerals.
Basement	A term usually applied to any widespread association of folded igneous and metamorphic rocks which are often unconformably overlain by relatively undeformed sedimentary rocks.
Basic	Describes igneous rocks relatively rich in the 'bases' of early chemistry (MgO, FeO, CaO, Fe_2O_3); silica (SiO_2) is relatively low (nominally 45-52%).
Bedding	A feature of sedimentary rocks, in which planar or near-planar surfaces known as bedding planes indicate successive depositional surfaces formed as the sediments were laid down.
Bedrock	A term used to describe unweathered rock below soil or superficial deposits. Can also be exposed at the surface.
Biohermal	Relates to a build-up of largely in-situ organisms that produce a reef or mound of organic origin.
Bioturbation	The disruption of depositional sedimentary structures by organisms e.g. activities such as burrowing
Bivalve	class of molluscs with paired oval or elongated shell valves joined by a hinge.
Blaes	Scots mining term for dark blue (blae) mudstone or shale.
Brachiopod	A phylum of solitary marine shelled invertebrates

Bravoite	A variety of pyrite, nickel-rich iron sulphide, steel grey in colour
Breccia	Coarse-grained clastic sedimentary rock consisting of angular fragments of pre-existing rocks
Brickclay	Mudstone used in the manufacture of structural clay products such as bricks, pavers, roofing tiles and clay pipes.
Brown Forest Soils	Free-draining, fertile soils with brownish subsoils where iron oxides created through weathering processes are bonded to silicate clays. They are found mainly in drier climate of the east and south of Scotland, and in sheltered Highland glens at lower elevations. Also known as Brown Earths.
Calcite	Calcium Carbonate [$CaCO_3$] a widely distributed mineral and a common constituent of sedimentary rocks, limestone in particular. Also occurs as stalactites and stalagmites and is often the primary constituent of marine shells.
Calcsilicate	A group of minerals whose bulk composition consists of calcium silicates.
Caledonian	Refers to a major mountain-building (orogenic) event related to the closure of the Iapetus Ocean during the Late Palaeozoic Era (Cambrian, Ordovician and Silurian Periods). It affected Scotland, Ireland, Scotland, Scandinavia and Greenland.
Carboniferous	A geological period [354–290 Ma] preceded by the **Devonian** and followed by the Permian.
Chert	A dense, microcrystalline form of silica which occurs as nodules or beds within parts of the Carboniferous succession of rocks
Complex	A large-scale spatially related assemblage of igneous rock units possibly, but not necessarily, with complicated igneous and/or tectonic relationships and of various ages and diverse origins.
Concretion	Hard, compact mass, usually rounded, in a sedimentary rock, formed by precipitation of a cementing mineral around a nucleus during or after deposition.
Conglomerate	A sedimentary rock, a significant proportion of which is composed of rounded pebbles and boulders, greater than 2mm in diameter, set in a finer-grained groundmass.
Contact metamorphism	The recrystallisation of country rocks when intruded by hot igneous rocks. Also known as thermal metamorphism.
Clast	Particle of broken down rock, eroded and deposited in a new setting.
Clastic	Applies to the texture of rocks which are comprised of fragments of pre-existing rocks which have been weathered or eroded.
Clayband ironstone	A bedded impure iron-ore, the iron occurring as **siderite.**
Columnar jointing	The crudely polygonal system of vertical joints formed in response to cooling of bodies of intrusive igneous rocks such as sills and dykes.
Cross-bedding	Cross-stratification formed by the migration of dunes and sand waves on a sediment surface.
Cross-lamination	Cross-stratification formed by the migration of ripples on a sediment surface. Foresets less than 10 mm thick.
Cross-stratification	A family of primary sedimentary structures formed by the migration of slip-faces of ripples and dunes in granular sediments. Characterised by internally inclined layers (foresets) bounded by planar surfaces.
Crust	The crust is the outermost layer of rocks making up the solid Earth. It is distinguished from the underlying mantle rocks by its composition, lower density, and the lower velocity at which it conducts seismic energy.

Dalradian	A Supergroup representing the youngest stratigraphic division of the Precambrian in Scotland and Ireland.
Desiccation cracks	Or shrinkage cracks are polygonal cracks formed in a sediment as it dries out in a terrestrial environment.
Devensian	The last glacial stage in Britain, lasting from around 70,000 BP (Before Present) to about 10,000 BP.
Devonian	A geological system [418–354 Ma], oldest of the Upper Palaeozoic erathem, preceded by the Silurian system and followed by the **Carboniferous**.
Dinantian	The Lower Carboniferous sub-system, [354–326 Ma] comprising the Viséan and the Tournaisian Series.
Dolerite	A dark coloured, medium grained igneous rock which contains the minerals plagioclase and pyroxene. Commonly found as **dykes** and **sills**.
Dolomite	Calcium magnesium carbonate, A sedimentary rock-forming mineral [$CaMg(CO_3)_2$].
Dolostone (Cementstone)	A sedimentary rock usually formed by the dolomitization (diagenetic conversion of calcium carbonate to calcium magnesium carbonate) of limestones.
Drumlin	A drumlin (Gaelic *druim* the crest of a hill) is an elongated whale-shaped hill formed by glacial action. Its long axis is parallel with the movement of the ice, with the blunter end facing into the glacial movement. Drumlins may be more than 45 m high and more than 0.8 km long, and are often in drumlin fields of similarly shaped, sized and oriented hills.
Dyke	Discordant, sheet-like bodies of intrusive igneous rock in a vertical, or near-vertical orientation
Echinoid	Marine animals belonging to the class Echinoidea (part of the phylum Echinodermata). Fossil records show that they first appeared in the Ordovician and are extant today, with approximately 1000 living species.
Erythrite	Hydrated Cobalt Arsenate [Co3(AsO4)2-8(H2O)]. A bright red-purple mineral formed as a weathering product of cobalt-containing minerals such as cobaltite. The characteristic red-purple colour is easily noticeable and was used to spot veins of cobalt-bearing ore.
Eurypterid	Dominantly aquatic arthropods commonly having a pair of swimming and digging appendages and an anterior pair of food-gathering pincers, usually small, termed chelicerae. They first appeared in the early Ordovician but became extinct in the Permian. Also known as sea-scorpions they were typically 100 to 450 mm long but the largest known species reached 2.5 m.
Eustatic	World-wide changes in sea-level caused either by tectonic movement or growth or melting of glacial ice-sheets.
Evaporite	Sedimentary rock formed by the precipitation of salts from natural brines.
Extrusive	Refers to igneous rocks which have been extruded onto the Earth's surface, rather than being intruded beneath the surface (intrusive).
Facies	The characteristic features of a rock unit, including rock type, mineralogy, texture and structure, which together reflect a particular sedimentary, igneous or metamorphic environment and/or process.
Fault	A fracture in the Earth's crust across which the rocks have been displaced relative to each other.
Felsite	A general term used to denote light-coloured, fine-grained igneous rocks
Fireclay	Sedimentary mudstones that occur as seatearths underlying almost all coal seams. They represent fossil soils on which the coal-forming vegetation grew. The term was originally derived from their ability to resist heat. They are mainly

	used in the manfacture of high-quality facing bricks.
Fluvial	Referring to a river environment.
Fluviodeltaic	Refers to sediments deposited by fluvial processes in a deltaic environment.
Fluviolacustrine	Refers to sedimentation partly in lakes nd partly in rivers, or to deposits laid down under alternating or overlapping lacustrine and fluviatile environments.
Footwall	The fault block which lies below an inclined fault surface.
Gabbro	A dark-coloured, coarse-grained igneous rock consisting mainly of plagioclase feldspar and pyroxene. Is low in silica and may contain biotite, olivine and magnetite.
Galena	Lead Sulphide [PbS], a dense lead to silver grey mineral with a bluish tint. It may contain up to 1% Silver in place of lead and is the leading ore of Silver.
Gangue	Generally valueless mineral or rock which accompanies an ore
Glaciofluvial	Refers to sediments deposited by flowing glacial **meltwater**
Greywacke	A texturally immature **sedimentary rock** containing larger grains in a fine-grained matrix of clay-and silt-sized particles. The larger grains may range from sand- to gravel-sized particles and are composed of quartz, rock fragments and feldspar. In a greywacke, the matrix materials should constitute more than 15% by volume.
Hanging-wall	The fault block which lies above inclined fault surface.
Holocene	The youngest epoch of the Quaternary Period. Covers the last 10,000 years.
Hornfels	A fine-grained rock that has been partly or completely recrystallised by contact (thermal) metamorphism.
Gley	A poorly-draining soil that develops under periodic or permanent waterlogging, with characteristic bluish-grey subsoil. The dominant soil types on the glacial tills of central Scotland.
Igneous rock	A rock formed by the crystallisation of molten magma.
Intrusive	Refers to igneous rocks which have been intruded into older rocks beneath the Earth's surface, rather than being extruded onto the surface.
Ironstone	Iron-rich sedimentary rock, the amount of iron found may permit the extraction of iron ore.
Lacustrine	Refers to a lake environment.
Lithodiversity	The diversity or range of lithology (rock type).
Lithology	The character of a rock expressed in terms of its mineral composition, structure, grain size and arrangement of its constituents.
Lode	Mineral vein or system of veins. Refers to productive veins only. Mostly commonly used in Cornwall.
Loxommatid	Large "amphibian" predator of the Late Carboniferous period.
Meltwater	Water produced by melting of snow or ice.
Mesotrophic	This term is applied to clear water lakes and ponds with beds of submerged aquatic plants and medium levels of nutrients.
Metamorphic basement	See **Basement**.
Metamorphism	The process of changing the mineralogy and structure of a rock as a result of the effects of heat and/or pressure.
Mineralisation	Conversion of organic tissues to an inorganic state as a result of decomposition

	by soil micro-organisms. The hydrothermal deposition of economically important metals in the formation of ore bodies.
Namurian	The lowermost series of the Silesian sub-system of the **Carboniferous** [326–316 Ma].
Niccolite	A former name for nickeline, a lead-grey, black or copper-coloured mineral consisting of Nickel Arsenide [NiAs]. The chief ore of Nickel.
Oil-Shale	Shale that contains organic substances that yield liquid hydrocarbons on distillation, but does not contain free oil.
Ostracod	A class of crustacean, typically about 1 mm in size, hinged into two calcareous valves. The fossil record indicates that they first appeared in the Cambrian and are still present today. They belong to the phylum Arthropoda.
Overfold	An overturned fold, in which the axial plane is inclined so that the fold limbs dip in the same direction.
Palaeoecology	The application of ecological concepts to the study of the relationship between ancient organisms and their environments.
Palaeosol	A fossilised soil.
Porphyritic	Textural term for igneous rocks in which large crystals, called phenocrysts, are set in finer groundmass, which may be crystalline or glass or both.
Periglacial	Conditions, processes and landforms associated with cold, nonglacial environments.
Petrography	The study of the mineralogy, texture and systematic classification of rocks, especially under the microscope.
Picrite	A term originally used to describe a variety of dolerite or basalt extremely rich in olivine and pyroxene. Chemically defined as a group name for rocks with SiO2 <47%, total alkalis <2% and MgO >18%.
Plug	Solidified lava that fills the conduit of a volcano. It is usually more resistant to erosion than the material making up the surrounding cone, and may remain standing as a solitary pinnacle when the rest of the original structure has eroded away.
Podzol	Podzol soils have distinct layers or horizons and are widespread throughout Scotland, generally associated with acid parent material and semi-natural heath or coarse grassland vegetation and coniferous woodland. They are characteristic of any topographic position where aerobic conditions prevail and water can percolate freely through the upper part of the profile. They are found at all elevations from sea level to the summit of the Cairngorms.
Pyroclastic	Describes unconsolidated deposits (**tephra**) and rocks that form directly by explosive ejection from a volcano.
Pyroclastic breccia	A rock comprising predominantly angular pyroclasts with an average size greater than 64 mm in diameter.
Sandstone dyke	A sheet-like body on sand or sandstone cutting through a bedded sediment or sedimentary rock formed by the upwards injection of liquefied sand through a fissure, often as a result os seismic activity.
Scoriaceous	A term applied to **vesicular** lava or **pyroclastic** rock with a bubbly or frothy texture.
Seatclay	A highly siliceous **seatearth.** It is also known as ganister.
Seatearth	A bed of rock underlying a coal seam, representing a fossil soil that supported the vegetation from which the coal was formed.
Seatrock	An alternative term for **seatearth.**

Sedimentology	The study of sedimentary rocks and of the processes by which they were formed; the description, classification, origin, and interpretation of sediments.
Sedimentary rock	A rock formed in one of three main ways: by the deposition of the weathered remains of other rocks (clastic sedimentary rock); by the deposition of the results of biogenic activity; and by precipitation from solution. Four basic processes are involved in the formation of a clastic sedimentary rock: weathering (erosion), transportation, deposition and compaction.
Serpentine	A green-coloured magnesium-rich phyllosilicate mineral often associated with ultrabasic igneous rocks. Serpentinite is a rock composed largely of serpentine.
Siderite	Iron Carbonate, a yellowish-brown mineral [FeCO3], most often found in bedded sedimentary deposits with a biological component, such as shales, clays and coal. It is also found in metamorphosed sedimentary rocks as more massively crystalline material, as a gangue mineral in hydrothermal deposits, and in pegmatites.
Silesian	The Upper Carboniferous sub-system, [326–299 Ma] comprising the Namurian and Westphalian Series.
Sill	A tabular body of igneous rock, originally intruded as a sub-horizontal sheet and generally concordant with the bedding or foliation in the country rocks.
Silurian	A geological system [433–418 Ma], youngest of the Lower Palaeozoic erathem, preceded by the Ordovician and followed by the **Devonian.**
Solifluction	Solifluction is a slow downslope flow of water-saturated fragmental material or soil. It is promoted by the existence of permafrost which traps snow and ice melt within the surface layer making it more fluid.
Spherulitic	A texture consisting of a spherical mass of acicular crystals, commonly feldspar, radiating from a central point; commonly found in glassy silicic volcanic rocks as a result of devitrification.
Stephanian	The uppermost series of the Silesian sub-system of the **Carboniferous** [305–299 Ma].
Strata	Rocks that form layers or beds.
Stratabound	Mineral deposit or mineralisation confined to a particular stratigraphic unit
Stratigraphy	The definition and description of the stratified rocks of the Earth's crust.
Strike-slip	A term used to describe a **fault** on which the sense of movement is at right angles to the direction of inclination on the fault.
Subaerial	Located or occurring on or near the surface of the earth.
Syncline	A basin- or trough-shaped fold in rock in which rock layers are downwardly concave. The youngest rock layers form the core of the fold and outward from the core progressively older rocks occur.
Tephra	An unconsolidated accumulation of **pyroclast**s.
Teschenite	Generally dark-coloured, medium to coarse-grained igneous rock. It is undersaturated (with respect to silica).
Tetrapod	A vertebrate animal with four feet, legs, or leglike appendages.
Trace fossil	A biogenic sedimentary structure formed by behavioural activity of an organism, e.g. tracks, trails, burrows, and borings.
Tuff	A rock comprising **pyroclasts** with average grain size less than 2 mm.
Unconformable	A term generally applied to applied to younger strata that do not conform in position or that do not have the same dip and strike as those of the immediately underlying rocks. Also applies to the contact between unconformable rocks.

Unconformity	A surface of contact between two groups of **unconformable** strata. Represents a break in the geological record where a combination of erosion and lack of deposition was taking place.
Vent	The opening at the earth's surface through which volcanic materials erupt or flow.
Vesicular	A texture in lava consisting of bubble-shaped cavities formed by expansion of trapped gases.
Viséan	The uppermost series of the Dinantian sub-system of the **Carboniferous** [342–326 Ma].
Volcaniclastic	Refers to **clastic** rocks or sediments composed mainly of particles of volcanic origin.
Westphalian	The middle series of the Silesian sub-system of the **Carboniferous** [316–305 Ma].
Xenolith	A rock fragment foreign to the igneous rock in which it occurs.

6 Acronyms and Abbreviations

AGLV	Area of Great Landscape Value
AONB	Area of Outstanding Natural Beauty
AVHC	Almond Valley Heritage Centre
AWI	Ancient Woodland Inventory (SNH)
BAPs	Biodiversity Action Plans
BGS	British Geological Survey
B-SSSI	Site of Special Scientific Interest (Biological).
CERS	Community Environmental Renewal Scheme (Forward Scotland)
COSLA	Convention of Scottish Local Authorities
DiGMapGB	Digital Geological Map of Great Britain (BGS)
G-SSSI	Site of Special Scientific Interest (Geological)
GLN	Geology and Landscape North programme (BGS)
GCR	Geological Conservation Review (JNCC)
GIS	Geographic Information System
GPS	Global Positioning System
JNCC	Joint Nature Conservatrion Committee
LBAP	Local Biodiversity Action Plan.
LaBRIGS	Lothian and Borders RIGS Group
LBAP	Local Biodiversity Action Plan
Ma	Million years
RIGS	Regionally Important Geological and Geomorphological Sites
RTPI	Royal Town Planning Institute
ODPM	Office of the Deputy Prime Minister (Westminster)
PPS9	Planning Policy Statement 9
SEA	Strategic Environmental Assessment
SEPA	Scottish Environment Protection Agency
SPP	Scottish Planning Policy
SNH	Scottish Natural Heritage
SWT	Scottish Wildlife Trust
SSSIs	Sites of Special Scientific Interest
SNWI	Semi-Natural Woodland Inventory (SNH)
WLC	West Lothian Council
WLGSs	West Lothian Geodiversity Sites
WLGAP	West Lothian Geodiversity Action Plan
WLLP	West Lothian Local Plan

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

West Lothian Geodiversity

Volume 2 – Figures

Geology and Landscape North Programme
Commissioned Report CR/06/008N

SCOTTISH EXECUTIVE

Lothian and Borders RIGS Group

SCOTTISH NATURAL HERITAGE

West Lothian Council

BRITISH GEOLOGICAL SURVEY
GEOLOGY AND LANDSCAPE NORTH PROGRAMME
COMMISSIONED REPORT CR/06/008N

West Lothian Geodiversity

Volume 2 – Figures

H F Barron, M A E Browne and A Finlayson

Contributors

S L B Arkley, S M Clarke, A Matthewson, A Pickering and K I G Lawrie and E K Hyslop

Editor

D J D Lawrence

Keywords

Geodiversity; West Lothian.

Front cover

Five Sisters Bing, West Calder

Bibliographical reference

BARRON, H F, BROWNE, M A E, AND FINLAYSON, A. 2005. West Lothian Geodiversity. *British Geological Survey Commissioned Report*, CR/06/008N8N. 190pp.

Keyworth, Nottingham British Geological Survey 2006

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desks at Nottingham, Edinburgh and London; see contact details below or shop online at www.geologyshop.com

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

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

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

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

British Geological Survey offices

Keyworth, Nottingham NG12 5GG

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

Murchison House, West Mains Road, Edinburgh EH9 3LA

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

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

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

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

☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast BT9 5BF

☎ 028-9038 8462 Fax 028-9038 8461

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

☎ 01491-838800 Fax 01491-692345

Columbus House, Greenmeadow Springs, Tongwynlais, Cardiff, CF15 7NE

☎ 029–2052 1962 Fax 029–2052 1963

Parent Body

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

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

Contents

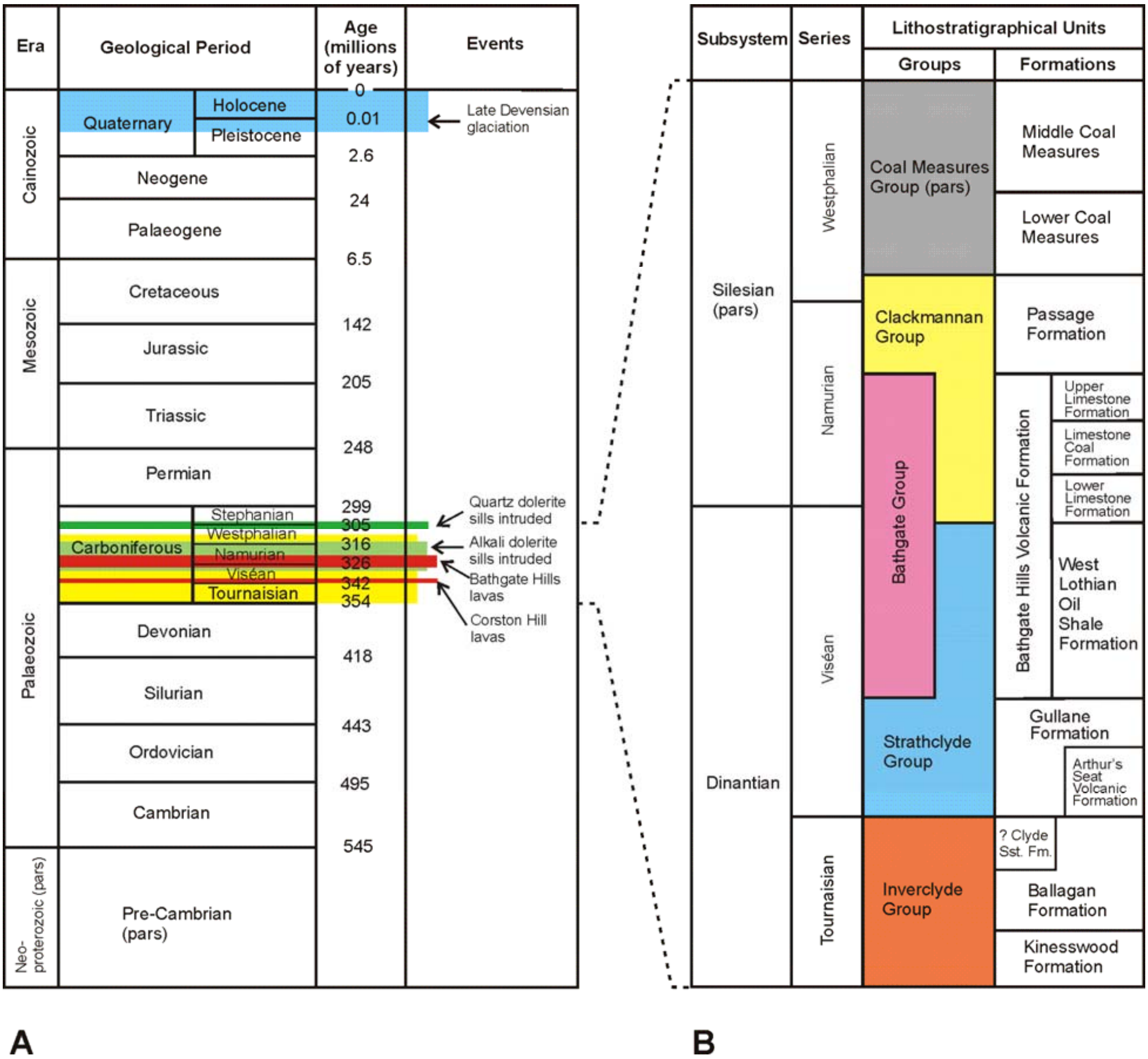


Figure 1 **A:** Part of the geological timescale with colour bars representing the rocks of West Lothian. Yellow bar = Carboniferous sedimentary rocks; red bars = extrusive igneous rocks; green bars = intrusive igneous rocks. **B:** Classification of Carboniferous strata in West Lothian.

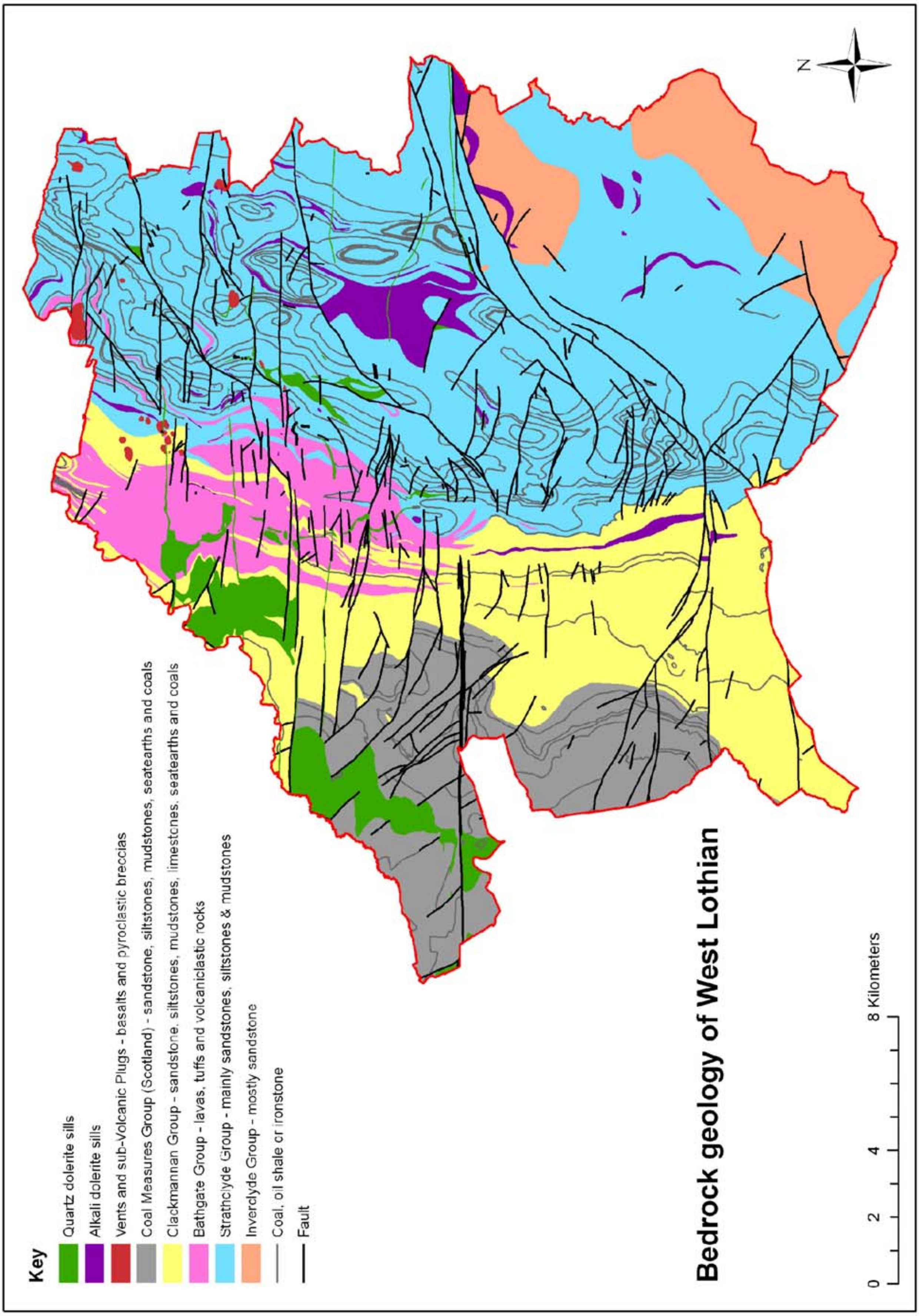


Figure 2 Bedrock geology of West Lothian. Map simplified from DiGMapGB-50. BGS, © NERC 2006.

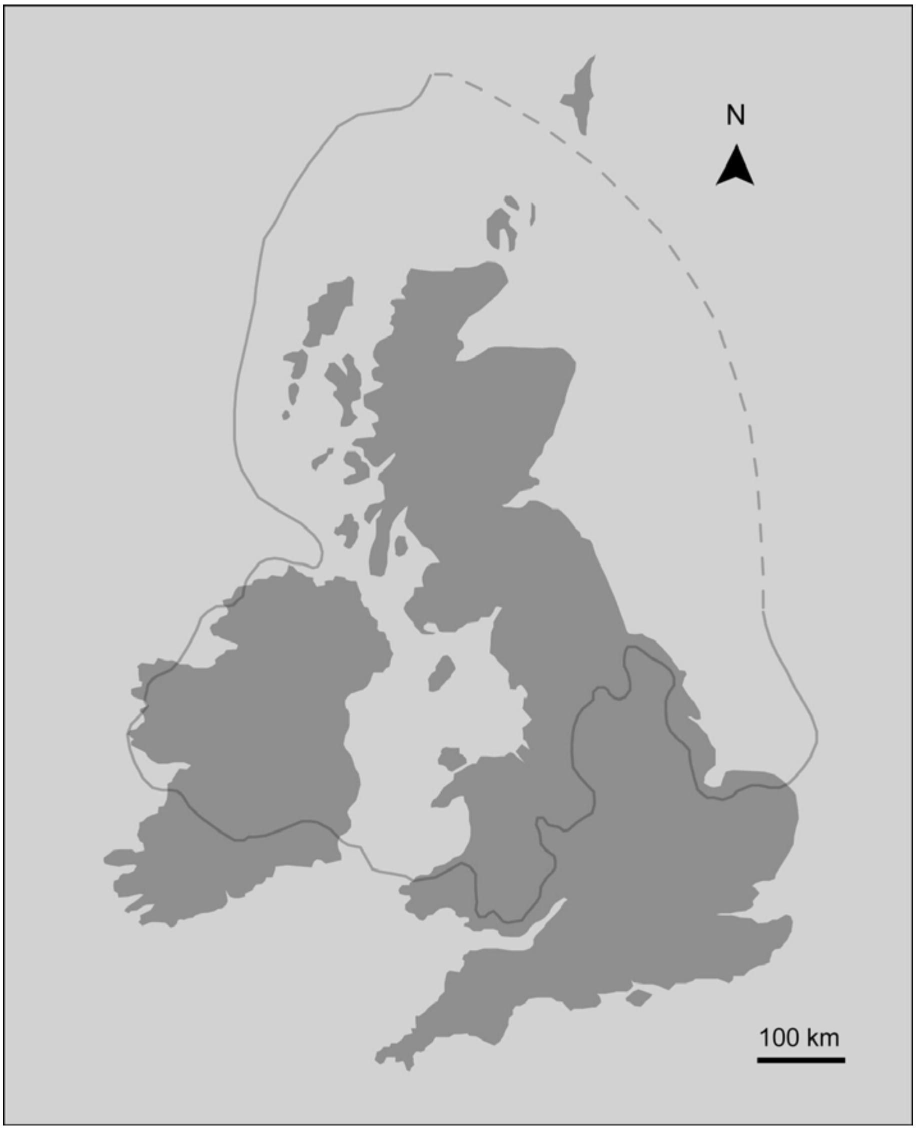


Figure 3 Maximum limits of Late Devensian glaciation in Britain. Solid line – mapped limit; dotted line – inferred confluence with Scandinavian ice. (from Boulton et al., 1977).

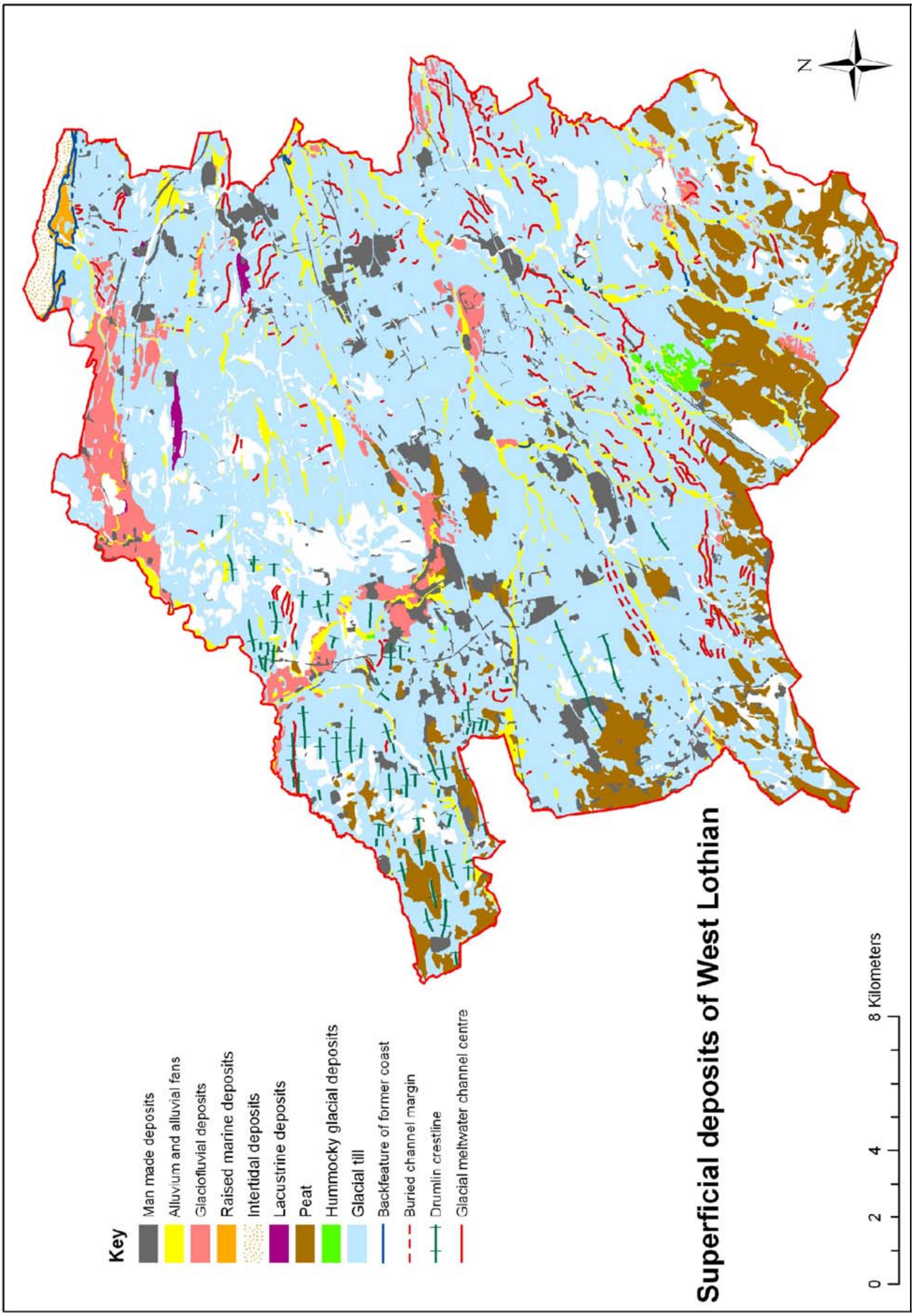


Figure 4 Superficial deposits of West Lothian. Map simplified from DiGMapGB-50. BGS, © NERC 2006.

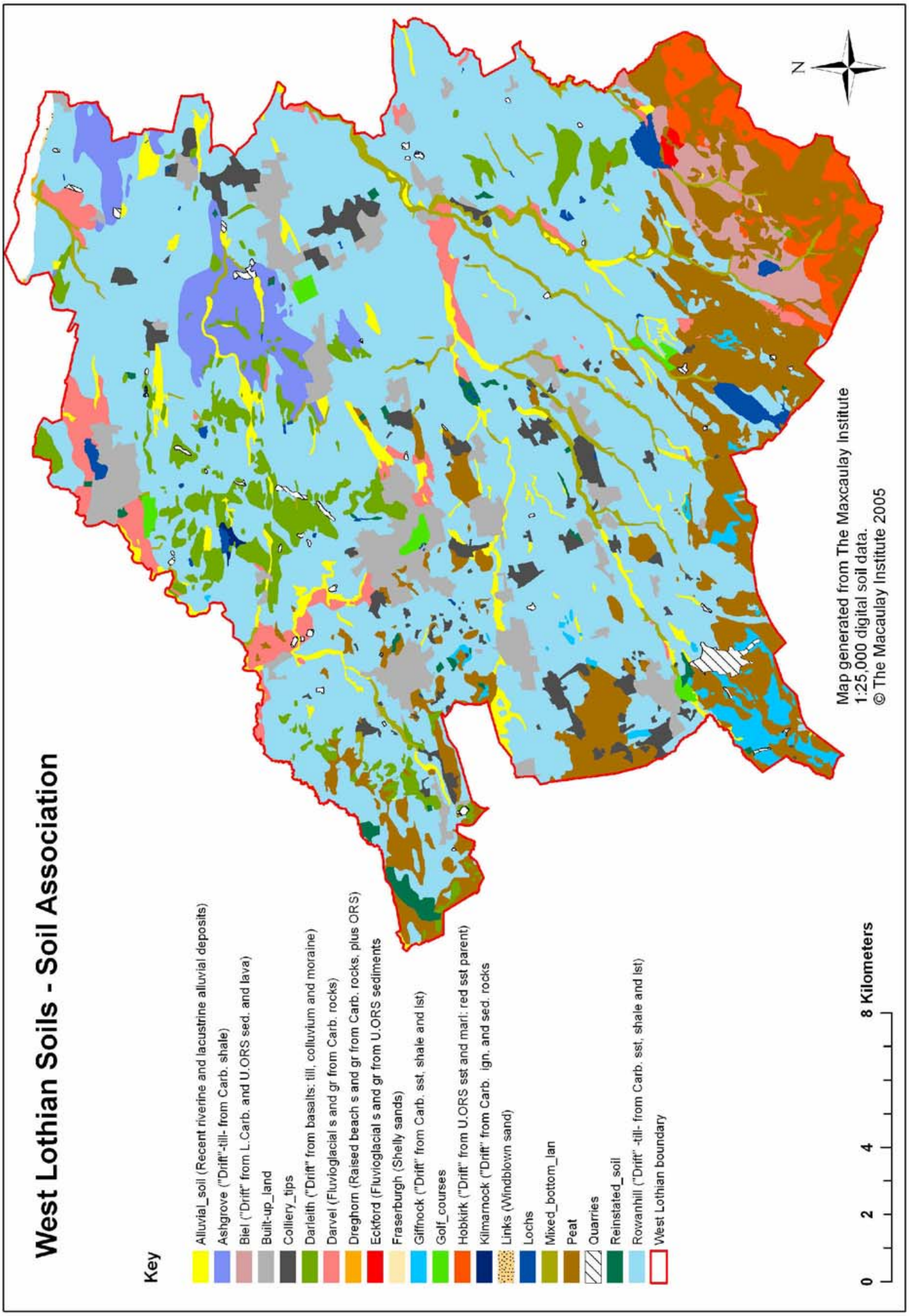


Figure 5 Soil Associations of West Lothian. ©The Macaulay Institute 2005.

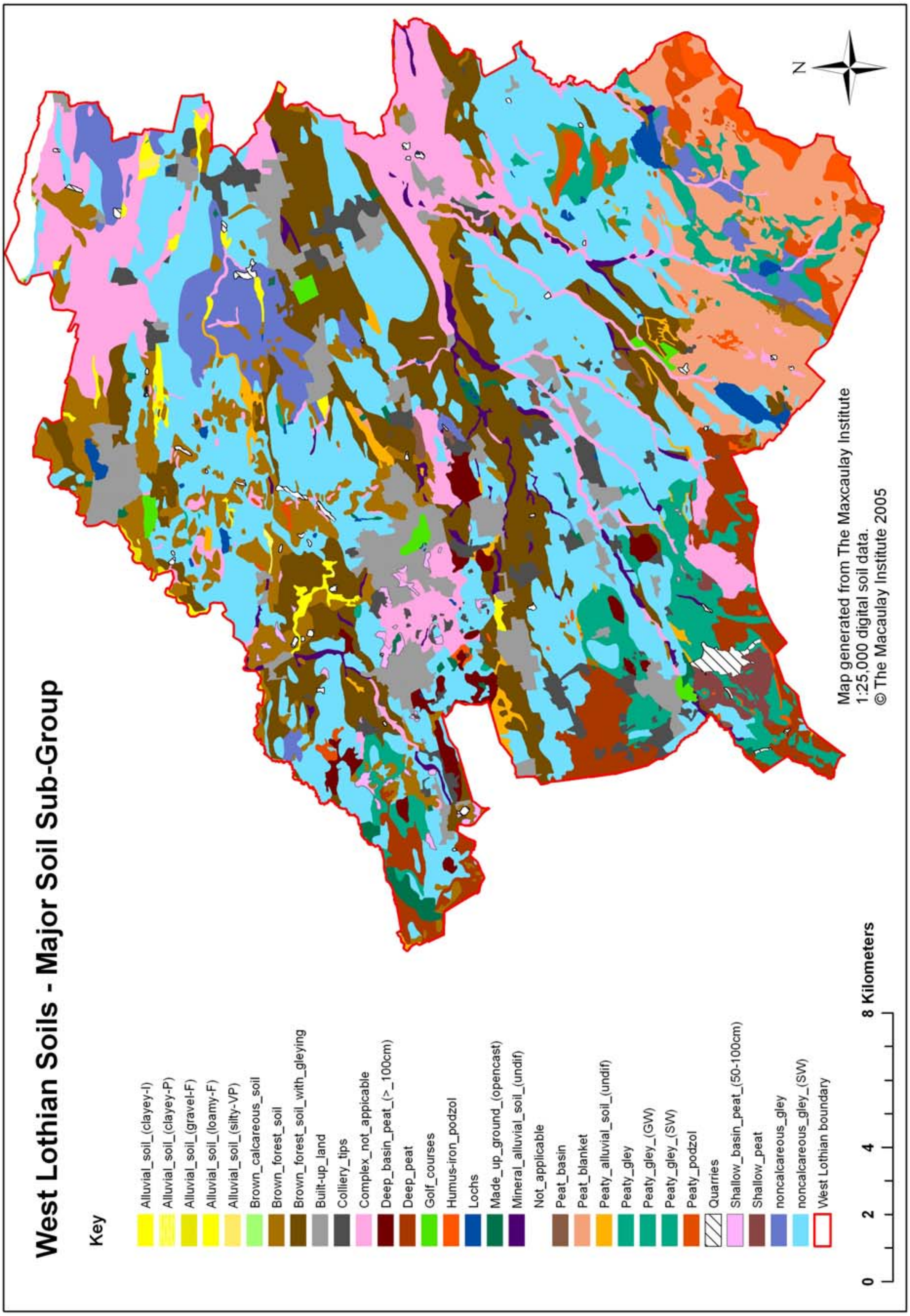


Figure 6 Major Soil Sub-Groups of West Lothian. © The Macaulay Institute 2005.

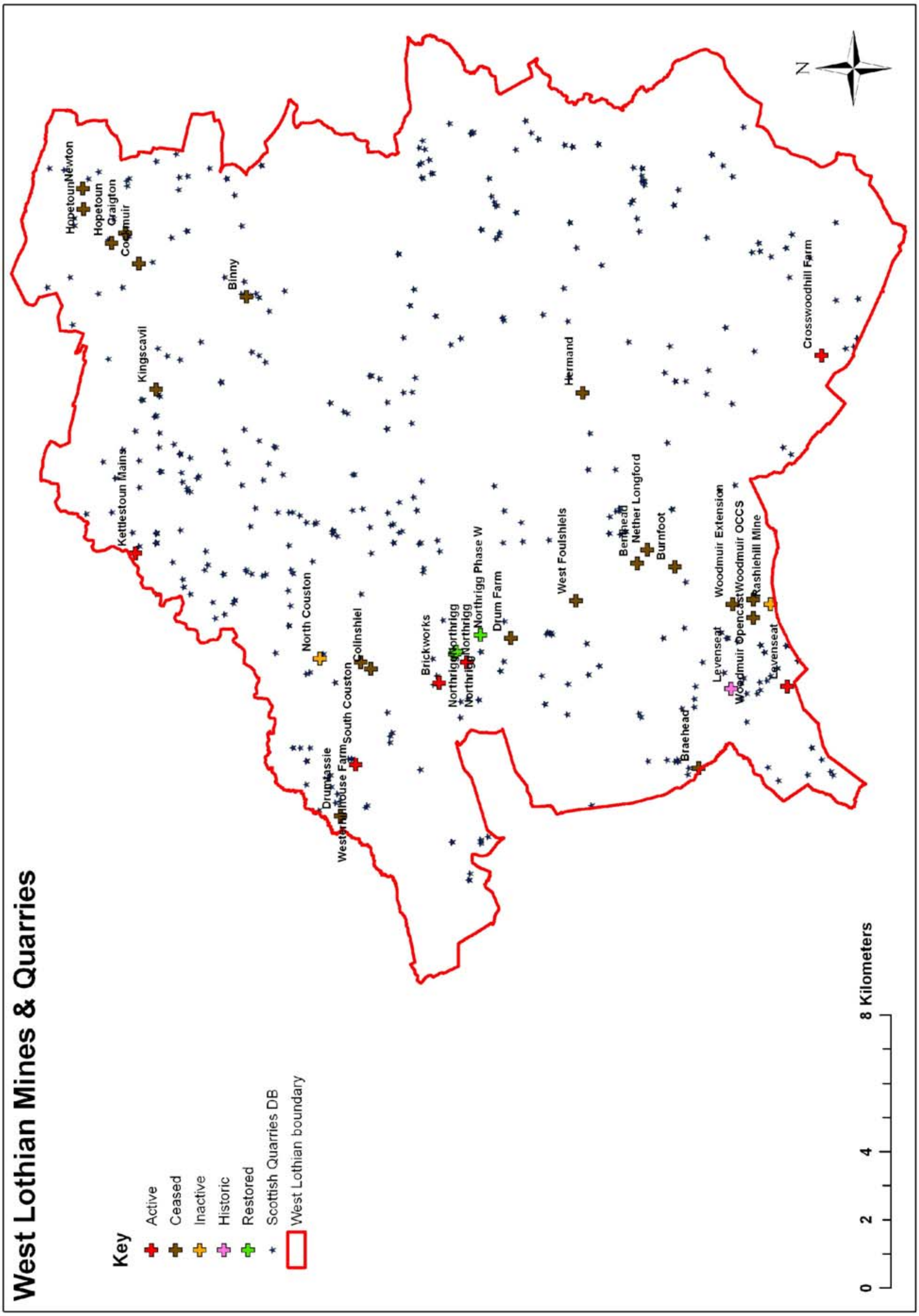


Figure 7 Mines and Quarries from the BGS BritPits database and the Scottish Quarries database.BGS, © NERC 2006.

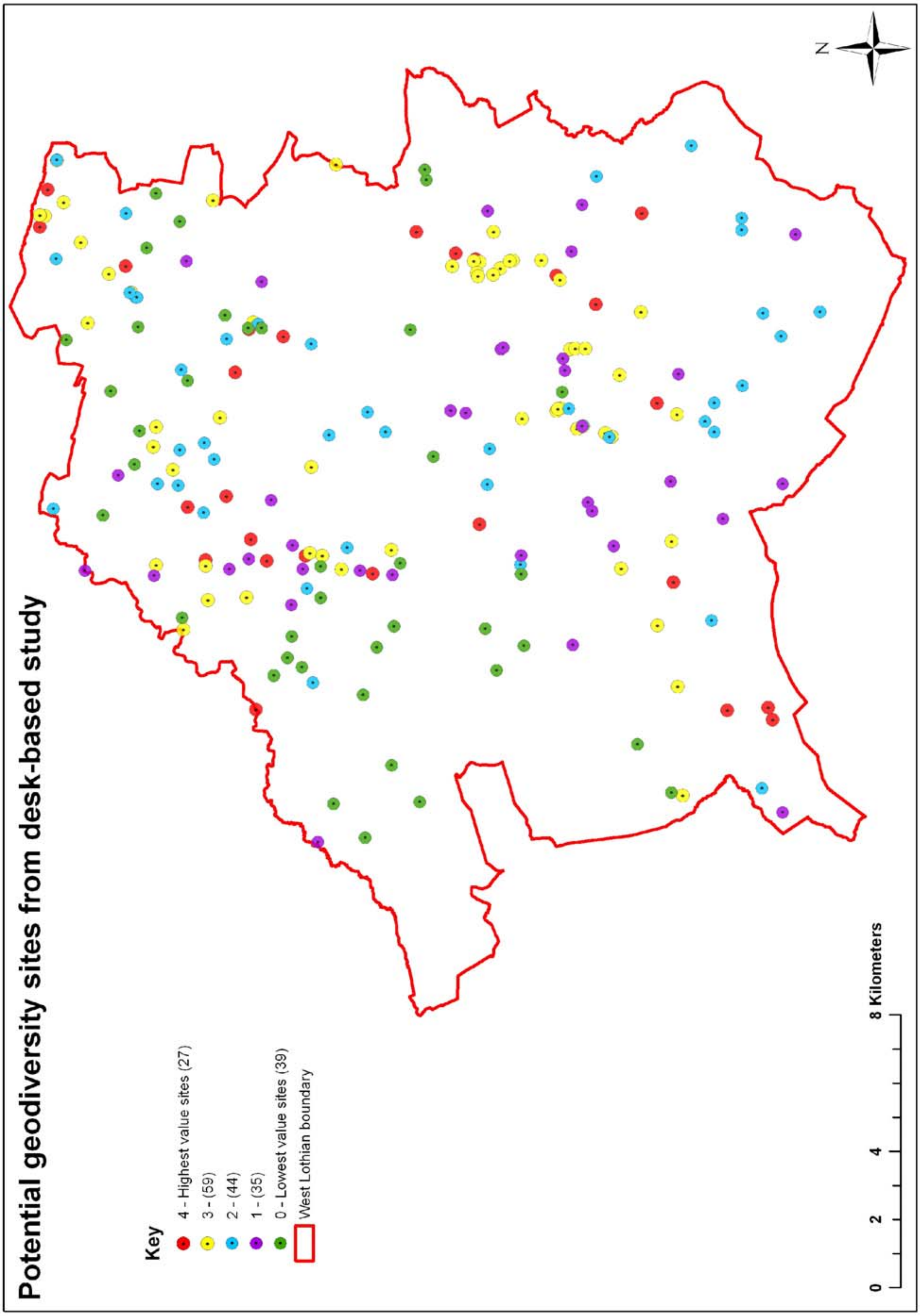


Figure 8 Potential West Lothian geodiversity sites from desk study.

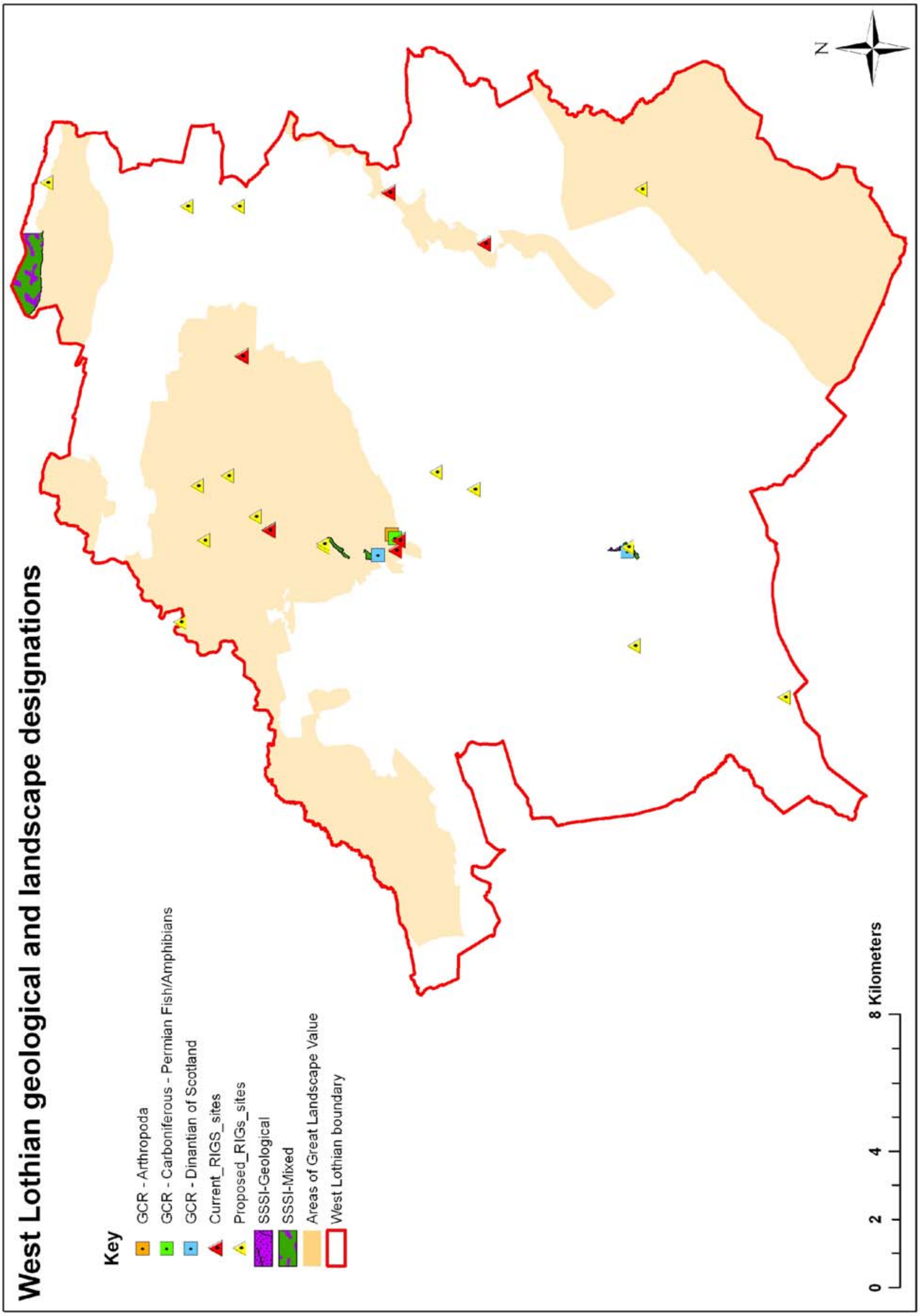


Figure 9 Geological and landscape designations of West Lothian. SSSI boundaries supplied under licence from SNH. © Scottish Natural Heritage. AGLV boundaries supplied by West Lothian Council and RIGS by Lothian and Borders RIGS Group.

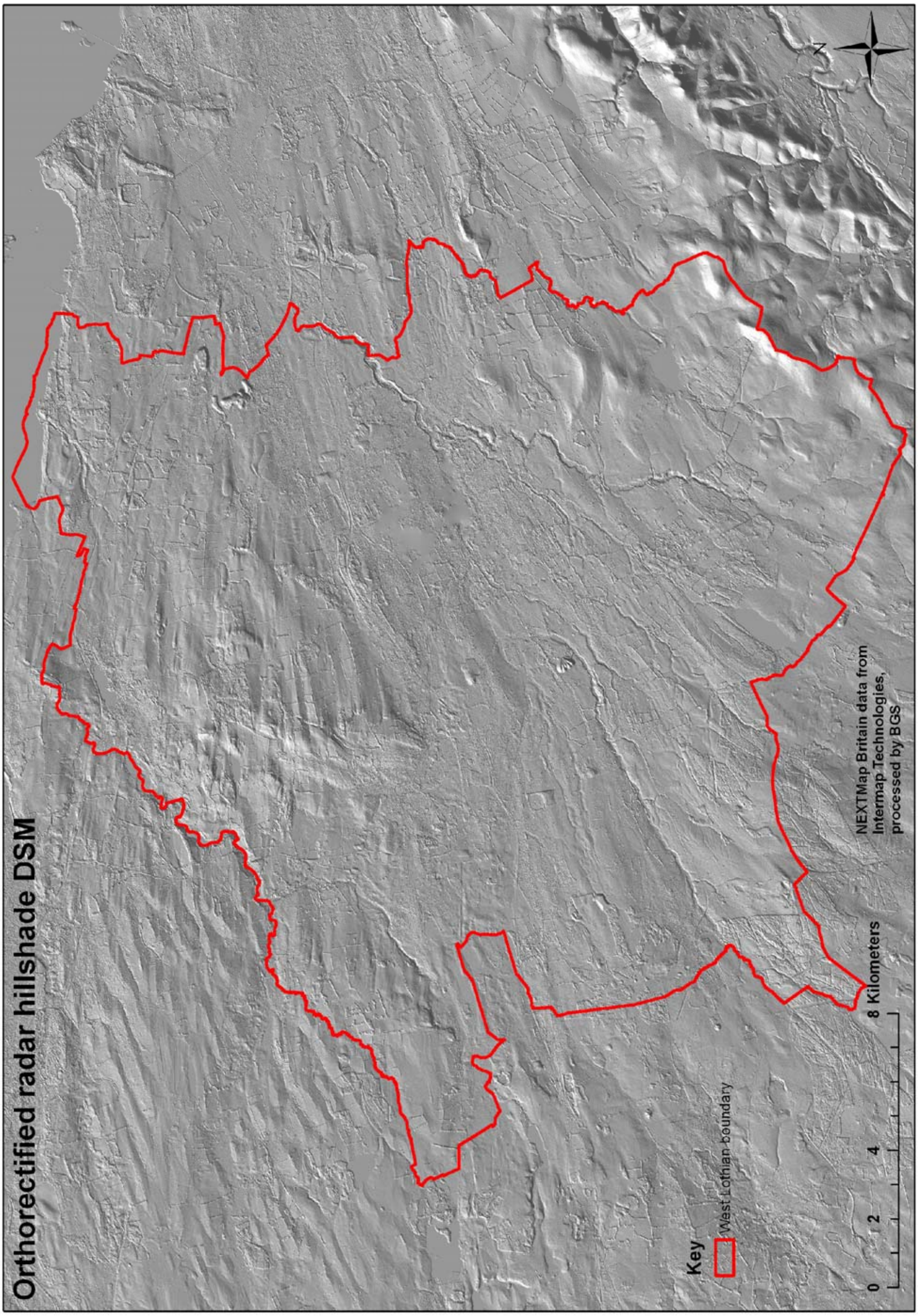


Figure 10 NEXTMap Orthorectified radar Digital Surface Model of West Lothian.

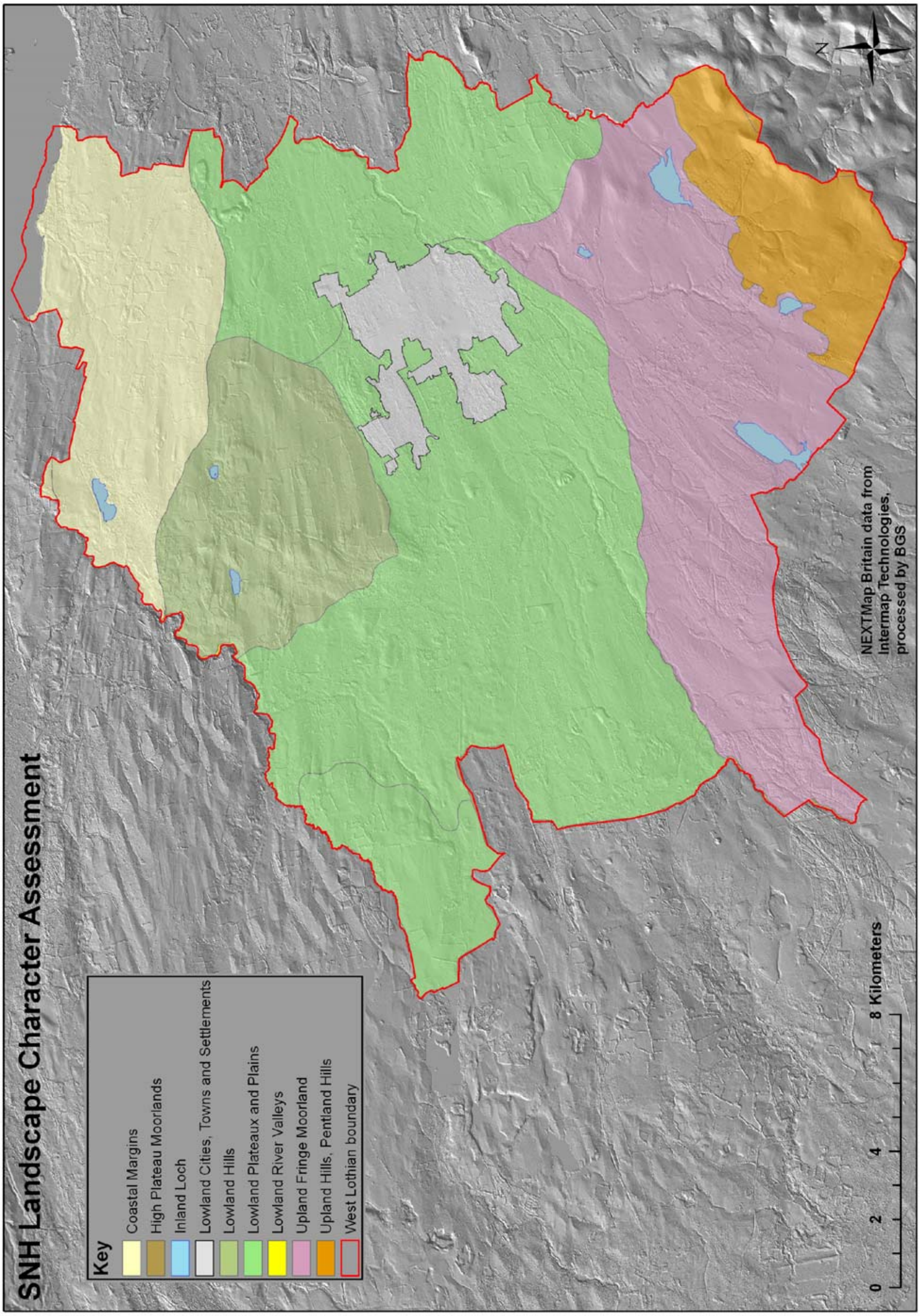


Figure 11 SNH Landscape Character Assessment of West Lothian. Data supplied under licence from SNH. © Scottish Natural Heritage.

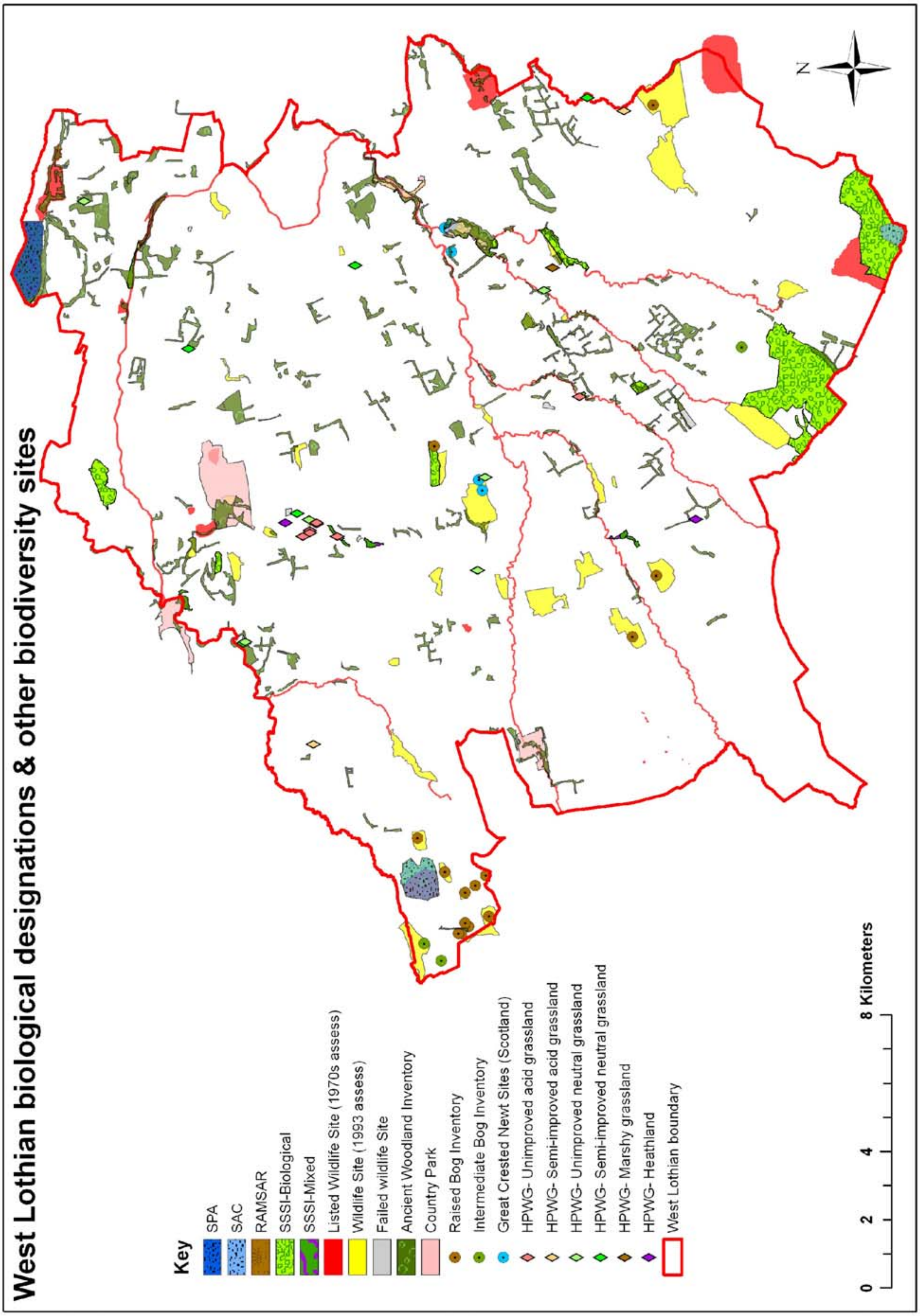


Figure 12 Biological designations and other biodiversity sites of West Lothian. Ramsar, SPA and SAC supplied by JNCC. © Crown copyright. All rights reserved. Scottish Natural Heritage, 100017908. [2006]

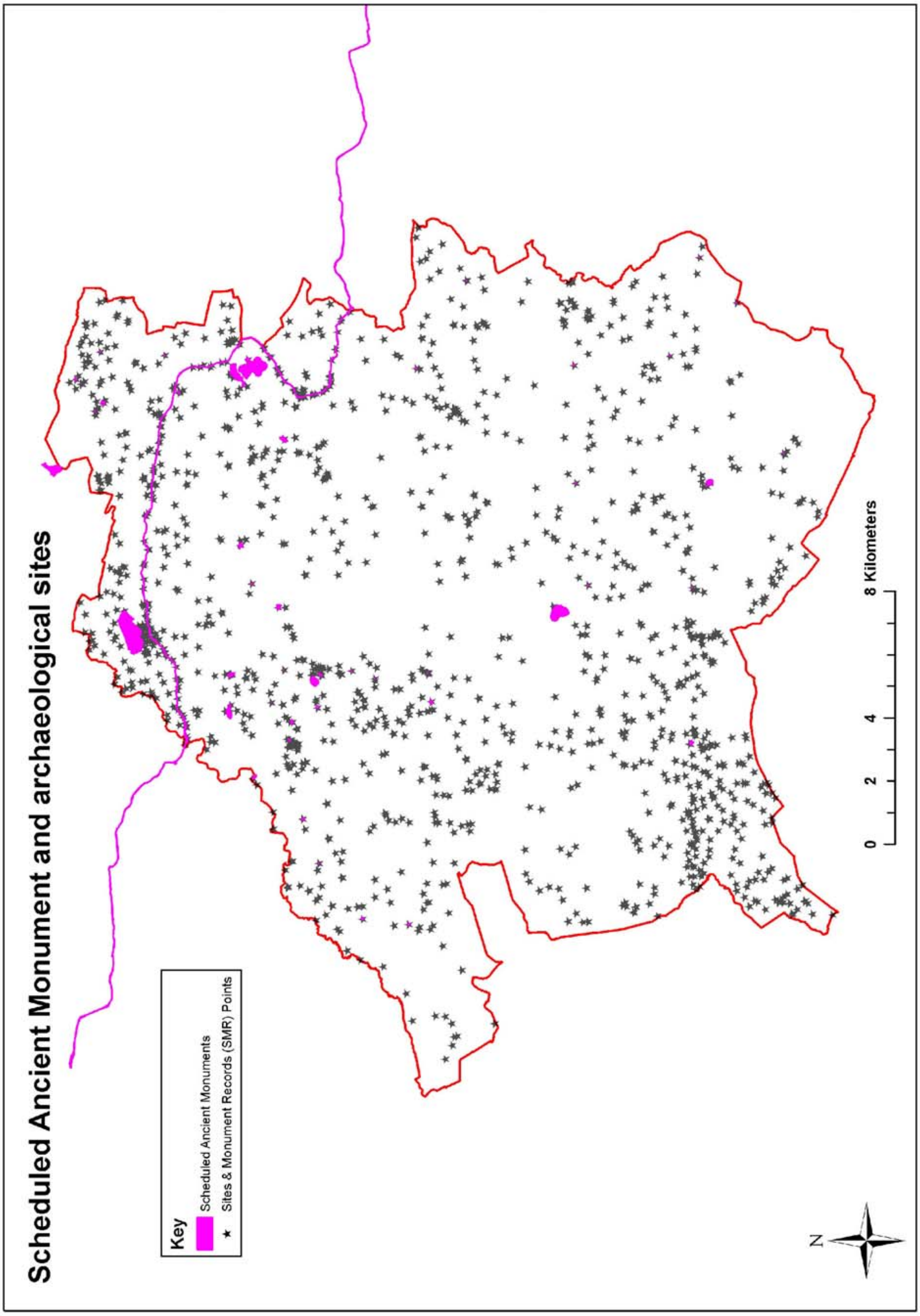


Figure 13 Scheduled Monuments and archaeological sites of West Lothian. Scheduled monument area information derived from Historic Scotland data dated 4-Aug-2005 © Crown Copyright (Historic Scotland). SMR data provided by WOSAS (West of Scotland Archaeology Service).

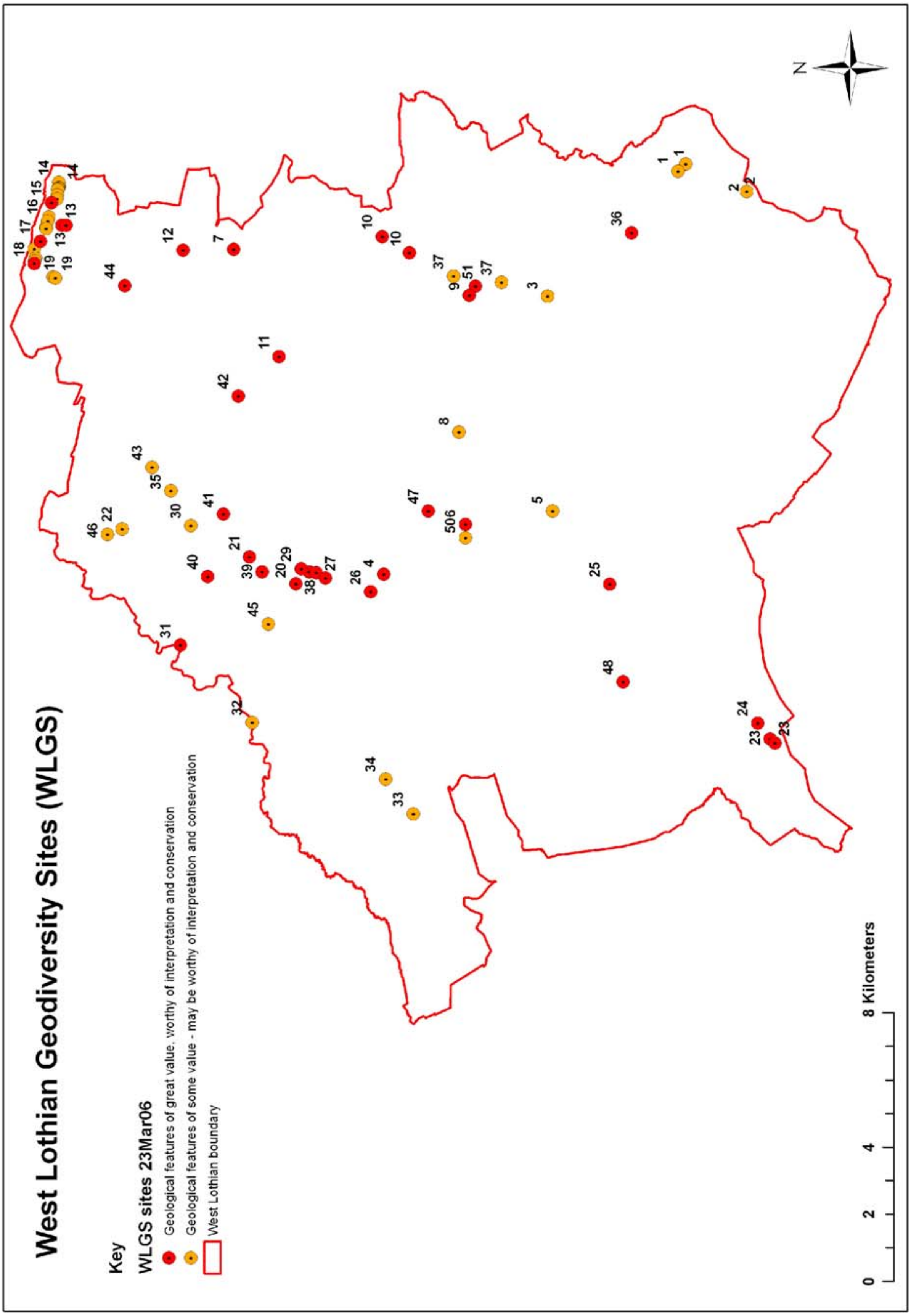


Figure 14 West Lothian Geodiversity Sites (WLGS).

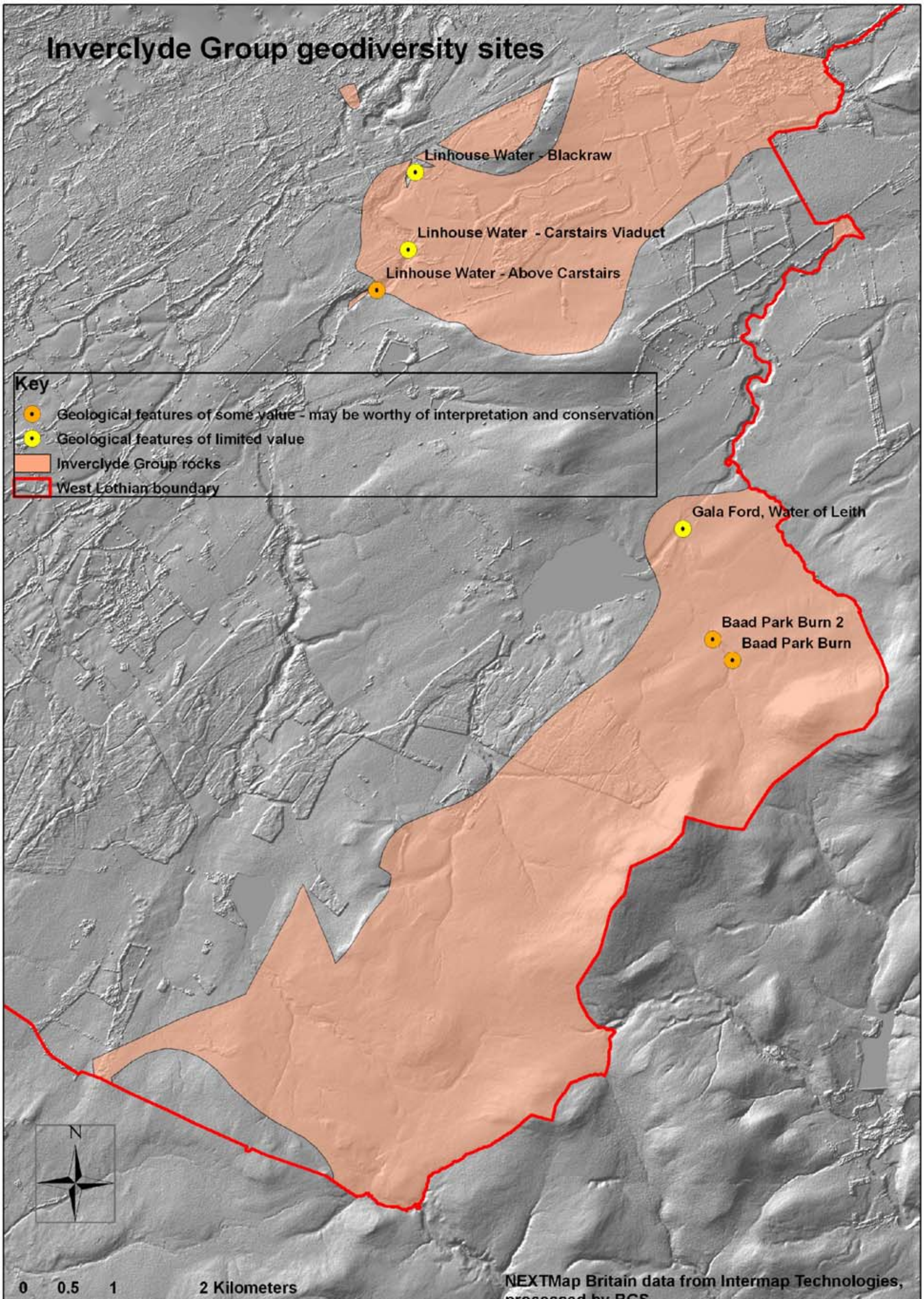


Figure 15 Inverclyde Group geodiversity sites of West Lothian.

Figure 16 View across Harperrig Reservoir from Auchinoon Quarry (WLGS 36) beside the A70. The south-east boundary of West Lothian runs along the skyline from East Cairn Hill to West Cairn Hill. Inverclyde Group rocks form the hills and most of the low ground beyond the reservoir.

Figure 17 Section in gently dipping mudstones, siltstones and thin sandstones of the Ballagan Formation (Inverclyde Group) capped by glacial till. Section approximately 5 m high. Baad Park Burn (WLGS 1) [NT 1125 6014], south-east of Harperrig Reservoir

Figure 18 West Lothian's highest hill – West Cairn Hill (562m) from Baad Park Burn, south-east of Harperrig Reservoir. West Cairn Hill is formed from Kinesswood Formation (Inverclyde Group) sandstones. WLGS 2 is located close to the break of slope on the right skyline of the hill.

Figure 19 East Cairn Hill (561 m summit)) from Baad Park Burn (WLGS 1), south-east of Harperrig Reservoir. The gently-inclined Kinesswood Formation (Inverclyde Group) sandstones show small-scale scarp featuring.

Figure 20 Laminated and cross-bedded red sandstones of the Ballagan Formation (Inverclyde Group). Baad Park Burn (WLGS 1) [NT 1103 6037], south-east of Harperrig Reservoir. East Cairn Hill in background.

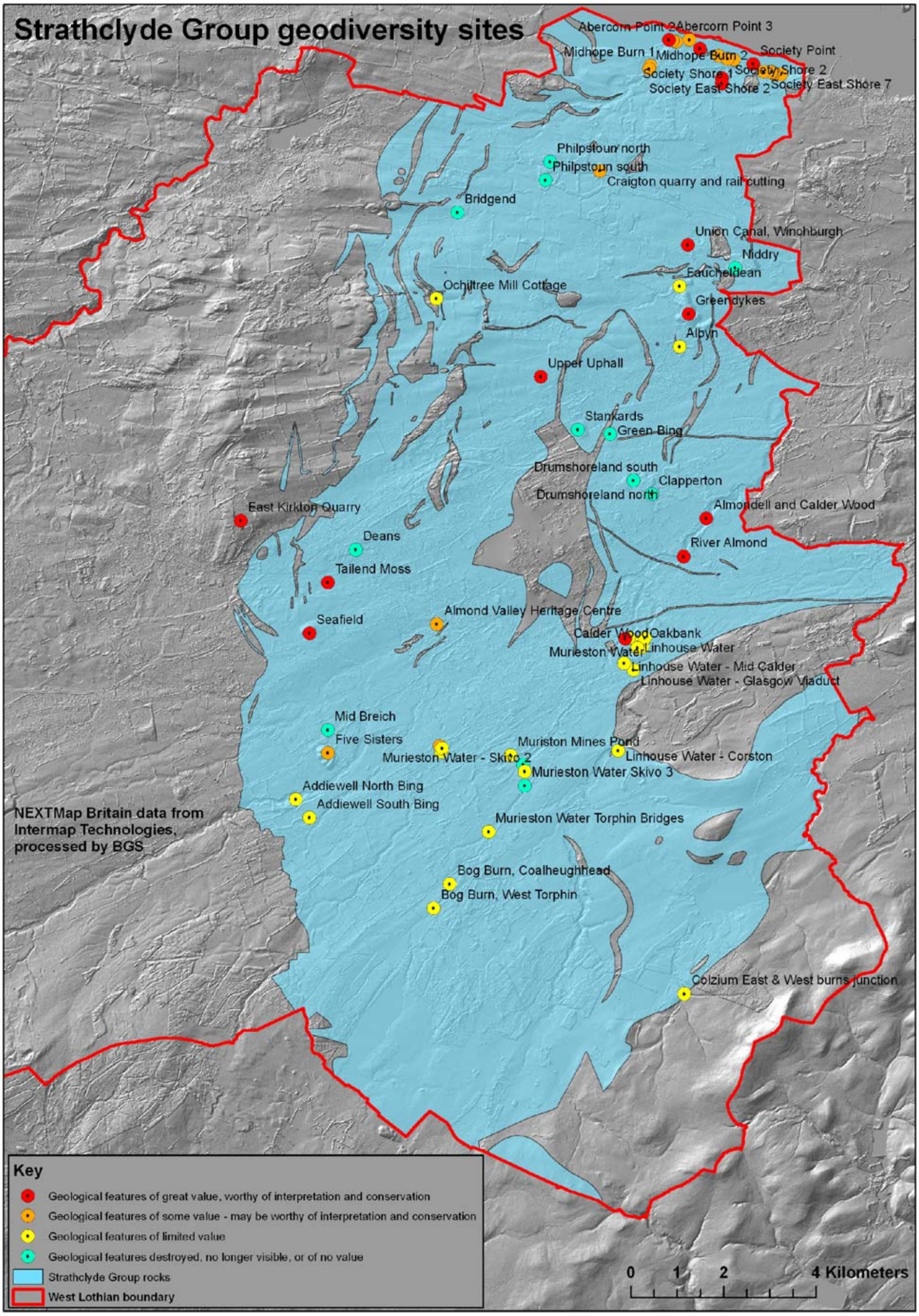


Figure 21 Strathclyde Group geodiversity sites of West Lothian.

Figure 22 Sign beside entrance gate [NS 9895 6891] to East Kirkton Quarry, Bathgate (WLGS 4).

Figure 23 Quarry face in East Kirkton Quarry [NS 9901 6913], East Kirkton Limestone, West Lothian Oil Shale Formation (WLGS 4).

Figure 24 Quarry face in East Kirkton Quarry [NS 9901 6913], East Kirkton Limestone, West Lothian Oil Shale Formation (WLGS 4).

Figure 25 The same face as Figure 24, taken in 1994. BGS Photograph P2882 © NERC. WLGS 4.

Figure 26 West Lothian’s most distinctive landmarks – the Five Sisters oil-shale bings [NT 009 641] (WLGS 5) near West Calder, viewed from the south-west. The bings are 91 m in height with a summit altitude of 240 m. They are protected as a Scheduled Monument.

Figure 27 Five Sisters oil-shale bings [NT 009 641] (WLGS 5) from the south. Burnt oil-shale is initially dark blue-grey (“blaes”), but rapidly oxidises to a characteristic red colour in contact with the elements.

Figure 28 Greendykes (Broxburn) [NT 087 736] oil-shale bing viewed from the west (WLGS 7).

Figure 29 South-west face of Seafield Law [NT 005 667] (WLGS 6), Seafield. This oil-shale bing has been re-profiled to replicate one of the most distinctive natural landforms of West Lothian – a 'crag and tail' glacial feature.

Figure 30 Weathered spent oil-shale on Seafield Law [NT 005 667] (WLGS 6).

Figure 31 Sluice weir on the River Almond 500 m upstream from the Almond Valley Heritage Centre NT 0325 6689] (WLGS 8).

Figure 32 Sandstone and siltstone beds of the Gullane Formation exposed in the bank of the Murieston Water [NT 0733 6658] (WLGS 9). The section is approximately 3 m high and the beds show fault-related deformation from the Calder Fault.

Figure 33 *Stigmaria* tree root fossil in Calders Member, West Lothian Oil Shale Formation, Almondell [NT 0887 6885] (WLGS 10).

Figure 34 View of steeply dipping Burdiehouse Limestone [NT 0860 6840] (WLGS 10). Calders Member, West Lothian Oil Shale Formation, River Almond.

Figure 35 Overfold in Broxburn Shale [NT 0790 6710], Hopetoun Member, West Lothian Oil Shale Formation, Calderwood (WLGS 10).

Figure 36 Small oil-shale bing at Upper Uphall [NT 0550 7225]. Hopetoun Member, West Lothian Oil Shale formation (WLGS 11).

Figure 37 Sitts resulting from he collapse of underground stoop and room working. Upper Uphall [NT 0550 7225] (WLGS 11). Hopetoun Member, West Lothian Oil Shale formation.

Figure 38 Ironstone nodules, Upper Uphall [NT 0550 7225] (WLGS 11). Hopetoun Member, West Lothian Oil Shale formation.

Figure 39 Obelisk Quarry, Hopetoun [NT 0942 7859] (WLGS 13). Quarry face in Dunnet Sandstone (Hopetoun Member, West Lothian Oil Shale Formation).

Figure 40 Obelisk Quarry, Hopetoun [NT 0942 7859] (WLGS 13). Close-up of Figure 39. Fine grained sandstone with interbeds of very fine grained sandstone and laminated carbonaceous siltstone ("tiger-stripe").

Figure 41 Obelisk Quarry, Hopetoun [NT 0942 7862] (WLGS 13). Fluvial channel features in Dunnet Sandstone.

Figure 42 Entrance to Obelisk Quarry, Hopetoun [NT 0942 7862] (WLGS 13).

Figure 43 Society East Shore 2. Sandstone overlying oil-shale, Dunnet Sandstone, Hopetoun Member, West Lothian Oil Shale Formation [NT 1058 7879] (WLGS 14).

Figure 44 Society East Shore 3. Sandstone with carbonate nodules overlying limestone. Dunnet Sandstone, Hopetoun Member, West Lothian Oil Shale Formation [NT 10538 78805] (WLGS 14).

Figure 45 Society East Shore 4. Cross-bedded sandstone. Dunnet Sandstone, Hopetoun Member, West Lothian Oil Shale Formation [NT 1052 7882] (WLGS 14).

Figure 46 Society East Shore 6. Dunnet Sandstone outcrops with Forth bridges beyond. Hopetoun Member, West Lothian Oil Shale Formation [NT 1048 7884] (WLGS 14).

Figure 47 Trough cross-bedded sandstone at Society Point. Binny Sandstone, Hopetoun Member, West Lothian Oil Shale Formation [NT 1009 7902] (WLGS 15).

Figure 48 Steps cut in cross-bedded sandstone at Society Point. Binny Sandstone, Hopetoun Member, West Lothian Oil Shale Formation [NT 1009 7902] (WLGS 15).

Figure 49 Sandstone dyke and carbonaceous lags in cross-bedded sandstone at Society Point. Binny Sandstone, Hopetoun Member, West Lothian Oil Shale Formation [NT 1009 7902] (WLGS 15).

A **B**

Figure 50 **A:** Damage to sandstone caused by core-cutting. **B:** Close-up of Figure 49 – carbonaceous lags (plant debris) in sandstone. Society Point, Binny Sandstone, Hopetoun Member, West Lothian Oil Shale Formation [NT 1009 7902] (WLGS 15).

Figure 51 *Stigmaria* tree root fossil at Society Shore 1 [NT 0967 7910] (WLGS 16). Barracks Limestone, Hopetoun Member, West Lothian Oil Shale Formation.

Figure 52 Blending in – wall of local sandstone built on eastward-dipping Dunnet Sandstone at Society Shore 2 [NT 0954 7913] (WLGS 16). Hopetoun Member, West Lothian Oil Shale Formation.

Figure 53 Easterly-dipping sandstone on the east limb of the Hopetoun anticline at Hopetoun Shore 1 [NT 0935 7919] (WLGS 17). Calders Member, West Lothian Oil Shale Formation.

Figure 54 Ripple-marked sandstone bedding-plane – close-up of Figure 53. Hopetoun Shore 1 [NT 0935 7919] (WLGS 17). Calders Member, West Lothian Oil Shale Formation.

Figure 55 Burdiehouse Limestone on the west limb of the Hopetoun anticline. Hopetoun Shore 3 [NT 0894 7935] (WLGS 17), Hopetoun Member, West Lothian Oil Shale Formation.

Figure 56 Small fault in Burdiehouse Limestone – close up of Figure 55. Hopetoun Shore 3 [NT 0894 7935] (WLGS 17), Hopetoun Member, West Lothian Oil Shale Formation.

Figure 57 Small-scale open fold in Burdiehouse Limestone – close up of Figure 55. Hopetoun Shore 3 [NT 0894 7935] (WLGS 17), Hopetoun Member, West Lothian Oil Shale Formation.

Figure 58 Outcrop of Binny Sandstone at Abercorn Point 1 [NT 0843 7950] (WLGS 18). Hopetoun Member, West Lothian Oil Shale Formation.

Figure 59 Cross-bedding in sandstones at Abercorn Point 3 [NT 0827 7954] (WLGS 18).Hopetoun Member, West Lothian Oil Shale Formation.

Figure 60 The Forth Bridges from Abercorn Point (WLGS 18).

Figure 61 **C**oarsening-up sequence Midhope Burn 2 [NT 0784 7981] (WLGS 19). Hopetoun Member, West Lothian Oil Shale Formation.

Figure 62 Midhope Burn 2 [NT 0784 7981] (WLGS 19). Hopetoun Member, West Lothian Oil Shale Formation. Section is to the right of that in Figure 61.

Figure 63 Broxburn Shale at Midhope Burn 1 [NT 0787 7898] (WLGS 19). Hopetoun Member, West Lothian Oil Shale Formation.

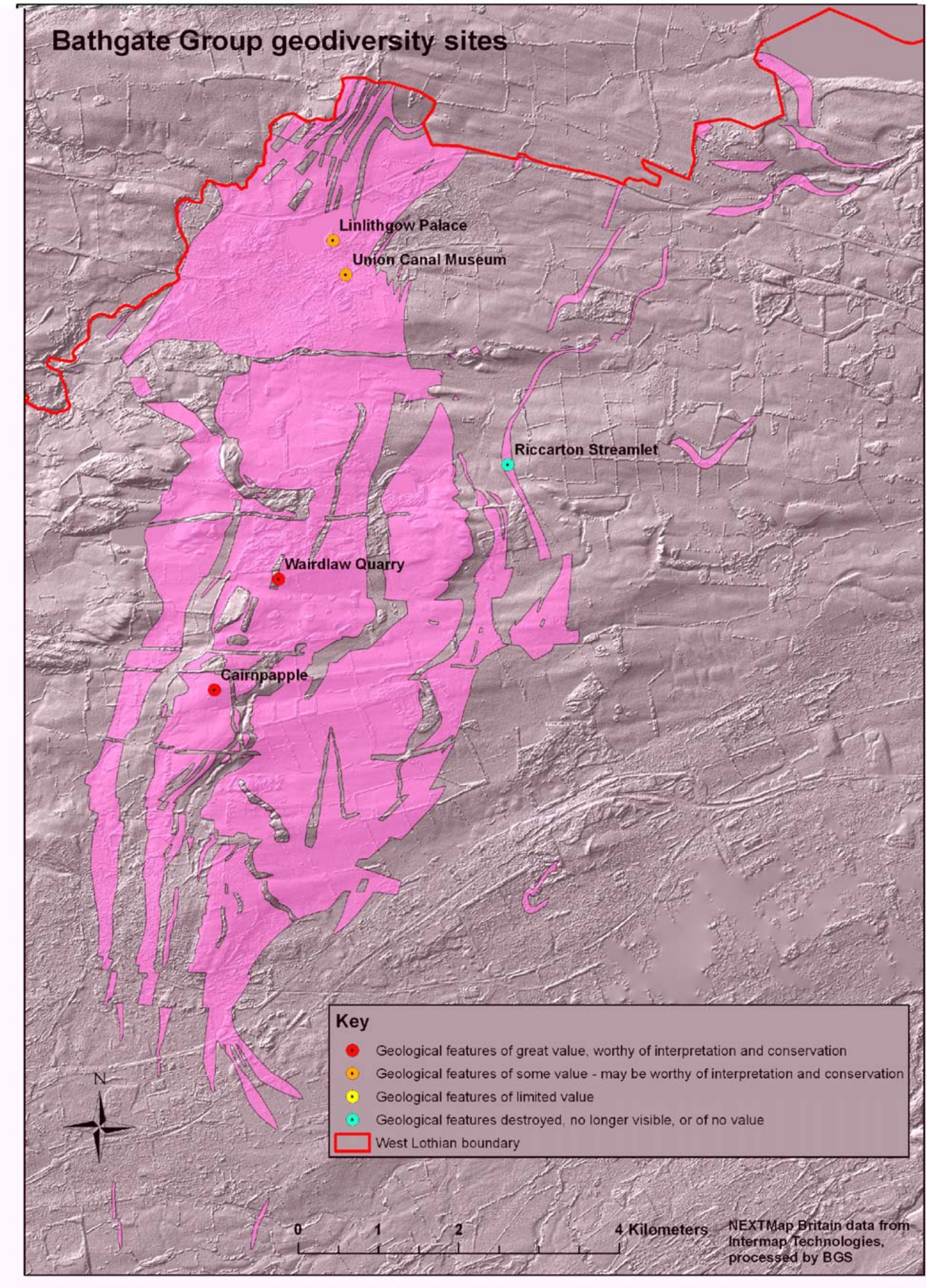


Figure 64 Bathgate Group geodiversity sites of West Lothian.

Figure 65 Stone circle and burial cairn on Cairnpapple Hill, viewed from the south-west. Rock types used are mainly local – basalt from the Bathgate Hills Volcanic Formation and quartz-dolerite from nearby intrusions [NS 9872 7174] (WLGS 20).

Figure 66 Stone circle and burial cairn on Cairnpapple Hill, viewed from the south-east. The cairn is a reconstruction representing the original Bronze Age cairn. [NS 9872 7174] (WLGS 20).

Figure 67 Stone circle and and satellite burial chambers on Cairnpapple Hill. Rock types used are mainly local – basalt from the Bathgate Hills Volcanic Formation and quartz-dolerite from nearby intrusions [NS 9872 7174] (WLGS 20).

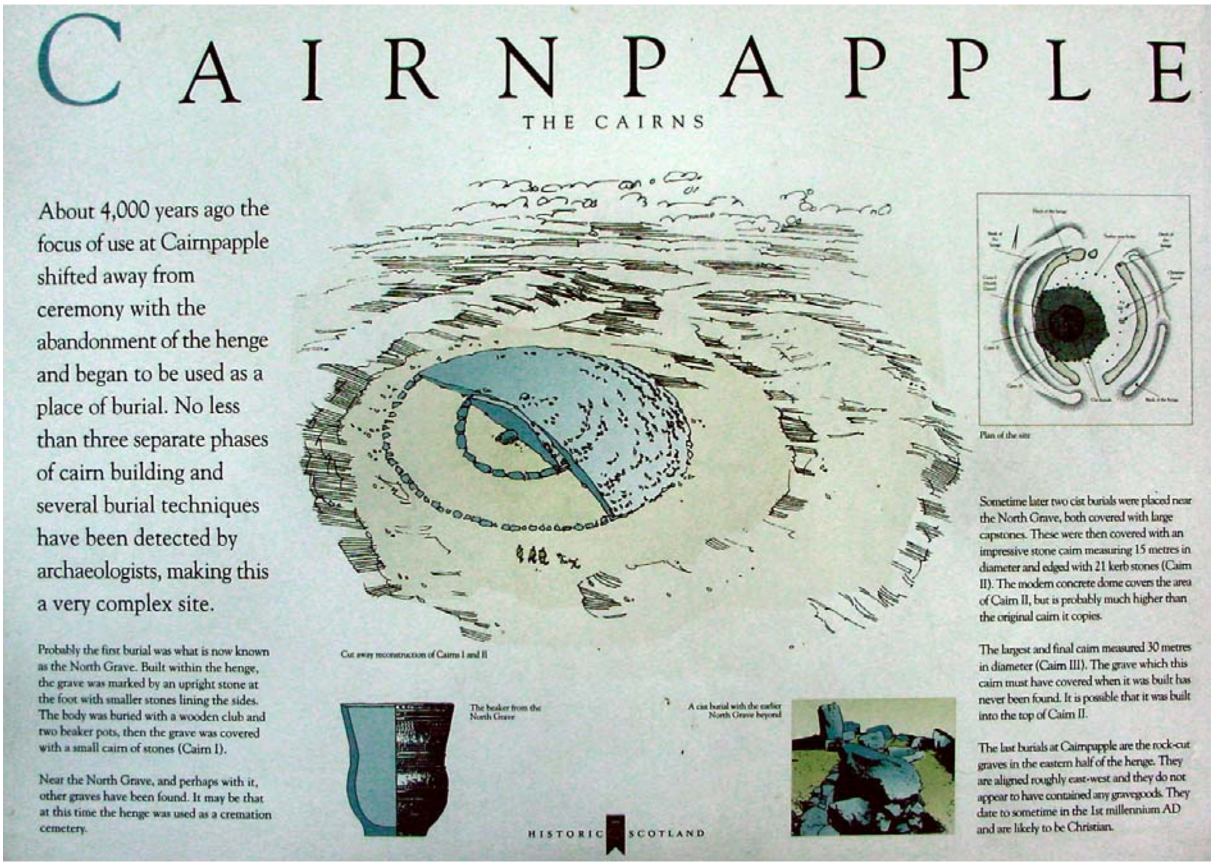


Figure 68 Historic Scotland interpretation board at Cairnpapple (WLGS 20).

Figure 69 Well-preserved lime kilns at Wairdlaw Quarry [NS 9955 7304] (WLGS 21).

Figure 70 View eastwards to Arthur's Seat from the northern boundary of Wairdlaw Quarry [NS 9952 7313] (WLGS 21).

Figure 71 Main quarry face at Wairdlaw Quarry. Wairdlaw Limestone (Lower Limestone Formation, Clackmannan Group) above lava of Bathgate Hills Volcanic Formation [NS 9952 7313] (WLGS 21).

Figure 72 Wairdlaw Quarry – small quartz dolerite quarry to north-west of main quarry [NS 9953 7320] (WLGS 21).

Figure 73 Drystone dyke of Wairdlaw Limestone at Wairdlaw Quarry [NS 9952 7313] (WLGS 21).

Figure 74 *Siphonodendron* coral fossil in the Wairdlaw Limestone at Wairdlaw Quarry [NS 9952 7313] (WLGS 21).

Figure 75 Wairdlaw Quarry flora – wild raspberry (*Rubus idaeus var. strigosus)*, blaeberry (*Vaccinium myrtillus*) and Scottish Bluebell (*Campanula rotundifolia*) [NS 9952 7313] (WLGS 21).

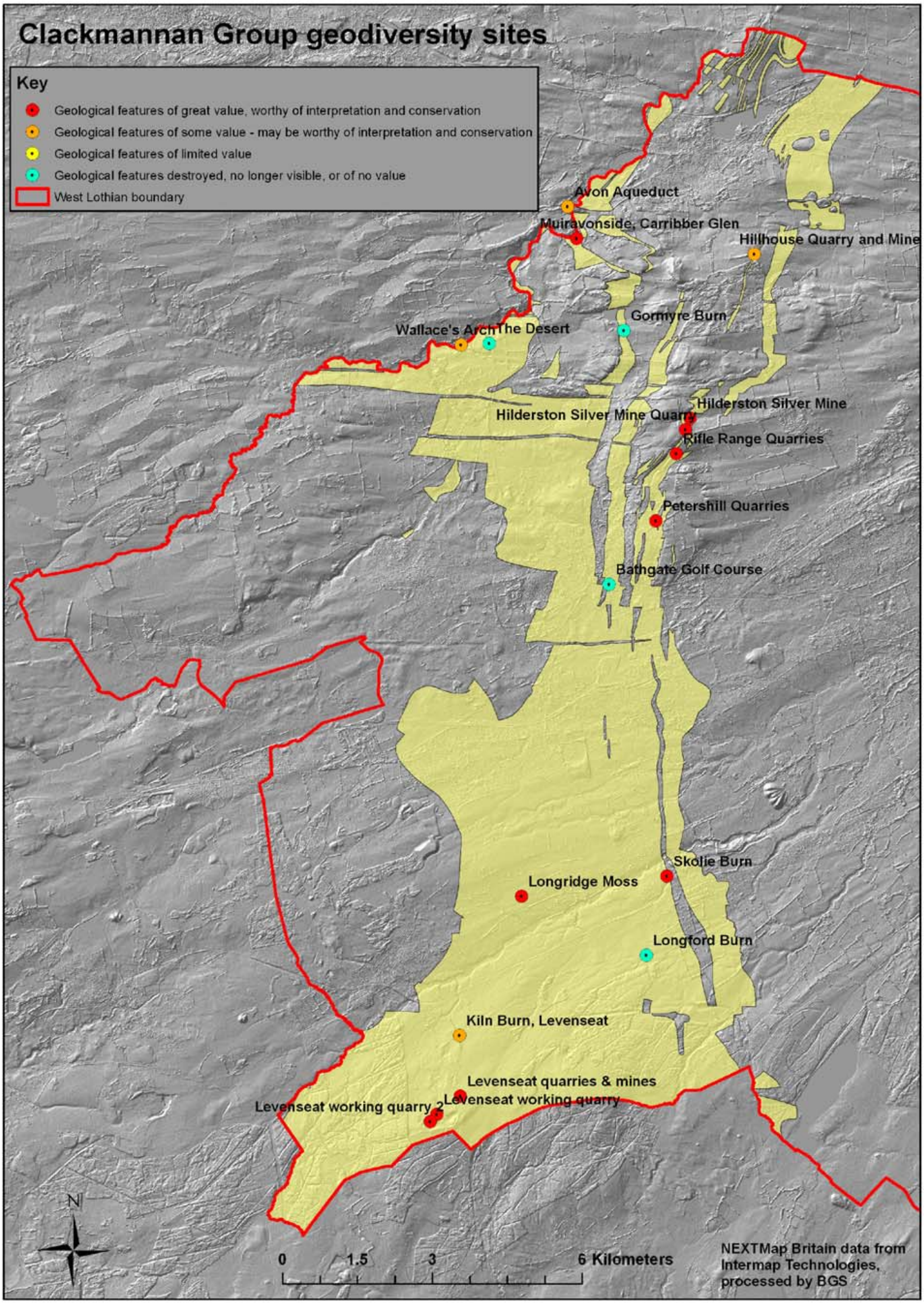


Figure 76 Clackmannan Group geodiversity sites of West Lothian.

Figure 77 Levenseat Sandstone above bedded black siltstones and mudstones. Quarry face is approximately 15 m high. Passage Formation, Levenseat working quarry 2 [NS 9397 5748] (WLGS 23).

Figure 78 Levenseat Sandstone, Passage Formation. Quarry face is approximately 15 m high. Levenseat working quarry 2 [NS 9397 5748] (WLGS 23).

Figure 79 Large fluvial channel in Levenseat Sandstone, Passage Formation. Quarry face is approximately 15 m high. Levenseat working quarry 1 [NS 9410 5763] (WLGS 23).

Figure 80 Old mine entrance in Castlecary Limestone, Upper Limestone Formation, Levenseat quarries & mines [NS 9547 5799]. Fauldhouse can be seen in the distance (WLGS 24).

Figure 81 Old mine entrance in Castlecary Limestone, Upper Limestone Formation, Levenseat quarries & mines [NS 9547 5799] (WLGS 24). Close-up of Figure 78.

Figure 82 Levenseat landfill site from Leven Seat hill [NS 9540 5762] (WLGS 24).

Figure 83 Skolie Burn [NS 9871 6240] (WLGS 25). View north from bridge to section in Lower Limestone Formation.

Figure 84 Skolie Burn [NS 9871 6240] (WLGS 25). Section in Lower Limestone Formation immediately north of bridge.

Figure 85 Skolie Burn [NS 9871 6240] (WLGS 25) section beneath the bridge. A picrite sill can be seen in the bed of the burn, overlain by sandstones and the Top Hosie Limestone of the Lower Limestone Formation.

Figure 86 Fossiliferous mudstone from the Lower Limestone Formation, Skolie Burn [NS 9871 6240] (WLGS 25).

Figure 87 Entrance sign to Petershill Reservoir Quarry, off the Bathgate to Bangour road [NS 9849 6952] (WLGS 26).

Figure 88 General view within Petershill Reservoir Quarry with bullrushes (*Typha latifolia)* [NS 9849 6952] (WLGS 26).

Figure 89 Bedding plane outcrop of fossiliferous Petershill Limestone in the Petershill Reservoir Quarry [NS 9852 6969] (WLGS 26).

A **B**

Figure 90 Fossil **c**orals from Petershill Quarries (WLGS 26). A: *Aulophyllum* B: *Siphonodendron junceum.*

Figure 91 Looking south-west in the Rifle Range Quarries [NS 9890 7087] (WLGS 27). Petershill Limestone, Lower Limestone Formation.

Figure 92 Main quarry face in the Rifle Range Quarries [NS 9890 7087] (WLGS 27). Petershill Limestone, Lower Limestone Formation.

Figure 93 Fossiliferous Limestone from the Rifle Range Quarries [NS 9890 7087] (WLGS 27). Petershill Limestone, Lower Limestone Formation.

Figure 94 Gigantoproductid brachiopod fossils from the Rifle Range Quarries [NS 9890 7087] (WLGS 27). Petershill Limestone, Lower Limestone Formation.

Figure 95 View south-east from Cairnpapple Hill (WLGS 20) to Hilderston Silver Mine and Quarry [NS 9908 7135] (WLGS 28). Pentland Hills in distance.

Figure 96 View north from Hilderston Quarry [NS 9908 7135] (WLGS 28) to Hilderston Silver Mine [NS 9917 7158] (WLGS 29). Silver was worked here intermittently from 1606 to the late 1800s.

Figure 97 View north-east across Hilderston Silver Mine [NS 9917 7158] (WLGS 29).

Figure 98 Main quarry face at Hilderston Quarry [NS 9908 7135] (WLGS 28). Excellent coarsening upward sequences in mudstones, siltstones and sandstones of the Lower Limestone Formation above Petershill Limestone.

A **B**

Figure 99 Hilderston Quarry [NS 9908 7135] (WLGS 28). A: *Thalassinoides* trace-fossils. B: Small-scale cross-bedding in sandstone, Lower Limestone Formation.

Figure 100 Lead−Zinc mine adit at Hilderston Silver Mine [NS 9917 7158] (WLGS 29).

Figure 101 Lead−Zinc mine adit at Hilderston Silver Mine [NS 9917 7158] (WLGS 29).

Figure 102 Notice board at Beecraigs Country Park. Hillhouse Quarry and Mine [NT 0046 7487] (WLGS 30) is located immediately north of the 'you are here' arrow.

Figure 103 View north-east from Hillhouse Quarry and Mine [NT 0046 7487] (WLGS 30).

Figure 104 Stoop and room workings in Hillhouse Limestone, Lower Limestone Formation, Hillhouse Quarry and Mine [NT 0046 7487] (WLGS 30).

Figure 105 Thistle and Willowherb at Hillhouse Quarry and Mine [NT 0046 7487] (WLGS 30).

Figure 106 Small quarry to the north-west of the mine, Hillhouse Quarry and Mine [NT 0029 7517] (WLGS 30).

Figure 107 Wallace's Arch, River Avon [NS 9459 7305] (WLGS 32). A natural arch in Passage Formation sandstone.

Figure 108 Wallace's Arch, River Avon [NS 9459 7305] (WLGS 32). A natural arch in Passage Formation sandstone.

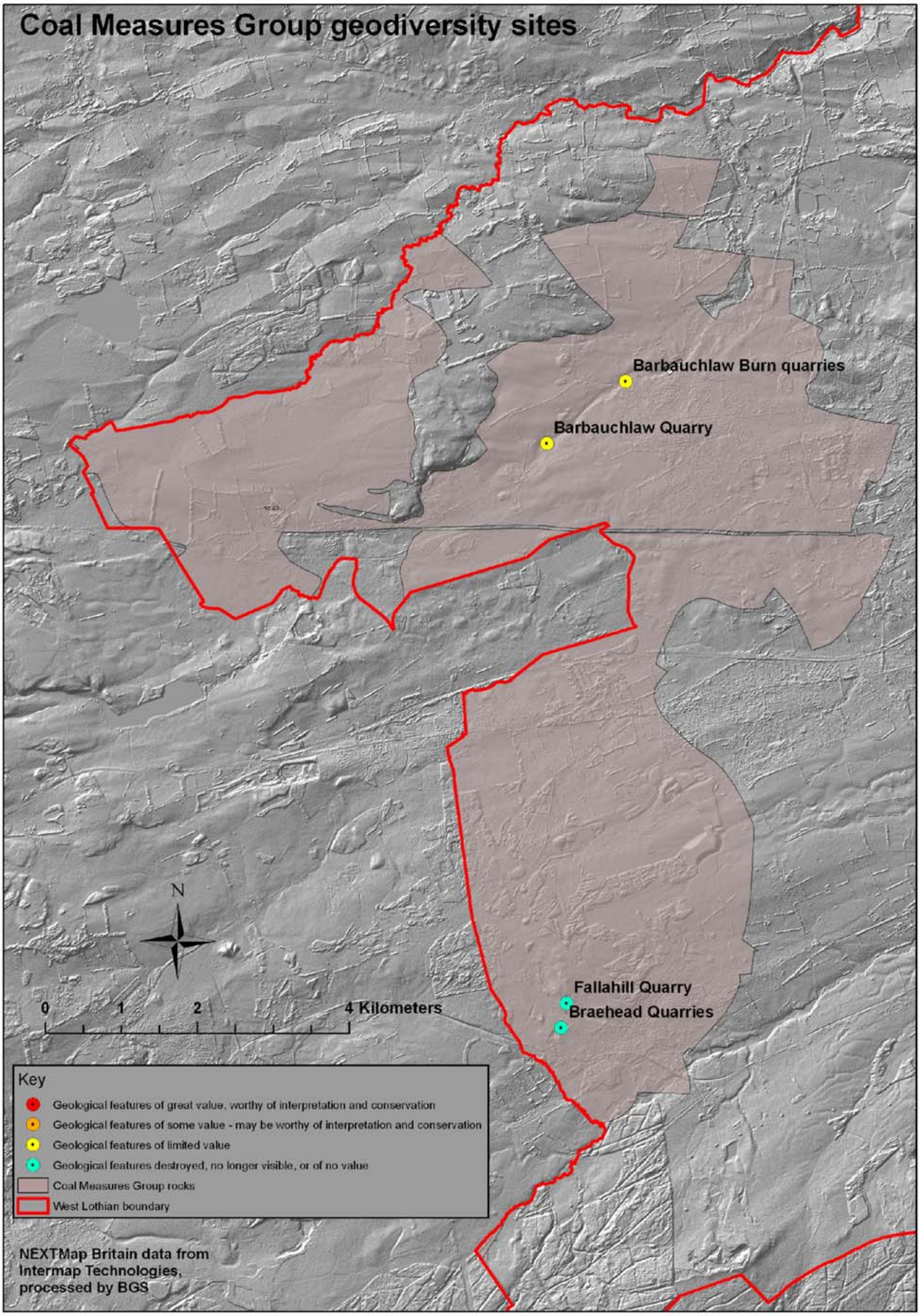


Figure 109 Coal Measures (Scotland) Group geodiversity sites of West Lothian.

Figure 110 Braehead Quarry [NS 9205 6055] west of Fauldhouse, an infilled and landscaped former building stone quarry.

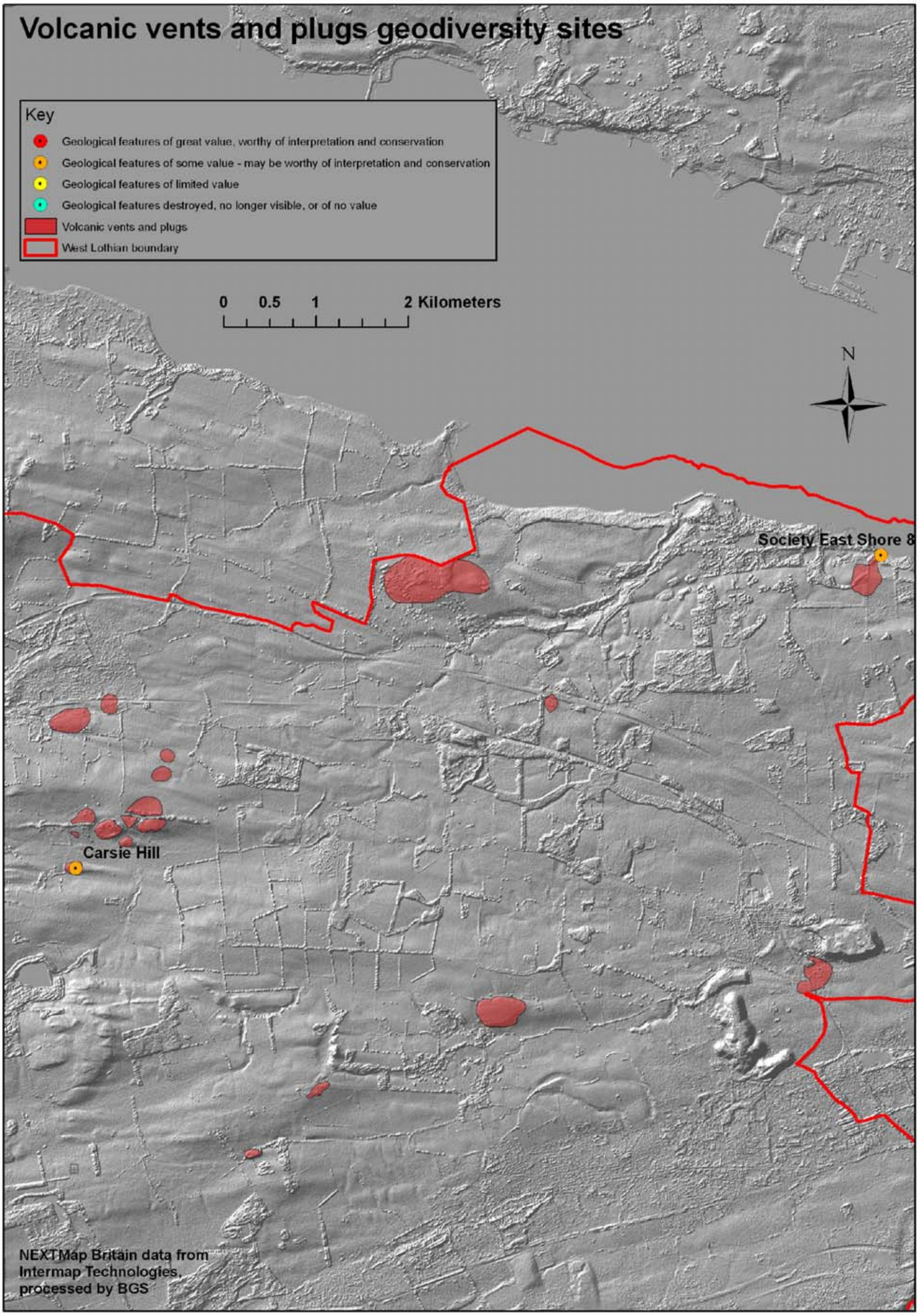


Figure 111 Volcanic vents and plugs geodiversity sites of West Lothian.

Figure 112 View south-west from Jock's Hill towards the volcanic vent of Carsie Hill [NT 0150 7547] (WLGS 35) (low hill in middle distance). Carsie Hill is also a Crag and Tail.

Figure 113 Pyroclastic breccia in volcanic vent on Carsie Hill [NT 0150 7547] (WLGS 35).

Figure 114 Outcrop of pyroclastic breccia in the Society Shore vent. Society Point can be seen in the distance to the right of the trees. Society East Shore 8 [NT 1021 7886] (WLGS 13).

Figure 115 Close-up of pyroclastic breccia from the Society Shore vent. Society East Shore 8 [NT 10218 78863] (WLGS 13).

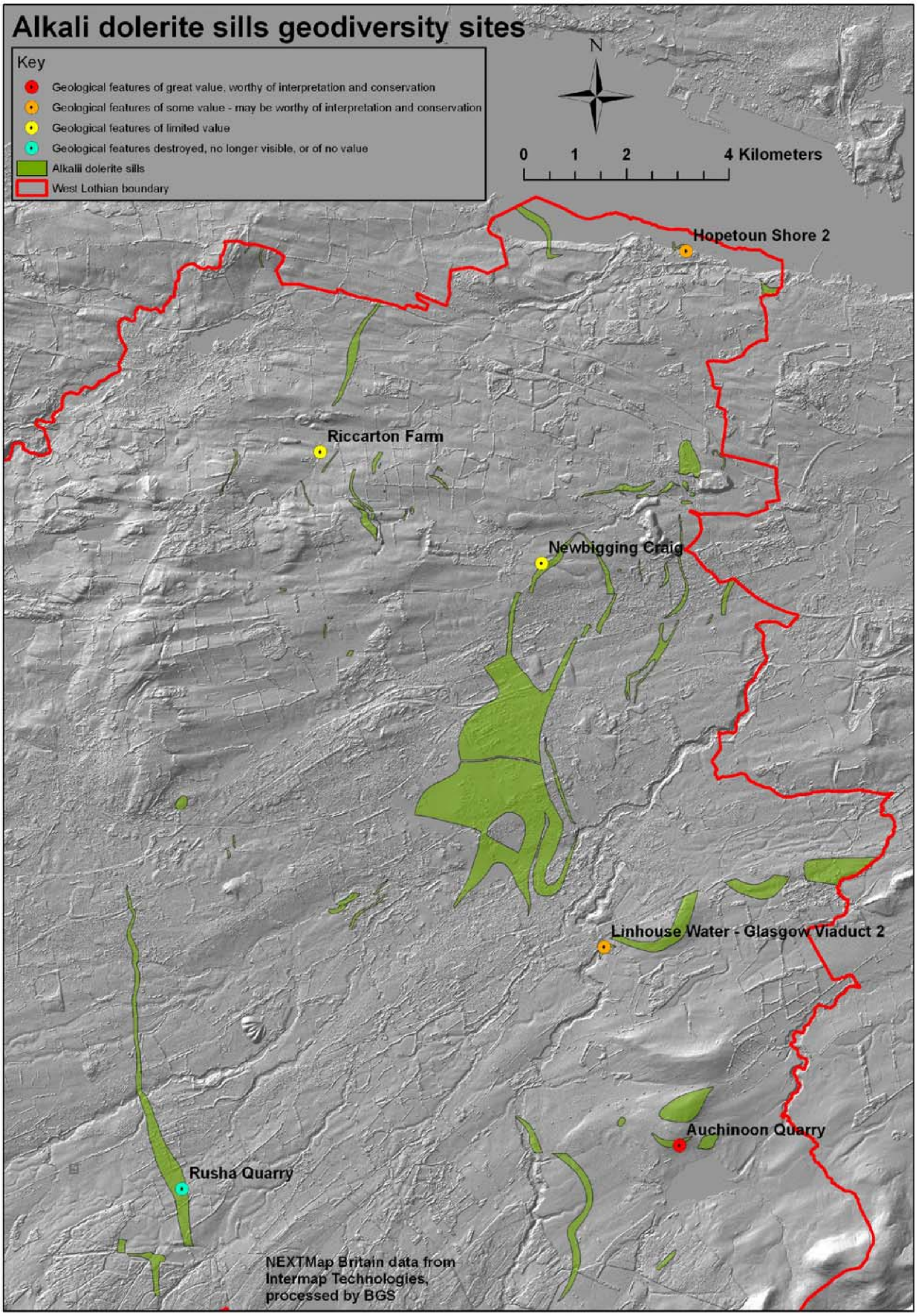


Figure 116 Alkali-dolerite sills geodiversity sites of West Lothian.

Figure 117 Auchinoon Hill from south-east of Harperrig Reservoir. Auchinoon Quarry (WLGS 36) left of centre.

Figure 118 Auchinoon Quarry [NT 0919 6175] (WLGS 36) with the Pentland Hills beyond. Dolerite sill in lower part of quarry with Gullane Formation laminated siltstones above.

Figure 119 Auchinoon Quarry [NT 0919 6175] (WLGS 36). 5 m of dolerite sill in lower part of quarry face with thermally metamorphosed laminated siltstones of the Gullane Formation above.

Figure 120 Centre section of Auchinoon Quarry [NT 0919 6175] (WLGS 36). Approximately 5 m of dolerite sill in lower part of quarry face with thermally metamorphosed laminated siltstones of the Gullane Formation above.

Figure 121 Auchinoon Quarry [NT 0919 6175] (WLGS 36). Dolerite sill in lower part of quarry with Gullane Formation laminated siltstones above. Siltstones have been thermally metamorphosed to calc-silicate hornfels by contact with sill. Face approximately 4 m high.

Figure 122 The Dalmahoy Sill (alkali-dolerite) in the bank of the Linhouse Water. Linhouse Water Glasgow Viaduct 2 site [NT 0772 6562] (WLGS 37).

Figure 123 Teschenitic dolerite sill intruded into the core of the Hopetoun anticline at Hopetoun Shore 2 [NT 0932 7918] (WLGS 17).

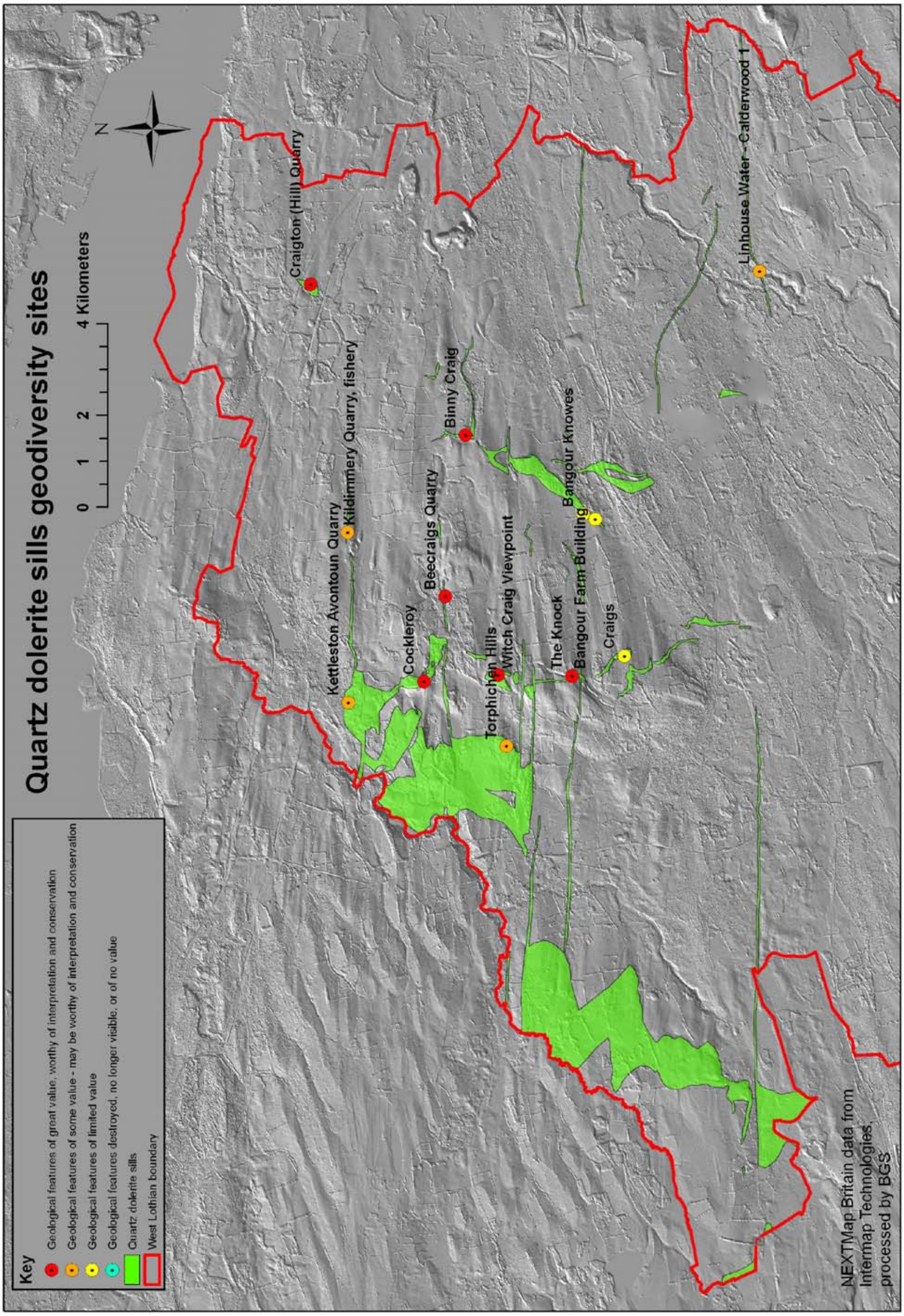


Figure 124 Quartz-dolerite sills geodiversity sites of West Lothian.

Figure 125 Panoramic view east to south-east from The Knock (305 m) [NS 9906 7114] (WLGS 38) towards Edinburgh and the Pentland Hills.

Figure 126 The Knock from the north-west [NS 9906 7114] (WLGS 38). Quartz-dolerite sill on the summit intrudes basalt lavas of the Bathgate Hills Volcanic Formation.

Figure 127 Quartz-dolerite sill, south-east face of The Knock [NS 9906 7114] (WLGS 38). The chilled contact with the basalt lavas of the Bathgate Hills Volcanic Formation can be seen here.

Figure 128 Sphaeroidal weathering in dolerite on The Knock [NS 9906 7114] (WLGS 38).

Figure 129 Millenium Stone circle, Knock Farm [NS 9912 7130] (WLGS 38). Cairnpapple Hill on top left (WLGS 20).

Figure 130 Witch Craig Viewpoint stone shelter [NS 9908 7275] (WLGS 39). Cockleroy can be seen above right-hand end of shelter.

Figure 131 Witch Craig Viewpoint [NS 9908 7275] (WLGS 39) and view north-west to Lochcote Reservoir.

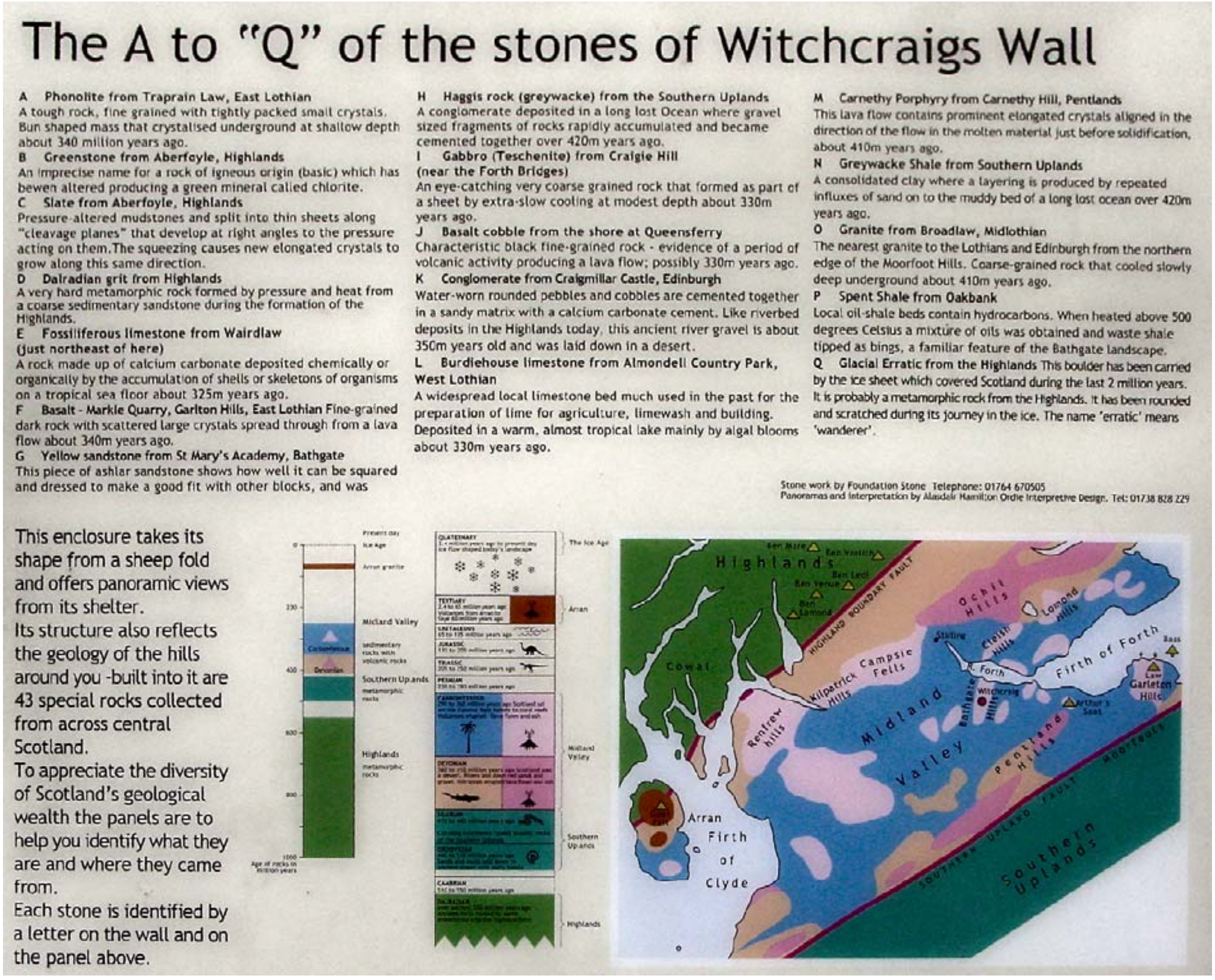


Figure 132 Witch Craig Viewpoint display board [NS 9908 7275] (WLGS 39).

Figure 133 View from Witch Craig Viewpoint [NS 9908 7275] (WLGS 39) towards Grangemouth.

Figure 134 Torphichen Preceptory ‘refuge stone’ with cross, Witch Craig [NS 9910 7273] (WLGS 39).

Figure 135 A misleading **(**pre- outdoor access code) sign on Cockleroy [NS 9894 7437] (WLGS 40).

Figure 136 Quartz-dolerite outcropping on the slopes of Cockleroy [NS 9894 7437] (WLGS 40). Cockleroy is composed of Bathgate Hills Volcanic Formation basalts intruded by a quartz-dolerite sill.

Figure 137 View west from Cockleroy [NS 9894 7437] (WLGS 40). Cockleroy is composed of Bathgate Hills Volcanic Formation basalts intruded by a quartz-dolerite sill.

A

B

Figure 138 Cockleroy [NS 9894 7437] (WLGS 40) rocks and flowers **A:** Vesicular basalt **B:** Scottish Bluebell (*Campanula rotundifolia*).

Figure 139 Entrance sign at Beecraigs Country Park [NT 0071 7425] (WLGS 41).

Figure 140 Beecraigs Quarry face climbing wall [NT 0080 7390] (WLGS 41) composed of quartz-dolerite, Beecraigs Country Park.

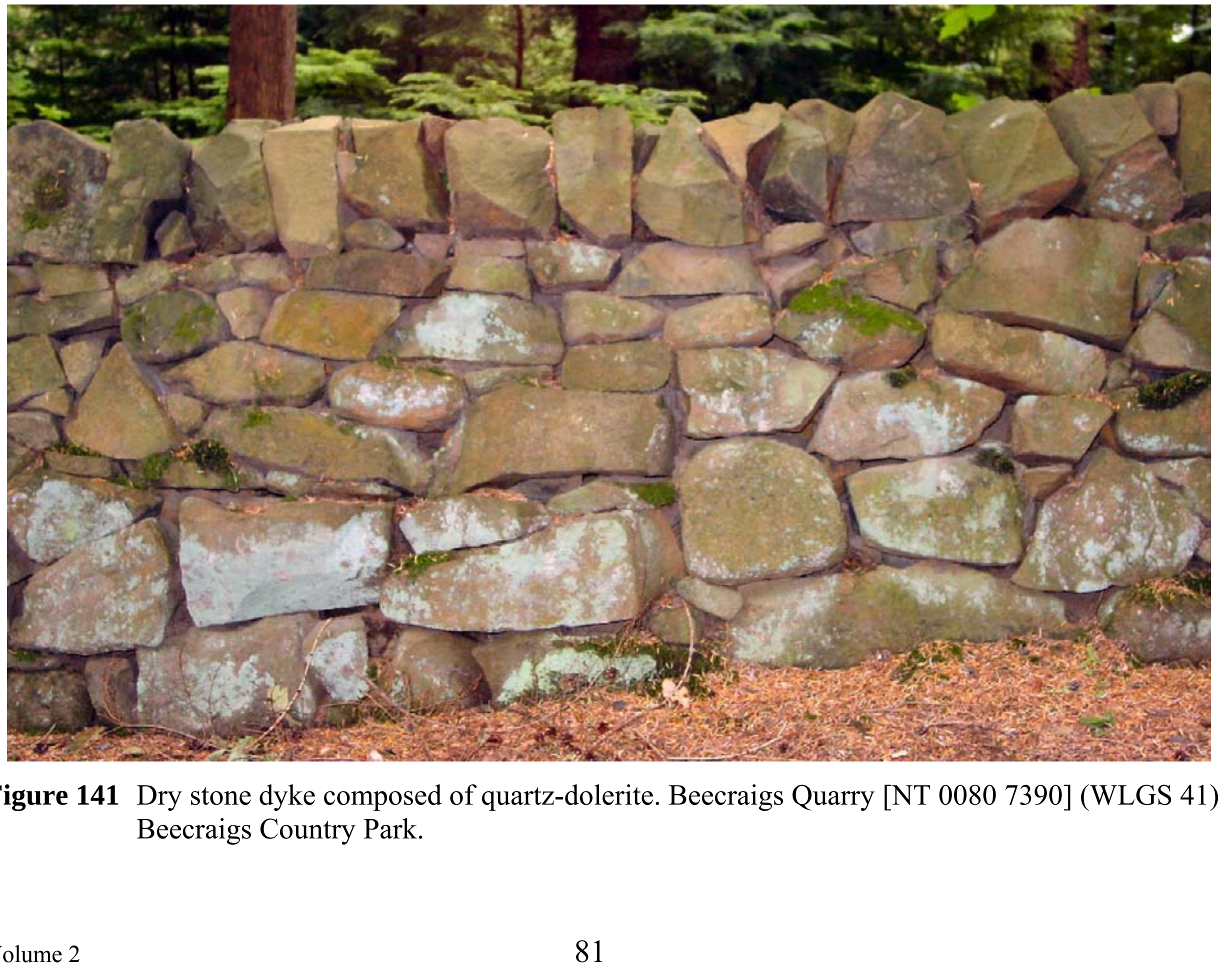


Figure 141 Dry stone dyke composed of quartz-dolerite. Beecraigs Quarry [NT 0080 7390] (WLGS 41), Beecraigs Country Park.

Figure 142 Panoramic view Binny Craig from the south – a classic ‘Crag and Tail’ landform sculpted from a basalt sill intruding the West Lothian Oil Shale Formation. ‘Crag’ on left and ‘Tail’ on right [NT 0432 7346] (WLGS 42).

Figure 143 Binny Craig Sill displaying columnar jointing in basalt. Binny Craig [NT 0432 7346] (WLGS 42).

Figure 144 View south from Binny Craig summit [NT 0432 7346] (WLGS 42) to the Pentland Hills.

Figure 145 Basalt of the Binny Craig Sill overlying baked shales of the West Lothian Oil shale Formation [NT 0432 7346] (WLGS 42).

Figure 146 Exposure of a quartz-dolerite dyke in Kildimmery Fishery Quarry [NT 0220 7603] (WLGS 43).

Figure 147 Exposure of a quartz-dolerite dyke in Kildimmery Fishery Quarry [NT 0220 7603] (WLGS 43).

Figure 148 Exposure of a quartz-dolerite dyke in the Linhouse Water at Linhouse Water – Calderwood 1 [NT 0790 6705] (WLGS 45).

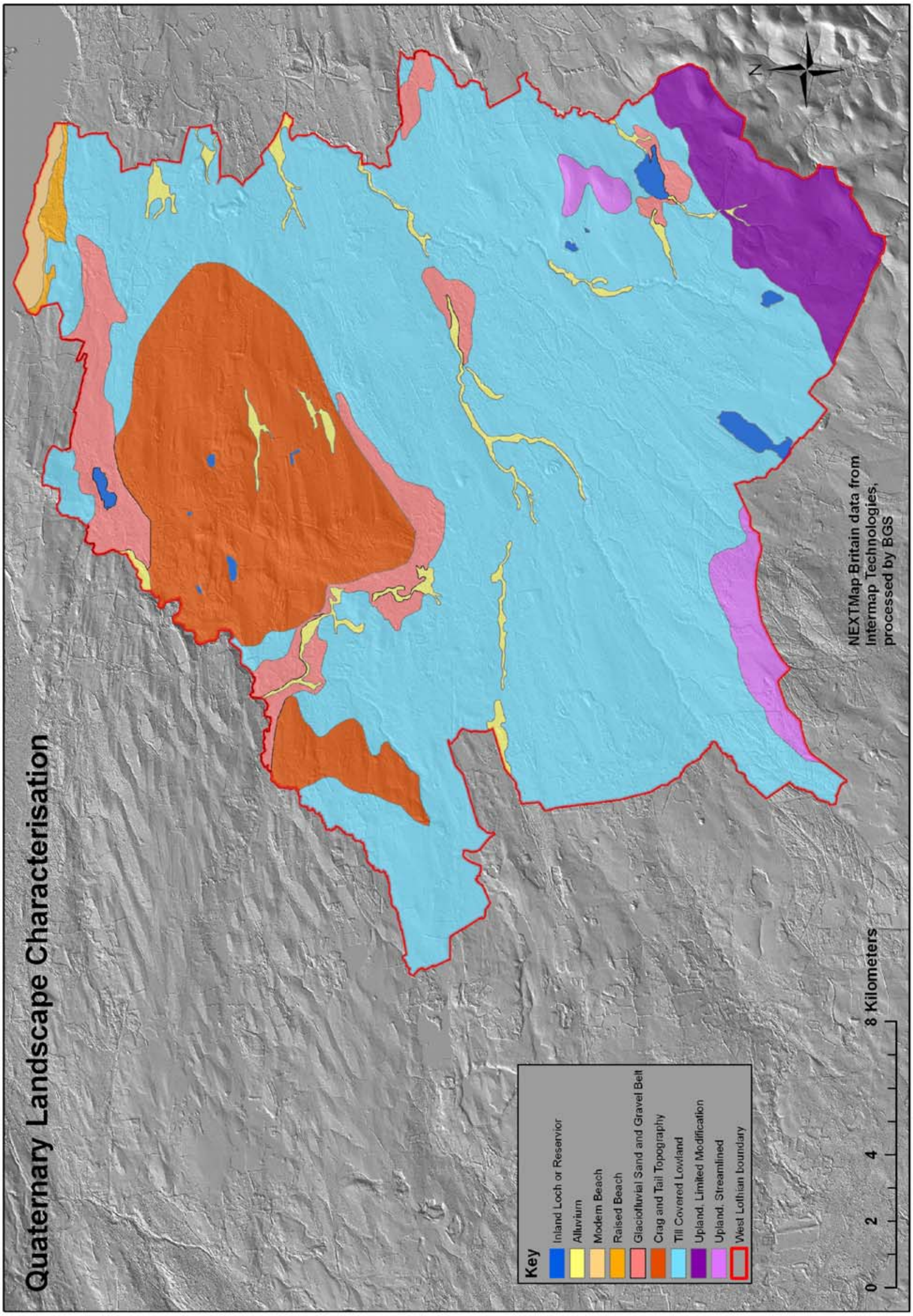


Figure 149 Quaternary Landscape Characterisation of West Lothian.

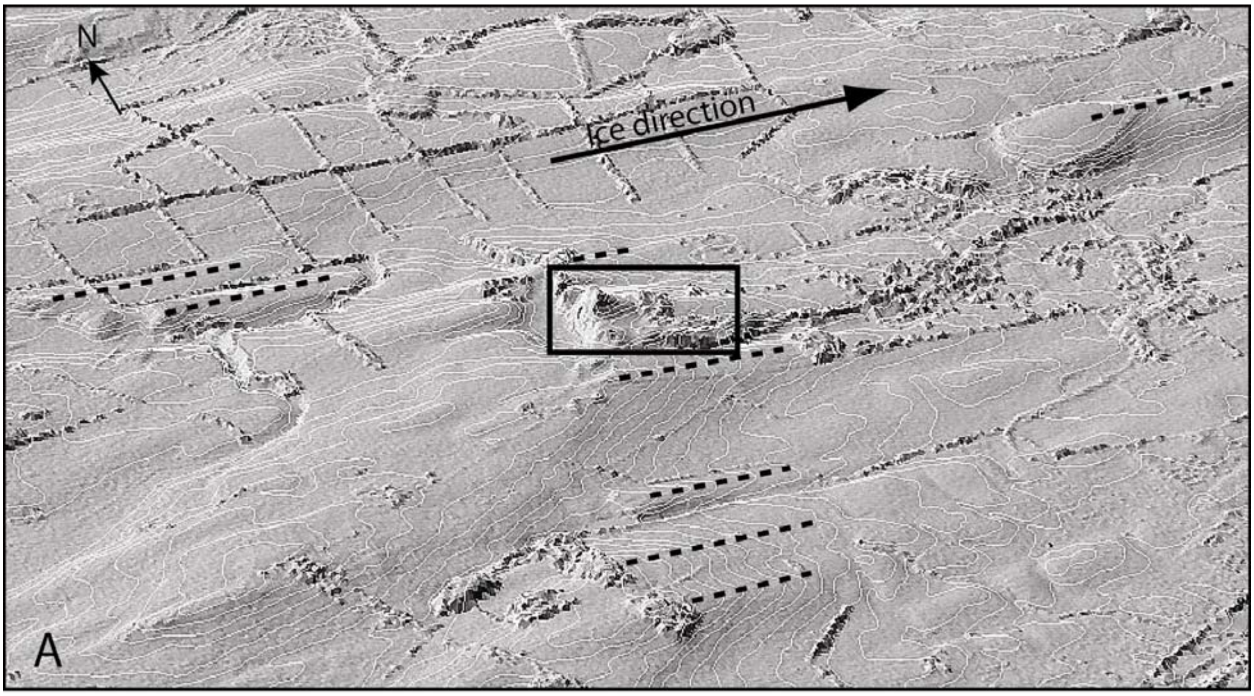


Figure 150 A: Oblique hill-shaded digital surface model showing Binny Craig (outlined) and surrounding crag and tails (dashed lines). Contours at 25 m intervals. B: Binny Craig clearly showing the outcrop of resistant basalt and 'tail' of protected softer rock (WLGS 42).

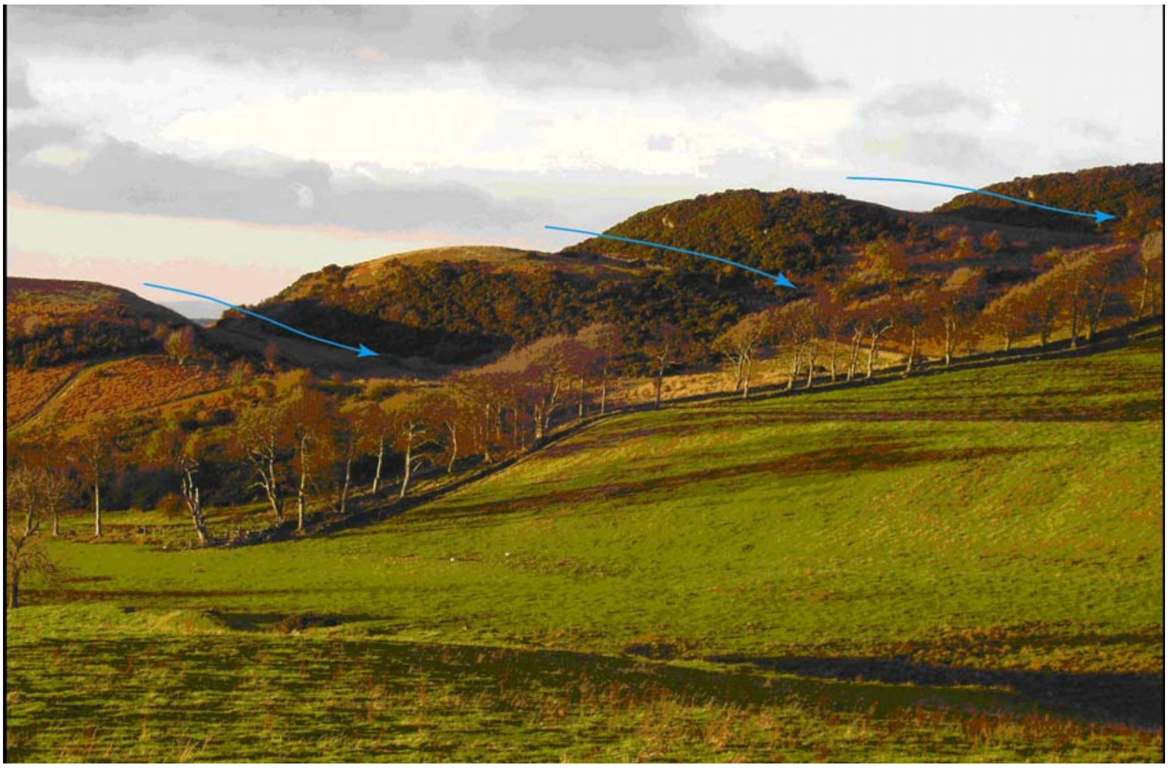


Figure 151 Deep channels cut by glacial meltwater along faults in Torphichen Hill [NS 975 725] (WLGS 46).

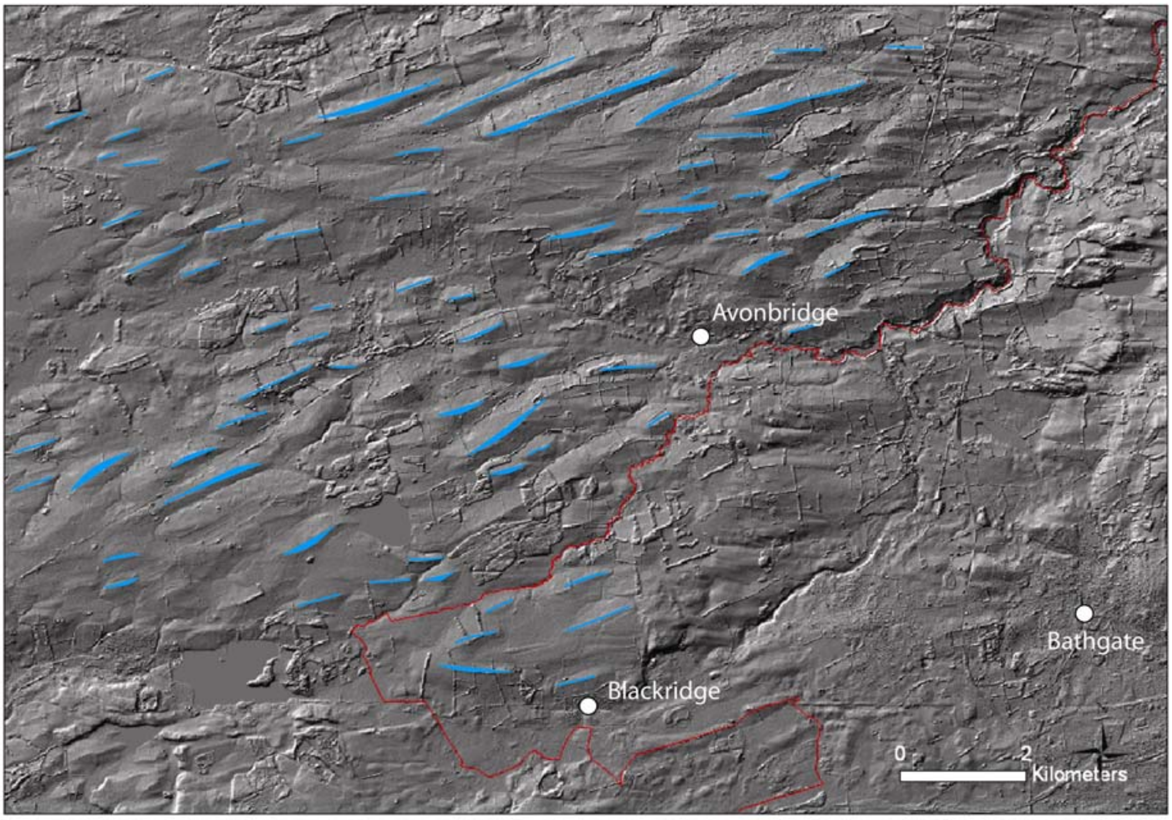


Figure 152 Drumlinized zone to the west of West Lothian. A transition from the drumlin zone to the crag and tail topography occurs where igneous rocks outcrop at the surface.

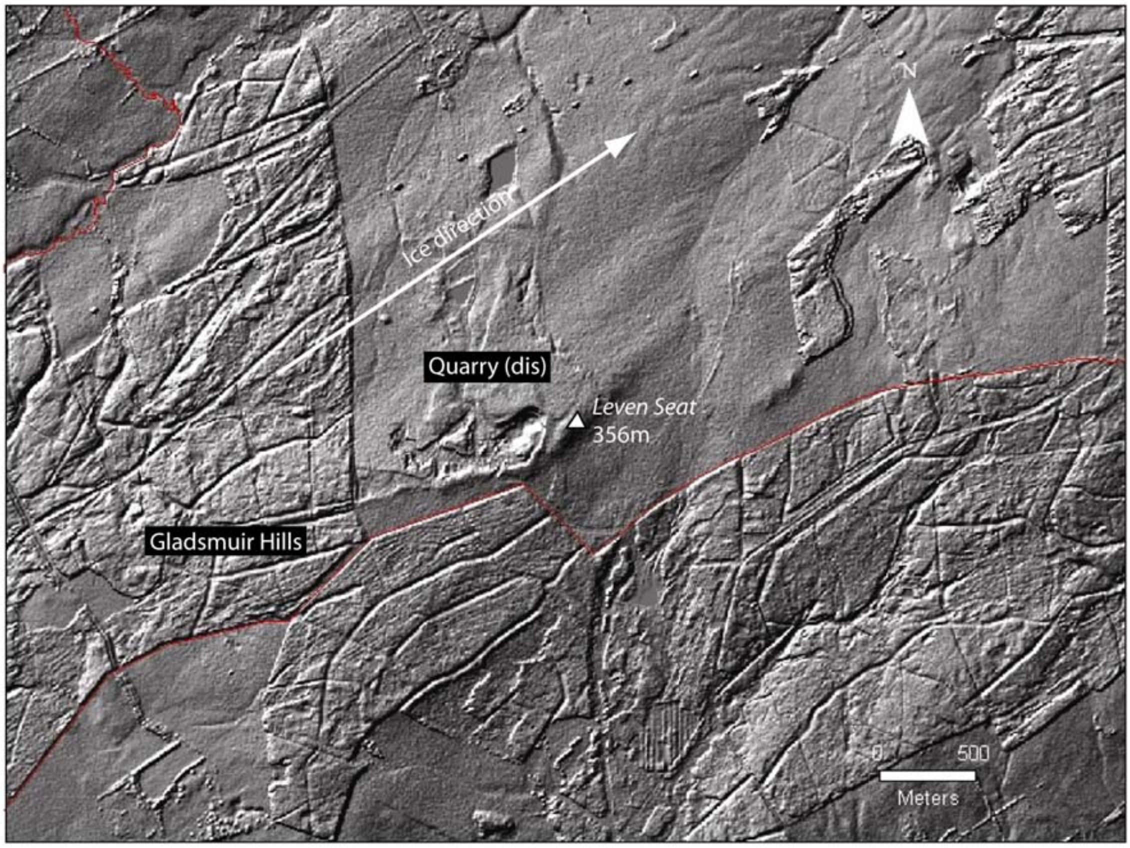


Figure 153 Streamlining of upland terrain around Leven Seat.

Figure 154 Post-glacial cemented raised beach deposits above the modern beach at Abercorn Point 2 [NT 0835 7952] (WLGS 18).

Figure 155 Linlithgow Loch and Linlithgow Palace. The loch is very large kettle hole formed by the melting of a large detached mass of ice trapped within glacial deposits [NT 004 776] (WLGS 47).

Figure 156 A glacial erratic of dolerite on the shore at Abercorn Point 3 [NT 0827 7954] (WLGS 18).

Figure 157 View west-south-west from Seafield Law to Easter Inch Moss from [NT 0010 6666] (WLGS 50).

Figure 158 View west-south-west from Seafield Law to Easter Inch Moss from [NT 0010 6666] (WLGS 50).

Figure 159 Seafield Law from Easter Inch Moss from [NT 0010 6666] (WLGS 50).

Figure 160 Peat on Easter Inch Moss [NT 0010 6666] (WLGS 50).

Figure 161 Soil on terraced gravel on glacial till in an area of active erosion and deposition. Linhouse Water [NT 0734 6613]. This site is 430 m upstream (south-west) of WLGS 51 (Calder Wood)

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

West Lothian Geodiversity

Volume 3 – Appendices

Geology and Landscape North Programme
Commissioned Report CR/06/008N

SCOTTISH EXECUTIVE

Lothian and Borders RIGS Group

SCOTTISH NATURAL HERITAGE

West Lothian Council

BRITISH GEOLOGICAL SURVEY
GEOLOGY AND LANDSCAPE NORTH PROGRAMME
COMMISSIONED REPORT CR/06/008N

West Lothian Geodiversity

Volume 3 – Appendices

H F Barron, M A E Browne and A Finlayson

Contributors

S L B Arkley, S M Clarke, A Matthewson, A Pickering and K I G Lawrie

Editor

D J D Lawrence

Keywords

Geodiversity; West Lothian.

Front cover

Five Sisters Bing, West Calder

Bibliographical reference

BARRON, H F, BROWNE, M A E, AND FINLAYSON, A. 2005. West Lothian Geodiversity. *British Geological Survey Commissioned Report*, CR/06/008N8N. 190pp.

Keyworth, Nottingham British Geological Survey 2006

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desks at Nottingham, Edinburgh and London; see contact details below or shop online at www.geologyshop.com

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

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

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

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

British Geological Survey offices

Keyworth, Nottingham NG12 5GG

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

Murchison House, West Mains Road, Edinburgh EH9 3LA

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

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

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

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

☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast BT9 5BF

☎ 028-9038 8462 Fax 028-9038 8461

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

☎ 01491-838800 Fax 01491-692345

Columbus House, Greenmeadow Springs, Tongwynlais, Cardiff, CF15 7NE

☎ 029–2052 1962 Fax 029–2052 1963

Parent Body

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

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

Contents

Appendix 1 Natural Heritage Designations in West Lothian

Adapted from National Heritage Designations in Scotland (December 1998), SNH website (http://www.scotland.gov.uk/library/documents-w4/nhd-00.htm)

INTERNATIONAL

Special Areas for Conservation (SACs)

In accordance with the EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC – commonly known as the Habitats Directive), SACs require to be designated to safeguard rare and threatened species and habitats listed in the Directive. Terrestrial SACs are normally SSSIs. Together with SPAs, SACs will form a network of European sites to be known as Natura 2000. The aim of the network is to maintain rare or endangered species and habitats at a favourable conservation status throughout Europe.

Special Protection Areas (SPAs)

Special Protection Areas are areas designated under Article 4 of the European Community Directive on the Conservation of Wild Birds 1979 (EC79/409), commonly known as the Wild Birds Directive. To comply with this Directive the Government is required to classify SPAs. These can include land and marine areas. Within these areas special measures are required to protect wild birds and their habitats particularly rare or vulnerable species listed in the Directive, and regularly occurring migratory species. Terrestrial SPAs are normally SSSIs.

Ramsar Sites

Ramsar Sites are wetlands of world wide importance particularly those containing large numbers of waterfowl. The Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat was ratified by the Government in 1976. It promotes the wise use of wetlands, and requires them to be protected from damage or pollution.

NATIONAL

Sites of Special Scientific Interest (SSSIs)

SSSIs are key areas of marine conservation and wildlife importance. They are special for the nature conservation value of the plants, animals or habitats as well as any rock formations. In addition to land they can include rivers, freshwater and inter-tidal areas as far as the low water mark. SSSIs are designated by SNH under the provisions of the Wildlife and Countryside Act 1981 and in accordance with specific guidelines to protect the special interest of the site from damage or deterioration. SSSI status does not change the use of the land but local authorities, owners and occupiers must consult with SNH on any developments or activities which may affect the site.

National Nature Reserves (NNRs)

National Nature Reserves are areas of national or international importance for nature conservation and include some of the most important natural and semi-natural habitats in

Great Britain. They are declared by SNH under the National Parks and Access to the Countryside Act 1949 and the Wildlife and Countryside Act 1981 for the purpose of study, research and the preservation of flora, fauna, geological and zoological interests. An NNR, unlike an SSSI, has to be managed appropriately to retain its special status.

Areas of Great Landscape Value (AGLVs)

The requirement to designate AGLVs is set out in Circular 2/1962. They are defined by local authorities in development plans with a view to safeguarding areas of regional or local landscape importance from inappropriate developments.

LOCAL

RIGS

Regionally Important Geological and Geomorphological Sites (RIGS), designated by locally developed criteria, are currently the most important places for geology and geomorphology outside statutorily protected land such as Sites of Special Scientific Interest (SSSI). The designation of RIGS is one way of recognising and protecting important Earth science and landscape features for future generations to enjoy.

The concept of RIGS was first initiated by the Nature Conservancy Council (NCC). RIGS sites started life as SSSIs denotified after the Geological Conservation Review (1997-1990). The statutory agencies wished to secure their conservation in another form. RIGS sites are those which, whilst not benefiting from national statutory protection, are nevertheless regionally or locally representative sites where '.... consideration of their importance becomes integral to the planning process' according to the Earth Science Conservation Strategy (ESCS).

Regional Parks

Regional Parks, designated under Section 48A of the Countryside (Scotland) Act 1981, are extensive areas of the countryside which provide for the co-ordinated management of informal recreation alongside and in close collaboration with the management of other land uses in the area. The four Regional Parks in Scotland, extending in total to 86,160 ha, were established by the former Regional Councils and confirmed by the Secretary of State for Scotland. Management of the Parks has now transferred to the new Local Authorities.

Country Park

A Country Park is an area designated for people to visit and enjoy recreation in a countryside environment. The purpose of a country park is to provide somewhere for visitors who do not necessarily want to go out into the wider countryside. Visitors can enjoy a public open space with an informal atmosphere, as opposed to a formal park as might be found in an urban area. For this reason country parks are usually found close to or on the edge of built-up areas, and rarely in the countryside proper.

Local Nature Reserves (LNRs)

A Local Nature Reserve is a place with special local natural interest, set up to protect nature, and for people to enjoy and appreciate. Local Authorities have exclusive statutory powers to set up and manage LNRs under Section 21 of the National Parks and Access to the Countryside Act 1949 as amended by the Local Government and Planning (Scotland) Act 1982.

Inventory of Historic Gardens and Designed Landscapes

The Inventory of Gardens and Designed Landscapes in Scotland provides a representative sample of important historic gardens or landscapes. It includes private gardens, parks, policies in country estates and botanical gardens. The Town and Country Planning General Development Procedures (Scotland) Order 1992 and Circular 6/1992 puts an obligation on planning authorities to consult with SNH and Historic Scotland on any developments within listed sites.

Wildlife Site

A network of sites all over Scotland is officially protected because of their value for wildlife and nature conservation - examples include National Nature Reserves and Sites of Special Scientific Interest. In order to complement this network, the Scottish Wildlife Trust has developed a system of 'Wildlife Sites', small areas which are of known local wildlife importance. SWT aims to secure the future of these sites for wildlife by identifying locally important habitats and species, and by working in co-operation with landowners to protect them.

For the Lothians, Lothian Wildlife Information Centre (LWIC) has two categories of Wildlife Site:

1. Listed Wildlife Sites − recorded in the 1970s
2. Wildlife Sites (1993) − recorded in the 1993

SWT Reserves

The Scottish Wildlife Trust (SWT) is also committed to acquiring and managing wildlife reserves: to help safeguard wildlife sites, to provide examples for others to follow, and for the public's benefit and enjoyment.

HABITATS AND SPECIES LISTS

- Ancient Woodland Inventory
- Semi-natural Woodland Inventory
- Intermediate Bog Inventory
- Raised Bog Inventory
- Great Crested Newt Sites (Scotland)

Appendix 2 Geodiversity Guidance for LBAPS

SCOTTISH
BIODIVERSITY
GROUP

Local Biodiversity Action Plans in Scotland

Sector Guidance Note 1

GEODIVERSITY

Summary

This guidance note explains the link between the physical components of the natural heritage represented by rocks, soils, landforms and active physical processes, and the biological components of the natural heritage represented by biodiversity and biological processes. Landscape and soils are the bridges that link the physical to the biological world. This note focuses on the relationships between:

- **features and processes of the physical Earth, and its species and habitats;**
- **the physical Earth, biodiversity and sustainable development.**

Introduction

The geological story of Scotland is all around us in our rocks, soils, landforms, landscapes and active processes. These physical components of the natural heritage, the geodiversity, are closely linked to biological components of the natural heritage, biodiversity, through the relationship between rocks, soils, habitats and species. The relationship is fundamental - most habitats cannot exist without the supporting medium of soils, and soil cannot form without weathering processes acting on the underlying subsoils and rocks.

Rocks, soils and landforms are resources that provide essentials for life. These include water, raw materials for manufacturing and construction, soil for agriculture, land for recreation, and coal, oil and gas for energy. They also support habitats and species, and so are vital for the Earth's biodiversity.

Geodiversity is a dynamic subject - not just old rocks. Animals and plants that are growing today, plants decaying to form peat bogs, and soil washed off the fields during storms are parts of the processes of creating rocks of the future. These processes of rocks first supporting soil development then plant and animal growth, which then decay and become part of the soil and rock formation cycle, are parts of the biodiversity cycle of life. Habitats and species (both now and in the future) cannot exist without this cycle.

Maintaining geodiversity is as important as maintaining biodiversity, since both are fundamentally linked.

Scotland's geological history

Scotland is made up of rocks which have formed over millions of years. Some of the oldest rocks in the Highlands were formed about 3 billion years ago when Scotland sat near the South Pole. Over time, the Scottish landmass drifted north towards the equator. Our coal reserves formed around 300 million years ago. At this time Scotland was sitting at the equator, covered in forests and enjoying a tropical climate. It must have seemed like a greenhouse: the atmosphere at this time contained nearly twice as much carbon dioxide than it does today. As Scotland 'drifted' northwards, red sandstone rocks formed whilst we passed through the northern desert belt.

The dynamic earth forces that drove Scotland north across the globe produced heat and pressure and caused earthquakes and volcanoes. These forces folded, faulted, cooked and stewed our rocks and produced volcanoes such as Edinburgh's Arthur's Seat. Many of the rocks altered or produced by these forces are hard and resistant to erosion. They thus have a strong influence on our landscape.

The rocks that underlie the surface are sometimes exposed on hillsides, in coastal cliffs, in river banks and in artificial excavations such as quarries and road cuttings. Rocks can also be seen in building stones, giving areas their own local architectural distinctiveness. The effects of past land-uses such as mining or quarrying can seem an eyesore, but may provide excellent habitats especially for pioneer species, and have good restoration potential. Quarries also provide excellent locations for recreation and earth heritage interpretation. Some locally distinctive habitats such as the orchids, lycopodium and staghorn mosses on North Addiewell bing in West Lothian, are directly related to mineral extraction.

Landscape, glacial landforms and associated sediments

Scotland has been covered by thick ice many times in its history. Moving ice rounded the hills and scratched and polished the rocks. It also created the wide straths and glens that today have small 'misfit' streams within them. As ice shaped the existing rocks, it left behind the eroded material (i.e. 'subsoils') as heaps of sand and gravel on the floodplains. These deposits often have distinctive terraced or mound shapes and can be very important for habitat. They are also an important economic resource. However, because the processes that formed them are no longer active, they are a finite resource that cannot be re-created. In the coastal zone, the melting ice left sea levels up to 45 m higher than present. This has left old shorelines inland, well above the current coast.

Active processes

The surface of our land is constantly changing. Slopes move, rivers erode and waves reshape the coastline. Sudden events like flooding can create problems for land managers. However, they are an important part of the natural cycle and are vital for the formation of some habitats. These include pools in rivers for adult Atlantic salmon and gravel bottomed shallows for spawning and young.

Species that have evolved in dynamic environments are able to withstand the habitat changes caused by sudden events. Fresh water pearl mussels for example, bury themselves deeper into the riverbed when water levels start to rise.

Soils

Soils are the interface between the physical Earth, habitats, species and biodiversity. Soils are a vital part of our ecosystem that directly influence what kind of plants and animals will live and grow in a given place. Soil distribution dictates vegetation cover and habitats for terrestrial ecosystems.

Soils have been developing since the last ice age ended on a range of materials, including those left by the glaciers. Distinctive geology often leads to particular soils, habitats and species. For example, the acid alpine soils of the Cairngorms and the serpentine soil on Shetland support unusual flora and fauna.

Soil properties such as texture and acidity, dictate what plants will grow. Some soils do not hold moisture well so plants growing in them have to be drought tolerant. Extreme soil conditions such as high calcium carbonate or high organic matter contents, create the unique flora of the Western Isles machair and the extensive peat bogs found throughout Scotland. Peat is a significant long-term store of the greenhouse gas carbon dioxide, so its disturbance and exploitation could have wider impacts.

Conservation

The physical Earth heritage resource holds information about the history and development of Scotland and the Earth. It also holds information about the development and distribution of native habitats and species. Geo-conservation sites of national and international importance were identified through the Geological Conservation Review process and are known as GCR sites. This review was undertaken over a twenty year period by leading scientists working across the British Isles. Many of the GCR sites they identified are protected as Sites of Special Scientific Interest (SSSIs). Some sites may receive limited protection through the non-statutory designation of a Regionally Important Geological and Geomorphological Site (RIGS).

It is important to remember that our Earth heritage does not just occur within designated sites and that habitats and species can rarely be conserved successfully without reference to the physical Earth heritage.

In order to plan for effective conservation of biodiversity, and understand its variety and mosaic, it is vital to understand the local geodiversity, and include it within the Local Biodiversity Action Plan (LBAP) process. The conservation of geodiversity is as important as that of the soil and what is living and growing on it. Examples of LBAPs where summary maps and accounts of geodiversity have been included are the West Lothian and recently published City of Edinburgh reports. An increased understanding and awareness of the links between biodiversity and geodiversity should lead to increased representation of Earth heritage in future LBAP studies.

Conclusion

Our complex biodiversity and the magnificent landscape over which it is draped only exist because of the underlying geodiversity. Scotland has evolved through varied geological processes, some of which continue to operate today. The natural landscape change that occurs today is usually related to coastal erosion or river flooding. Whilst these processes are less dramatic than those seen in the past (e.g. when volcanoes were erupting and mountains forming) they are significant for biodiversity, planning and development.

The links between the physical Earth heritage and biodiversity must be understood to enable effective management of habitats and species. Protecting a vulnerable plant or insect community from erosion by the sea will be unsuccessful if it was the erosion processes that first created the habitat niche. An understanding of the earth heritage is also fundamental to the wider goal of sustainable development because Earth heritage features and processes have created many of our important finite resources.

Earth heritage information

There are a number of organisations that can provide detailed information about the physical Earth heritage resource in your local area.

- The British Geological Survey is the government agency charged with advancing the geoscientific knowledge of the UK landmass (and adjacent continental shelf) by systematic surveying, long term monitoring and data collection. Part of their mission is 'to meet the needs of the governmental and scientific communities of the UK'. Their 8 Scottish District Geologists are based in Edinburgh and can be contacted for advice and assistance (0131 667 1000).
- Scottish Natural Heritage has a group of Advisory staff also based in Edinburgh who have expertise in Earth Sciences. They can be approached through the local SNH offices.
- The Macaulay Land Use Research Institute in Aberdeen and the Scottish Agricultural College are able to provide information on soil distribution and the relationship between land use, land cover and underlying soil.
- Staff within the Geography, Geology or Earth Science departments of local universities and colleges may also be able to help, and there are also a number of well-qualified independent experts who could provide advice on this subject.

Local RIGS groups undertake some Earth heritage conservation. There are currently RIGS groups in Fife, Lothian and Borders, Highland and Tayside. A Scottish national RIGS association is currently being set up although the UK RIGS Geoconservation Association already exists. Conservation bodies such as Scottish Wildlife Trust and the Royal Society for Nature Conservation have an active interest in geodiversity.

Further Reading

Ellis, N.V. (Ed) Bowen, D. Q., Campbell, S., Knill, J.L., McKirdy, A.P., Prosser, C.D., Vincent, M.A. and Wilson, R.C.L. (1996) *An introduction to the Geological Conservation Review*. GCR Series No 1, Joint Nature Conservation Committee, Peterborough

Thompson, A., Hine, P.D., Poole. J.S., and Greig, J. R. (1998) *Environmental Geology in Land Use Planning: A Guide to Good Practice*. Report to the Department of the Environment, Transport and the Regions by Symonds Travers Morgan, East Grinstead (80pp)

West Lothian Council (1997) *Planning for Biodiversity Action in West Lothian.* STS17 (12/97)

Edinburgh Biodiversity Partnership (2000) *The Edinburgh Biodiversity Action Plan*. Royal Society for Nature Conservation (1999) *RIGS Handbook*.

McKirdy A.P. and Crofts, R. Scotland – The Creation of its Natural Landscape. A Landscape Fashioned by Geology.

Appendix 3 Detailed geology of West Lothian

INVERCLYDE GROUP

The oldest Carboniferous rocks in the Midland Valley of Scotland belong to the Inverclyde Group. It comprises the Kinnesswood, Ballagan, and Clyde Sandstone formations but the last named unit has not been definitively recognised in West Lothian. These formations are characterised by sandstone with pedogenic (soil profile) carbonate concretions (calcrete) and by silty mudstone containing thin beds of dolostone (cementstone) and limestone; also the absence of carbonaceous rocks especially coal seams and oil shales. They were laid down between 345m and 355m years ago (Tournaisian; Courceyan to earliest Chadian Stage). Locally in the Pentlands, the base of the group is taken at an unconformity on Lower Devonian and older strata. The Inverclyde Group was laid down whilst Scotland lay in low latitudes south of the Equator. At this time, the climate was generally considered to be semi-arid and seasonally wet. It is because of the semi-arid climate that the sandstone-dominated Kinnesswood Formation contains calcareous and dolomitic pedogenic (soil profile) horizons (calcrete) and the overlying Ballagan Formation is characterised by ferroan dolostone (cementstone), and evaporite (mainly gypsum).A rather discontinuous vegetational cover of the land surface was probably the norm.

Kinnesswood Formation

The Kinnesswood Formation consists predominantly of white, pink to red-brown, medium-grained quartzose sandstones that are cross-bedded and arranged in upward-fining units. Fine-grained, planar or poorly bedded sandstones, red-brown and pale green mudstones/siltstones and nodules and thin beds of concretionary carbonate (cornstone) also occur. Rip-up clasts of mudstone and carbonate are also found especially in sandstone sub-unit and unit bases. Lithic, matrix supported conglomerate and coarse pebbly sandstone are found at the base of the formation where it rests unconformably on older strata. The clasts, usually no more than 10cm, consist mostly of lavas and also vein quartz, quartzite, jasper, chert and wacke sandstone. The cross-bedded sandstones were deposited in river channels (and on river banks) apparently flowing mainly from the southeast and the fine-grained sandstones and mudstones represent overbank deposits formed on the associated floodplains. The carbonate nodules and beds that characterise the formation, are calcrete deposits that developed in soil profiles on stable alluvial plains under the influence of a fluctuating water table in a semi-arid and seasonally wet climate. The calcretes are best developed towards the base of the formation. The formation is estimated to be 100 m to 400 m thick in the Pentlands.

Ballagan Formation

The Ballagan Formation is characterised by grey mudstone and siltstone, with nodules and beds of ferroan dolostone (cementstone), the beds generally less than 0.3 m thick. Gypsum, and to a much lesser extent anhydrite, and pseudomorphs after halite occur. Desiccation cracks are common and the rocks frequently show evidence of brecciation. Both these features are associated with reddening of the strata that is otherwise much more common in West Lothian contrasted to the classical Ballagan outcrops such as at Ballagan Glen, Stirlingshire. Thin sandstone beds are commonly present, and thick localised sandstones are also found in the formation especially in West Lothian. Where present, the restricted fauna is characterised by the bivalve *Modiolus latus*, but ostracods are more abundant along with Estherids and Sprirobids.

The Ballagan Formation is interpreted as being laid down in coastal alluvial plains, lakes and marginal marine flats. These were subject to periodic desiccation with fluctuating salinity partly as a result of seawater being introduced by storm flooding events. The open sea lay to the east initially. Later it is more evident to the south of the Midland Valley of Scotland with the more marine faunas in the `cementstones' being found in the Solway Firth Basin. The lack of sulphide in the mudstones and the sourcing of the magnesium and calcium ions in the cementstones has been explained by the limited events of seawater inundation of the alluvial plains and its lakes. Argillaceous limestone is present where lakes were deep enough to avoid post-burial dolomitisation. The inundations in general left no marine faunal record but provided a strong geochemical signal in the sulphate evaporites, ferroan dolostones and Strontium isotopes. Because of the dominance of the siliciclastic component over the evaporitic, it has been concluded that the formation was laid down in a humid environment subject to drier periods of evaporation rather than a generally arid one. The maximum thickness of the formation of about 900 m is in the West Lothian area.

The detailed sequence of informal members in the Ballagan Formation is in ascending succession; Lower Shale (100m thick), Middle Sandstone (180 m to 400m thick), Upper Shale (400 m thick) and Upper Sandstone. The 'Upper Sandstone' of the Pentland Hills may actually belong to the Clyde Sandstone Formation. Elsewhere this last named formation consists predominantly of fine- to coarse-grained sandstone, commonly pebbly, with beds of red-brown or grey mudstone. Pedogenic limestone, as nodules or beds, and calcite-cemented concretionary sandstones are also present. The pebble clasts are largely of intrabasinal limestone or mudstone origin. These strata were laid down in a wide variety of fluviatile environments ranging from braided stream to floodplain with well-developed overbank deposits. Distinguishing the Ballagan and Clyde Sandstone formations apart in the Edinburgh district is difficult because although calcretes are characteristic of both the Kinnesswood and Clyde Sandstone formations, pedogenic limestone is also developed in the Ballagan Formation that in this district is also distinctly richer in sandstone than is its norm.

STRATHCLYDE GROUP

The Strathclyde Group is a varied sequence of rocks, sedimentary and volcanic, characterised by the presence of carbonaceous beds, including coal and oil-shale. They were laid down between 345m and 326m years ago (Visean; earliest Asbian to Brigantian Stages). The group is largely fluviatile and lacustrine in origin, with a few marine incursions from time to time. The base of the Strathclyde Group is taken at the base of the Arthur's Seat Volcanic Formation in the Lothians (342m yrs old). Strathclyde Group strata consist of interbedded sandstone, siltstone and mudstone with common seatearths, coal seams and sideritic ironstone. Deposition of the Strathclyde Group marks a lithological change from concretionary limestone and dolostone-bearing strata typical of the Inverclyde Group to a coal-bearing sequence in which volcanic rocks may be common. The local Strathclyde Group strata are assigned to the Arthur's Seat Volcanic, Gullane and West Lothian Oil-shale formations.

Oil-shales and freshwater limestones are minor but important components of the group. These reflect the development of substantial lakes ('Lake Cadell', 2000-3000 km^2) in a humid climate. These particular lake sediments are characterised by the accumulation of abundant remains of filamentous, mat-forming, benthonic cyanophyte (blue-green) microbes/algae. The non-filamentous planktonic Botryococcus brauni appears to be a minor constituent of these oil shales and limestones. Cryptalgally laminated dolostones have been recognised as of the value of in regional correlation and as time markers of basin-wide 'regression'. Deposition of these carbonates was in a hydrologically closed, shallow, playa-type lake. In contrast, the oil-shales formed in hydrologically open, thermally stratified, deep lakes where shore-levels and water levels were stable over long periods. Switches between the two systems were caused either by climate change (increased aridity and seasonality within an overall humid, sub-tropical environment) or by local earth movements and vulcanicity. However a second category of closed lake is known in which microbial tufa carbonates accreted in shallow, volcanigenically supplied nutrient-rich sub-basins.

Other volcanic rocks occur in the group apart from those in the Arthur's Seat and Bathgate Hills Volcanic formations including the following named tuff horizons, Crosswood Ash, Seafield-Deans Ash, Port Edgar Ash and Barracks Ash. The Port Edgar Ash comprises tuffs of comminuted sedimentary debris which have been encountered in boreholes in the Society area [10 79]. The Seafield-Deans Ash consists of a pile of tuffs, locally 90 m or more in thickness, occurring in the Seafield and Deans area [01 66], where it takes the place of some oil-shale seams in the Pumpherston Shales.

The palaeoclimate during deposition of the Strathclyde Group was mainly humid (coals, oil-shales and sideritic mud grade palaeosols) but the presence of calcretes and calcareous mudstones ('marls') in the West Lothian Oil-Shale Formation point to periods of semi-arid climatic conditions through Asbian Stage times. Regular orbitally forced glacio-eustatic sea-level oscillations started abruptly around 330Ma (early Asbian) with a 100Ka periodicity and that these characterised the late Palaeozoic from then on. Prior to this time pre-Asbian climates were relatively stable with infrequent changes. Fluctuations in climate occurred during glacial sea level lowstands. It is only in the Brigantian (Raeburn Shell Bed and younger marine beds) that any marine cycles are seen in the Strathclyde Group that might be associated with such a systematic mechanism.

Palaeocurrent flow in the Strathclyde Group is generally from the north throughout and Argon/Argon ages on detrital muscovites appear to link the flow direction with a source of the detritus in Scandanavia. This source area remained a major topographic high and supplied sediment to Scotland for over 100Ma because of post-orogenic uplift and exhumation events.

Arthur's Seat Volcanic Formation

The oldest rocks (earliest Visean) in the Strathclyde Group in West Lothian belong to the Arthur's Seat Volcanic Formation. These extrusive igneous rocks belong to a suite of mildly alkaline basaltic lavas which is recognised across the Midland Valley and is chemically distinct from the Lower Devonian igneous rocks of the Pentlands. To aid description of the Dinantian alkali basaltic rocks of the Midland Valley, and to aid correlation of flows with the vents and plugs from which they originated, the alkali olivine basalts (mugearites and hawaiites) and their more coarse-grained equivalents have been classified on the basis of the nature and size of the phenocryst phases (Olivine, pyroxene and feldspars). Volcaniclastic rocks known as tuffs and lapilli-tuffs also occur; these may be air-fall or water-lain in origin. The formation is up to 200 m thick in this area and absent in places.

Gullane Formation

The Gullane Formation consists of a cyclical sequence predominantly of pale-coloured, fine- to coarse-grained sandstones interbedded with grey mudstones and siltstones. Subordinate lithologies are coal, seatearth, ostracod-rich limestone and dolostone, sideritic ironstone and, rarely, marine beds with low diversity faunas lacking for example corals. The depositional environment was predominantly fluviodeltaic, into lakes that only occasionally became marine. Desiccation cracks, soft sediment deformation textures and bioturbation are sedimentological features typical of this formation. The Gullane Formation in the Edinburgh district is locally divided into informally named members. In ascending stratigraphical order, these are the Abbeyhill Shales, Granton Sandstones and Wardie Shales. The Abbeyhill Shales overlie the Arthur's Seat Volcanic Formation. These are grey and green mudstone and siltstone that may be bituminous and include thin ostracod-bearing limestones deposited in an overall non-marine environment.

The overlying sequence is known as the Granton Sandstones. This member includes thick beds of fluvial and lacustro-deltaic, off-white, cross bedded, sandstones interbeddded with siltstones and mudstones with a couple of thin marine bands. The Wardie Shales overlie the Granton Sandstones. These comprise mudstone, siltstone and thin sandstones beds with oil-shale, dolostone and ironstone with the thin marine Muirhouse Shrimp Bed near the base of the succession (in west Edinburgh). The thin non-marine dolostones contain ostracods and algal bodies. The Dalmahoy Oil-shale occurs locally at the top of the Wardie Shales. Further marine bands in the Gullane Formation include the Woodhall, Campbell Park, West Mills (Lower and Upper) and Redhall marine bands.

West Lothian Oil-Shale Formation

The West Lothian Oil-Shale Formation is characterised by several, well-developed distinctive seams of oil-shale within a cyclical sequence dominated by pale-coloured sandstones interbedded with grey siltstones and mudstones. Subordinate lithologies are coal, ostracod-rich limestone and dolostone, sideritic ironstone and beds of fossiliferous mudstone deposited in a marine environment, including limestones with rich and relatively diverse faunas. Thick, pale green-grey or grey argillaceous, calcareous beds containing supposed volcaniclastic detritus described as 'marl' are also present and may have formed on extensive semi-arid plains. The 'marl' can rest directly on the mud-cracked top of an oil shale. The environment of deposition was of fluvio-lacustrine deltas, subject to periodic inundation by incursions of marine water, with large freshwater lagoons rich in algae and other organic matter in which accumulated oil-shales. Sections in most parts of the formation can be seen on the coast from South Queensferry to Blackness. The formation is laterally equivalent to part of the Bathgate Hills Volcanic Formation in the west and north. The top is drawn at the base of the Hurlet Limestone. The maximum thickness of the formation is in excess of 1120 m in West Lothian. The formation is divided into a lower Calders Member and an upper Hopetoun Member.

The lower part of Calders Member comprises a succession of mudstones, siltstones and sandstones with thin beds of argillaceous limestone and dolostone, and oil-shale. The member is on average about 290 m thick. The Redhall Marine Band defines the base of the member within the district. The overlying sequence of strata, which is about 50 m thick, includes the Dalmahoy Oil-Shale. Strata in the upper part of the member include the Pumpherston Shell Bed, a fossiliferous mudstone with a marine fauna and the overlying Pumpherston Oil-Shale that is a well-known mined horizon within the Calders Member in the Livingston district.

The Hopetoun Member is on average about 830 m thick in the Lothians. It consists of a sequence of mudstones, siltstones, sandstones and calcareous mudstones ('marl') with thin beds of oil-shale, coal, limestone and dolostone. The lower boundary of the Hopetoun Member is defined at the base of the Burdiehouse Limestone. The limestone is a lacustrine deposit, 6−9 m thick, containing abundant fossilized ostracod, plant and fish remains and the roof mudstones contain Lingula and a poor marine fauna. In the Harburn mines [NT 041 584] it was recorded as a cream or grey limestone, with conchoidal fracture. The overlying Camps Oil-shale is well recognised in the Livingston area. The Under Dunnet Oil-shale is a little higher in a generally argillaceous succession and the marine band in its roof is the Dunnet Shell-Bed. The main part of the Dunnet, Champfleurie, Broxburn, Fells, Grey, Mungle, Raeburn and Fraser Oil- shales historically have been mined. The marine mudstones of the Raeburn and Fraser Shell-Beds have been recognised in West Lothian with the Basket Marine Band and Under Limestone developed near the top of the Hopetoun Member. Interbedded with the argillaceous succession are thin dolostone beds such as the Barracks and Fells Limestone, and bedded to massive pale greenish-grey limestones or calcareous mudstones (marl) such as the Broxburn and Houston Marls. Mined coal seams include the Houston Coal that in places is in two leaves and of inferior quality and ranges in thickness from 0.6 to 2.0m; the Two Foot Coal from 0.4 to 0.6m and of inferior quality; the Hurlet Coal up to 2.4 m in leaves, pyritous and of low quality. Above the Hurlet Coal, the base of the Hurlet Limestone which defines the top of the Hopetoun Member, is correlated across the Midland Valley of Scotland.

The East Kirkton Limestone represents a world famous, development of non-marine limestone belonging to the Hopetoun Member intercalated within the Bathgate Hills Volcanic Formation. It lies below the Hurlet Limestone but its stratigraphical relationship to the Under Limestone is not known. The East Kirkton Limestone is only exposed at a disused quarry [NS 990 690] at East Kirkton. At this locality it dips 20 to 45 degrees to WSW. The limestone and mudstone sequence is between 9 and 19m thick, comprising mainly laminated limestone with some nodular, spherulitic and massive limestone beds and lenses interbedded with black mudstones, thin ironstones and reworked tuffs. The limestone contains siliceous laminae and lenses of chert which may be the result of contemporaneous hot spring waters. Locally within the limestone beds there are stromatolites (algae), clusters of gypsum crystals and thin lenses of coal. Within the black mudstone and laminated limestone beds, there is a sparse but diverse terrestrial early fauna and flora which has been extensively collected (1985-1992) and studied by a team from the National Museums of Scotland. The bulk of the fossils consist of plants (gymnosperms and pteridosperms) and dominantly land-living animals, including the oldest known terrestrial tetrapods (amphibians and reptilomorphs), terrestrial/aquatic eurypterids, scorpions, millipedes, a mite and a harvestman. The arthropods included *Hibbertopterus scouleri* and sparse articulated vertebrate skeletons of the genera *Acanthodes, Balanerpeton, Cosmoptychius, Elonichthys, Eurynotus, Rhadinichthys, Silvanerpeton* and *Tristychius*. Terrestrial taxa include a species of the genus *Ophiderpeton*. The fauna also includes the ‘famous’ very early stem-group amniote *Westlothiana lizziae*. Charred wood fragments occur within this sequence and suggest that the surrounding forest was subject to forest fires which may have driven the land animals to their deaths in the lake. The overlying mudstone and reworked tuff contain, besides ostracods and bivalves, a relatively diverse fish fauna which is more typical of the formation and it is inferred that the water body had become connected to the larger Lake Cadell. This suggests that the East Kirkton Limestone was the result of temporary lacustrine conditions with an exceptional chemistry allowing preservation of a terrestrial fauna but lacking the normal aquatic fauna.

BATHGATE GROUP

The Bathgate Group is a persistent group of volcanic rocks which interdigitate with the sedimentary rocks of the upper part of the Strathclyde Group and the larger part of the Clackmannan Group. In the West Lothian the group comprises the Bathgate Hills Volcanic Formation.

Bathgate Hills Volcanic Formation

The Bathgate Hills Volcanic Formation occurs in the north-western part of the district and is up to 600 m thick and is intercalated with and replaces sedimentary formations. The basal beds of the formation are tuffs which lie at a widespread horizon just above the Two Foot Coal in the Hopetoun Member. Towards the top of the volcanic pile, olivine-basalt lava becomes predominant, occurring in layers or flows with vesicular or rubbly tops. The central parts of lava flows are commonly hard, compact and very fresh, hence well exposed at outcrop. The top and base of flows are typically amygdaloidal and/or scoriaceous with much hydrothermal alteration and are consequently less well exposed, giving rise to a conspicuous ridged topography (trap featuring) in places which reflects the alternating hard and 'soft' parts of the flows. Kaolinised or reddened tops to flows seen in boreholes, particularly in the central part of the Bathgate Hills indicate subaerial erosion. However, thin impersistent intercalations of sandstone, mudstone, seatclay and coal are common, indicating that, for much of the time, the lavas did not accumulate to any great height above sea level. Coals and seatclays with rootlets are commonly developed directly on top of lava flows and fragments of fossil wood have been found incorporated in the base of flows, including some 'trunks' in apparent position of growth recorded at Grangepans by

Cadell in ‘The Story of the Forth’ in 1925. In the northern part of the outcrop, between Linlithgow and Bo'ness, there is evidence to suggest that magma was erupted on to, or even intruded into, wet unconsolidated sediments. Lavas are commonly brecciated and amygdaloidal with much hydrothermal alteration and calcite veining. Irregular blocks of lava and rounded pillow-like masses are wrapped in a matrix of disturbed sediment, and sediment infills cavities or occurs as clasts within the lavas. Petrographically the lavas are remarkably uniform. All are microporphyritic with phenocrysts of olivine and variable amounts of clinopyroxene up to 2mm in diameter. Microphenocrysts of plagioclase feldspar are extremely rare. Large areas of basalt are exposed in a belt running through the Riccarton Hills but this belt dies out to the north. A more widespread belt of basaltic rocks lies to the west and is exposed on the hills to the north and south of Linlithgow. The basalts and tuffs are thought to have erupted from local volcanic vents, such as those now exposed to the south-east of the extrusive rocks at Tar Hill and The Binns. These vents are now filled with volcaniclastic rocks (agglomerate).

The basal pyroclastic deposits of the Bathgate Hills Volcanic Formation extend upwards, generally to the level of the Hurlet (West Kirkton) Limestone, and locally to the Petershill Limestone (=Mid and Main Hosie limestones). Excavations have revealed a 4m-thick section of these deposits above the East Kirkton Limestone in East Kirkton Quarry, which has been formally named the Geikie Tuff . The pyroclastic rocks are usually green, grey green or purple brown with broad colour banding. Bedding is generally poor, although sporadic graded bedding and load casts suggest subaqueous deposition. Clasts are poorly sorted and are usually subangular to subrounded, although beds of ellipsoidal lapilli are common. Texture is variable and grain size varies widely from fine ash tuffs to pyroclastic breccias with clasts up to 8cm long. The clasts are almost entirely of fine-grained basalts, commonly amygdaloidal, or of reworked tuffs. Layers and lenses of chert and abundant spherulites of carbonate, which are a feature of the East Kirkton Limestone, have been interpreted as evidence of hot-spring activity associated with the volcanicity, but others have argued that the carbonate features are lake-floor precipitates formed within a volcanic setting, but without hot-spring activity.

The overall regional setting of the Bathgate Hills volcanicity has been described and a detailed account given of the interaction between eruption, erosion, clastic deposition and carbonate precipitation in Lower Limestone Formation time. Jameson (1987) envisaged the volcanic rocks accumulating above sea level to form islands surrounded by coastal plains, restricted lagoons and a variety of carbonate reef facies, which accumulated during longer periods of volcanic quiescence. This succession was terminated by subaerial exposure and erosion followed by renewed volcanic activity. The model accounts for the difficulties encountered in trying to correlate the various limestones within and adjacent to the volcanic succession, since many of them were probably only local developments on the fringes of ephemeral land areas. Most of the earlier volcanic deposits accumulated at or close to sea level, probably on vegetated coastal plains, in coal-forming swampy conditions or in shallow restricted lagoons. This is well demonstrated by borehole sections through the basal, predominantly pyroclastic rocks which have numerous horizons of seatclay with rootlets and fossil wood, coaly strata, and other clastic sediments with shallow water sedimentological features.

Carbonaceous shales and argillaceous carbonates in the Silvermine area, which are interpreted as lagoonal, contain syn-sedimentary Pb-Zn mineralisation. This, and the siliceous 'sinter' deposits in the freshwater East Kirkton Limestone are possible indicators of hydrothermal activity associated with the vulcanicity. Later, as the coastal lagoons became infilled by sedimentation and pyroclastic activity, or were overwhelmed by lava flows, the volcanicity became predominantly subaerial in the centre of the Bathgate Hills. Here, lava flows commonly have kaolinised or reddened tops and intercalations of sedimentary rocks are few. Elsewhere, however, in more distal areas such as Bo'ness and Bathgate which remained close to sea level, coal-bearing strata continued to accumulate in considerable thicknesses between eruptions and there is good evidence for interaction between lava flows and wet, unconsolidated sediment.

Eventually, as volcanic activity waned, a marine transgression spread over the whole area and, by the end of Upper Limestone Formation time, limestones such as the Calmy and Castlecary were deposited without interruption across the site of former volcanic islands.

CLACKMANNAN GROUP

The Clackmannan Group includes the Lower Limestone, Limestone Coal, Upper Limestone and Passage formations. These units are characterised by strongly cyclical sequences of sandstone, siltstone, mudstone, limestone, coal and seatearth, the presence (or absence especially of limestone) and proportions differing in each of the formations. Thus, beds of limestone are more conspicuous in the Lower and Upper Limestone formations than elsewhere, coals are most common in the Limestone Coal Formation, and sandstones and seatearths are the most prominent constituents of the Passage Formation. Depositional environments, likewise, show an underlying similarity, being related to the repeated advance and retreat of fluviodeltaic systems into an embayment of varying salinity. Scotland during the Namurian and succeeding Westphalian was located more or less on the Equator. Its climate was essentially tropical with extensive swampy forests (mires and 'mangrove' swamps) rapidly producing large trees that subsequently died to produce great thicknesses of peat that with time and deep burial became transformed into coal. The Lower and Upper Limestone formations contain the highest proportion of marine deposits, while alluvial deposits dominate the Passage Formation; the Limestone Coal Formation occupies an intermediate position. The base of the Clackmannan Group is taken at the base of the Lower Limestone Formation, where a cyclical sequence of marine limestone-bearing strata rests conformably on the West Lothian Oil-shale Formation of the Strathclyde Group. This group is mostly Namurian in age (but ranges from late Viséan Series to early Langsettian Stage of the early Westphalian Series).

Lower Limestone Formation

The Lower Limestone Formation comprises repeated upward-coarsening cycles of limestone, mudstone, siltstone and sandstone. Thin beds of seatrock and coal may cap the cycles. The limestone beds are fossiliferous and pale to dark grey in colour, most were deposited in a tropical marine environment. The mudstone (which may also contain marine fossils) and siltstone are predominantly grey to black. A few non-marine faunal beds are also known. Nodular clayband ironstone and limestone are well developed in the mudstone sequences. The sandstone is usually fine- to medium-grained and generally off-white to grey in colour. Except locally, coal seams are thin (<0.3 m) and few in number in the Lower Limestone Formation. Other minor lithologies in the formation include cannel coal and blackband ironstone (interleaved mud ironstone and coal). Conspicuous beds of limestone are a distinctive characteristic of the Lower Limestone Formation. The Hurlet Limestone defining the base of the formation, the Inchinnan Limestone, the Blackhall Limestone, the Main, Mid and Second Hosie limestones and, defining the top of the formation, the Top Hosie Limestone. The Hosie Limestones are well seen in the Skolie Burn in the SSSI section between [NS 9885 6249] and [NS 9871 6242]. The rocks of the Lower Limestone Formation are the youngest Visean strata in West Lothian. They have been assigned to the Brigantian Stage. The thickness of the formation is not well constrained but in the range of 100 to 200 m.

The formation is predominantly of lower coastal plain, shallow-water marine origin as is shown by the presence of marine fossils in the limestones and many of the mudstones. Upper coastal plain lakes are represented by the few nonmarine faunal bands known. However, largely marine deltaic environments are represented by the upward-coarsening cycles and delta distributary and fluvial ones by the upward-fining cycles. The marine deltas were probably of lobate form, based on the limited occurrence of lake deposits and of seatrocks and coal seams.

In the Bathgate Hills the formation is interbedded with and replaced by basaltic tuffs and lava flows of the the Bathgate Hills Volcanic Formation and the key limestone horizons are more difficult to identify, may be undeveloped or be fused together.

The Hurlet Limestone has been recognised in the Mid Tartraven No.4 Borehole [NT 0062 7254] about 46m below the Blackhall (Tartraven) Limestone which crops out at Mid Tartraven. The Hurlet Limestone in this borehole is 6.66m thick, buff to grey, and massive with some crinoid and shell debris. At West Kirkton [NS 988 690], a temporary exposure at the water board site showed the Hurlet (West Kirkton) Limestone resting abruptly on volcanic breccias and overlain by calcareous and tuffaceous sandstones. At the base of this carbonate succession is a fine-grained grey impure limestone followed by dark grey silty mudstones and thin limestones with crinoid ossicles and brachiopods. The succeeding granular to fine-grained tuffaceous sandstone, 2m thick, is overlain by 5m of bedded bioclastic limestone with minor cherty patches.

At the now infilled West Kirkton Quarry [NS 9882 6879], also in the Bathgate Hills, the limestone contains a fauna of corals, brachiopods and crinoid fragments. The argillaceous marine strata stratigraphically above the limestone were particularly fossiliferous, with a diverse fauna of colonial corals, bryozoa, a greater variety of brachiopods, gastropods, and nuculoid and pectinoid bivalves. The Craigenhill Limestone horizon has not been positively identified in the Bathgate area, although there is a bed of limestone developed locally between lava flows, 25m above the Hurlet Limestone at West Kirkton [NS 9880 6905]. The Blackhall (Tartraven) Limestone has been identified in several sections where it is overlain by the richly fossiliferous Neilson Shell Bed. In boreholes near Mid Tartraven, the limestone sequence is between 7.9 and 12m thick and overlies a thin coal. The bulk of the limestone is bioclastic with abundant crinoid and some coral and bryozoan debris. However, the base of the limestone is darker, laminated and includes fissile calcareous mudstone which generally lacks fossils. This change in lithology could represent an upward change from lagoonal or estuarine conditions below to shallow-marine conditions.

The Neilson Shell Bed normally occurs in mudstones intercalated with and towards the top of the limestone or stratigraphically above it. The characteristic fauna of the Neilson Shell Bed, seen well, for example, at Breich Water [NS 9886 6276], is dominated by brachiopods including Crurithyris urii, gastropods including the discoidal form Straparollus (Euomphalus) carbonarius, common nuculoid bivalves, and orthocone and coiled cephalopods including goniatites. Within the southern Bathgate Hills, the Petershill (Hillhouse) Limestone is believed to be equivalent to the Main and Mid Hosie limestones. It is the thickest limestone in the succession and it is exposed in several disused quarries, e.g. [NS 984 695]. The limestone developed during an interval between outpourings of Bathgate Hills lavas. The succession has been described in terms of a lower, carbonate Reservoir Member and an upper, clastic Silvermine Member. The carbonate member at Petershill has been interpreted in terms of a transgressive-regressive sequence with two periods of subaerial exposure marked by erosion surfaces. The transgression is marked by the carbonaceous shales containing Lingula towards the base of the member. The depositional environment, as identified, ranges from a shoreward lagoon to the north, passing southwards into a near-shore turbulent zone and a reef-like build-up and thence into an offshore shallow shelf.

The exceptional development of limestone at Petershill is probably related to a volcanic rise on which limestone could accumulate without being swamped by clastic sediment. The Petershill Limestone must also have been deposited in a period relatively free from volcanic eruptions and in a moderately humid tropical environment. The marine bioclastic limestone exposed at Wairdlaw [NS 994 731] appears to be isolated within the Bathgate Hills Volcanic Formation. It also appears to lie at a higher stratigraphical horizon than the Petershill Limestone, although its faunal assemblage is similar to that at Petershill. It is possible, therefore, to correlate the Wairdlaw Limestone with the Second or Top Hosie limestones or more likely a combination of both since the volcanic rise continued to develop into Limestone Coal Formation times. At

Wairdlaw, the limestones with coral colonies and interbedded mudstones are 4 m thick, overlain by mudstones containing *Calamites* (horsetails), *Productus* and scales of *Palaeoniscus*. The input of mud containing *Calamites* suggests the influence of nearby vegetated land.

Limestone Coal Formation

The Limestone Coal Formation comprises sandstone, siltstone and mudstone in repeated cycles. The majority coarsen upwards, but others fine upwards. The cycles are usually capped by seatearth and coal (3-10% of the total succession). The siltstone and mudstone are usually grey to black, while the sandstone is usually fine- to medium-grained and off-white to grey. Coal seams are common and many exceed 0.3 m in thickness. Minor lithologies include cannel, and blackband and clayband ironstone, the latter nodular as well as bedded. Beds containing large numbers of shells (coquinas) of *Lingula* or of the non-marine bivalves *Naiadites* and *Curvirimula* occur in the fine-grained rocks, including the ironstones and cannel. Because of the form of preservation, these shells usually do not form conspicuous musselbands like those of the younger strata of the Lower Coal Measures. Marine shells are present in some fine-grained strata but marine limestones are not a feature. Upward-fining parts of the succession, dominated by fine- to locally coarse-grained sandstone, are widely developed. The Johnstone Shell Bed and Black Metals Marine Bands can be correlated throughout the Midland Valley, but the coal seams are not so easily correlated and retain their local names. The Johnstone Shell Bed, a marine band towards the base of the formation includes one to two discontinuous beds of thin limestone (the Slingstane).

The Limestone Coal Formation is the oldest of the three subdivisions of the Clackmannan Group and it includes the strata stratigraphically above the Top Hosie Limestone at the top of the Lower Limestone Formation up to the base of the Index Limestone which is the lower boundary of the Upper Limestone Formation. The strata fall within the lower part of the Pendleian Stage (E1a) of the Namurian Series. The formation is over 100m thick. The upper part of the Limestone Coal Formation includes most of the coals which have been of economic importance thickness. The Wilsontown Main (=Bathgate Main), Bathgate Jewel, Woodmuir Smithy, China and Balbardie Gas coals were the most widely worked seams in the Bathgate area. From above the Petershill Limestone and its associated clastic sedimentary rocks, lavas (with some tuffs) occur throughout the Limestone Coal Formation. In the south, around Bathgate, lava flows probably occupy 50 per cent or less of the formation but they increase in thickness and number northwards, so that north of Cairnpapple Hill they replace all but the highest beds, which contain worked coals. Still farther north, virtually the whole of this part of the succession, up to just below the Index Limestone, consists of lavas and minor pyroclastic rocks. To the north of the M9 motorway, sedimentary intercalations between the lavas become thicker and more numerous, and pyroclastic rocks become more common in the Bo'ness Coalfield. The formation is of fluvial, deltaic, coastal to marine origins with the coal seams representing extensive tropical, afforested mires and swamps.

Upper Limestone Formation

The Upper Limestone Formation is characterised by repeated upward-coarsening cycles comprising grey limestone overlain by grey to black mudstones and calcareous mudstones, siltstones and paler sandstones capped by seatrocks and coal. The limestones contain marine faunas and are usually argillaceous. The sandstones are generally off-white and fine- to medium-grained. The coals are usually less than 0.6 m thick. Minor lithologies present include ironstone and cannel. Upward-fining sequences of coarse- to fine-grained sandstones passing up into finer-grained rocks are also present. The base of the formation is taken at the base of the Index Limestone. The top is drawn at the top of the Castlecary Limestone where not eroded penecontemporaneously by incising river channels. The main limestones are the Index, Orchard, Calmy and Castlecary limestones. The rocks of the Upper Limestone Formation form the middle of the three Clackmannan Group units within the Namurian Series. They are assigned to the late Pendleian (E1) and Arnsbergian (E2) stages. The Castlecary Limestone at the top of the Formation lies just below the top of the Arnsbergian Stage. The formation is predominantly of shallow-water marine shelf and deltaic origin but also in part of lacustrine origin. The presence of paleosols, including coals, shows that subaerial delta top and lower alluvial plain environments existed. However, the heavily bioturbated striped beds (usually thinly interbedded siltstone and sandstone) indicate that delta lobe abandonment was a common event with subsequent marine reworking of the delta top. The existence of alluvial plain environments is also confirmed by the presence of the upward-fining channel sandstone bodies. These are particularly well developed where associated with significant intraformational unconformities, such as that which cuts out the Castlecary Limestone. Limestone and hard calcareous mudstone represent only 1% - 3% of the total lithology in this formation reflecting higher siliciclastic input and perhaps less stable shelf depositional setting. Coal seams account for no more than 3% of the succession and sandstones about 50%.

Above the Index Limestone a persistent development of lavas, up to 40m thick, is present between Kipps Hill [NS 986 738] and Bathgate. It has also been traced westwards in boreholes and mine workings as far as Barbauchlaw [NS 927 681] and Polkemmet [NS 934 640]. In boreholes and mines between Hilderston Farm [NS 968 711] and Mosside Farm [NS 975 670], the development of lavas is present between the Index and Orchard limestones, but east of Gormyre [NS 974 729] it may extend upwards almost to the Calmy Limestone. Some of the flows on Kipps Hill are very fresh glassy basanites with well-developed columnar jointing. To the north, between Bowden Hill [NS 976 745] and Cockleroy [NS 989 743], the continuation of these lavas is ‘confused’ by sills of quartz-dolerite and WNW-trending faults and their outcrop appears to merge with lavas below the Index Limestone. Thin beds of tuff have been recorded both below and above the Orchard Limestone near Kinneil Mills [NS 977 783] on the River Almond; and a thick bed of green tuff, directly beneath the Calmy Limestone is well exposed in a wooded glen [NS 979 734] south of Lochcote Reservoir. Volcanic rocks also occur from above the Calmy Limestone to the base of the Castlecary Limestone in a borehole at Easter Jaw [NS 8718 7452]. The youngest recorded volcanic activity in the district occurs above the Castlecary Limestone in the base of the Passage Formation. On the south side of Bowden Hill [NS 979 744] a trench exposed 2.6m of tuffs some 5m above the top of the Castlecary Limestone and tuffs are recorded at this level in a borehole at Melonsplace [NS 9506 7425].

Passage Formation

The Passage Formation is characterised by an alternation of fine- to coarse-grained sandstones (with some conglomerates) and structureless clayrocks (including some high-alumina seatclay and fireclay). The clayrocks are commonly mottled reddish brown and greenish grey. Upward-fining cycles or non-cyclic sediments predominate over upward-coarsening cycles. Bedded grey and black siltstones and mudstones are also present, and beds of limestone, ironstone, cannel and coal. Marine bands, represented mainly by mudstone but also inconstant limestones and ironstones are to be found in the lower half of the unit. Marine faunas become progressively impoverished upwards. The formation is over 100m thick around Levenseat thickening to more gradually northwards. The strata range in age from the upper part of the Arnsbergian Stage of the Namurian into the Langsettian Stage of the Westphalian. The post-Arnsbergian stages are thin and incomplete and faunal or microfaunal evidence for the presence of the Chokierian and Alportian stages is lacking. The top of the formation is placed at the base of the Lowstone Marine Band. Where the marine band does not occur the base of the Lowstone (Armadale Stinking) Coal is used. Coal seams form 0% - 4% of the succession and sandstones average about 55%. A period of uplift, erosion and regression in the early part of the Passage Formation brought about a change from the deltaic conditions with major marine incursions, which prevailed during the Upper Limestone Formation, to predominantly meandering fluviatile deposition with an influx of coarse detritus from the north. The relatively thick beds of limestone and marine mudstone that are characteristic of the underlying formation are much thinner in the lower part of the Passage Formation and are vestigial in the upper part. At the top of the formation fluvial sedimentation is replaced by the fluviodeltaic conditions of the overlying Coal Measures.

The sandstones of the Passage Formation are white, pale grey or yellow in colour and tend to occur mainly in beds which are coarse grained at the base and become finer grained upwards.

The upward-fining sandstones may occur singly or as a series with the base of each resting on a scoured surface cut into the underlying beds. The coarser sandstone in the lower part of each unit may contain scattered small pebbles or angular clasts of siltstone or mudstone. Locally, fossilised drifted tree trunks occur in the basal parts of the thicker sandstone beds. The finer beds may be ripple laminated and include partings of siltstone and mudstone. The single upward-fining sandstones are commonly less than 5m thick. Thicker sandstones, formed from a series of upward-fining sandstone units, may be up to 24m thick. The thinner sandstones are considered to be simple channel fills and the thicker sandstones may represent the deposits of meander belts.

The petrography and provenance of the Passage Formation sandstones has been studied. These sandstones were derived from a low-grade metamorphic source intruded by acid igneous masses comparable to the Upper Dalradian rocks of the Highlands. A sandstone in the lower part of the formation at Leven Seat [NS 943 580] has been worked for many years as a silica sand and used for moulding sand and several other non-industrial uses. The sandstones pass up by gradation into siltstone and mudstone. The argillaceous strata range in colour from dark grey or pale grey to mottled lilac, reddish brown and yellow. Some mudstones are bedded, particularly the marine mudstones, but in many cases both the siltstone and mudstone show little sign of bedding. The original stratification is believed to have been obliterated by root systems and soil-forming processes. Rootlets can be seen in the darker beds but partial oxidation as a result of the lowering of the water table has removed carbon from the variegated, pale coloured rocks making rootlets less obvious. The rocks are thought to be the overbank deposits of a large river system. The kaolinite clay of which the muds are composed may have been a product of tropical weathering. The mudstones were economically the most important of the rock types in the Passage Formation. They include seams with the properties of fireclay which have been worked in several places, although the industry is dormant at the present time. A thin bed of tuffaceous siltstone close above the Castlecary Limestone has been recorded north-west of Torphichen [NS 967 723]. This is believed to be the highest stratigraphical level at which the Bathgate Hills Volcanic Formation occurs.

No.2 Marine Band tends to be the most persistent of the marine horizons in the Passage Formation, although it also is liable to have been eroded and replaced by sandstone. It most often consists of a marine shale with a thin limestone up to 1m thick. The limestone is known as the Roman Cement Limestone and, in places, it is characterised by the presence of abundant ribbed brachiopod shells (orthotetids). There is also a fossiliferous clayband ironstone, known as the Curdly Ironstone, close above the No.2 Marine Band, which was formerly worked in the Levenseat area.

The interval between No.2 Marine Band and the Netherwood Coal contains fireclays that have been worked at various localities and are collectively known as the Glenboig Lower Fireclays. They are overlain by the Levenseat Sandstone. Coals are present higher in the formation but for the most part are very thin and impersistent. The Bowhousebog Coal is the most persistent up to 1m thick locally, but it tends to be sulphurous and of poor quality. It has only been worked in a small way, usually with fireclay. The Glen Coal occurs near the top of the formation. It has been worked around Armadale and its lateral equivalent, the Crofthead Slatyband Ironstone was worked extensively during the last century around Fauldhouse. The Bonnybridge Upper Fireclays occur around the position of the Bowhousebog Coal and have been worked around Whitburn.

COAL MEASURES GROUP (SCOTLAND)

The Coal Measures Group (Scotland) is sub-divided into three formations; Upper, Middle and Lower. Only the Lower Coal Measures and, to a minor extent, the Middle Coal Measures are represented in West Lothian. The Group comprises sandstones, siltstones and mudstones with coal and seatearth. The strata are generally grey in colour. The Coal Measures were deposited in a warm and humid climate and palaeomagnetic evidence indicates that, at that time, the area lay in equatorial latitudes. The strata are believed to have been deposited in delta-plain and alluvial-plain environments with drainage generally from a large continental area to the north. The sediments accumulated under conditions of continuous but non-uniform subsidence modified by eustatic (ice age driven) changes in sea level. Periodic brief incursions by the sea left important marine horizons which are the basis of the subdivision of the succession. A wide range of alluvial and lacustrine environments of deposition is represented. These include tropical wetland forested mires and soils (coal and seatearth), floodplain (planty or rooted siltstone and mudstone), river and delta distributary channel (thick sandstones), prograding deltas (upward-coarsening sequences) and shallow lakes (mudstones with non-marine faunas). Marine bands are rare but provide important stratigraphical markers.

Lower and Middle Coal Measures

The Lower and Middle Coal Measures comprise sandstone, siltstone and mudstone in repeated cycles commonly 8-12 m thick which most commonly coarsen upwards, but also fine upwards, with seatearth and coal at the top. The mudstone and siltstone are usually grey to black, while the sandstone is fine- to medium-grained and off-white to grey in colour. Coal seams are common and many exceed 0.3 m in thickness amounting cumulatively to 5% – 8% of the total succession. Minor lithologies include cannel and blackband and clayband ironstone, the latter nodular as well as bedded. Bands composed mainly of non-marine bivalves, the characteristic 'musselbands', usually occur in mudstone or ironstone with two, the Auldshiels and the Kiltongue persistent enough to be named. Upward-fining parts of the succession, dominated by fine- to coarse-grained sandstone, are widely developed and thick multistorey sandstones are a feature. Cumulatively these amount to about 53% of the unit. There are more than 11 seams that have been mined in the Lower Coal Measures. The main seams formerly mined are the Colinburn, Armadale Main, Armadale Ball, Mill, Shotts Gas, Lower Drumgray, Mid Drumgray, Upper Drumgray, Kiltongue, Ladygrange and Airdrie Virtuewell coals. Middle Coal Measures are restricted to a small area west of Fauldhouse where the Airdrie Blackband Coal may have been mined. These seams are still being exploited today in opencast sites. The Lower Coal Measures are over 150 m thick.

INTRUSIVE IGNEOUS ROCKS

Various intrusive and extrusive igneous rocks are exposed in West Lothian, including teschenitic dolerite, quartz dolerite, olivine basalt, trachybasalt and minor trachyte.

Alkali-dolerite sills

Sills of alkali-dolerite generally occur in the eastern part of the district. They intrude the Lower Carboniferous sedimentary succession of the Strathclyde Group stratigraphically mainly below the Bathgate Group volcanic rocks of the Bathgate Hills. These dolerites are generally medium to fine-grained and of olivine-basalt composition. They are similar petrographically and compositionally to the lavas of the Bathgate Hills and could be coeval with them. However, a sill of this type also crops out to the south of the volcanic rocks, over a distance of 8km from Blackburn southwards to Rusha Farm [NS 992 609], and at Pate's Hill [NS 990 595] where the outcrop is displaced towards the west by faulting. This sill is emplaced higher in the sedimentary succession within and near the base of the Clackmannan Group (Lower Limestone Formation) at about a constant stratigraphical level, just below the Top Hosie Limestone. The sill is composite, with an upper layer of analcime-dolerite (teschenite) overlying a basal picrite. The junction between the layers is sharp, but with no chill on either side, and is sinuous in places. The main distinction between the layers is in the relative proportions of olivine and plagioclase, both rock types having abundant analcime and little hornblende or biotite. The analcime-dolerite was formerly quarried for roadstone and the picrite (or 'leckstone') was used for the soles of baker's ovens on account of its unusually low thermal conductivity. Several quarries in the Blackburn area are all now filled, but a quarry at Rusha Farm used to show about 6m (1992) of analcime-dolerite overlying 4.5m of dark greenish grey picrite. The analcime-dolerite is also exposed in the Breich Water, in a railway cutting [NS 989 620] at Addiewell and in Longhill Burn [NS 989 598]; at the last locality the sill underlies baked, decalcified shale. An olivine-dolerite, formerly quarried at Boghall [NS 994 683], near Bathgate, and shown as a circular outcrop on the map, is probably an intrusion of some sort. The quarry is now completely filled and has been built upon. Within the volcanic sequence, outcrops of particularly fresh rock with well-developed columnar jointing could be interpreted as contemporaneous sills within the lava pile. However, they could also comprise the more massive, central part of lava flows. The Hillhouse Sill, seen above the Petershill Limestone at Hillhouse Quarry [NT 004 747], shows transgressive junctions with these Clackmannan Group (Lower Limestone Formation) sedimentary rocks. By far the most extensive sill is in the Houston-Uphall area but there are no longer any surface exposures of this sill and any small old quarries have long since been infilled .It is best known from old borehole records that indicate it is over 70 m thick.

Quartz-dolerite sills

The quartz-dolerite sills of West Lothian form part of the south-western margin of the Midland Valley Sill Complex. The outcrop of this major sill is imperfectly annular and characteristically dips inward towards the centre of the carboniferous sedimentary basin. It has been suggested that the morphology and emplacement of the Midland Valley Sill were controlled by the shape of this pre-existing Carboniferous syn-sedimentary basin. The thickest parts of the sill occur within the centre of the basin, which had a syndepositional dip of up to 5 degrees towards its centre at the time of emplacement. No obvious feeder dykes have been identified within the thickest central part of the sill. Emplacement was at least in part controlled by down-dip gravitational flow of the magma from a series of feeder dykes located on the flanks of the sill. These dykes extend above the level of the sill. Magma first accumulated in the bottom of the basin and from there advanced up-dip under pressure of head fed by the dykes. The quartz-dolerite sill is well exposed in and around Torphichen particularly on Gormyre Hill [NS 976 727], Cow Hill [NS 970 740], Bowden Hill [NS 976 745] and in the village of Torphichen itself [NS 967 723]. The sill is quarried in a number of places and is an important source of crushed rock aggregate.

The quartz-dolerite sills occur as broadly concordant sheets up to 120m thick with locally transgressive dyke-like bodies that cut across the regional dip of the country rocks. These sills form prominent topographical features, for example at Cockleroy [NS 990 745] and Wairdlaw [NS 996 732], with typically brown coloured, spheroidal-weathering outcrops. A steeply inclined transgressive step within the Midland Valley Sill Complex extends from the eastern end of the sill outcrops east of Cockleroy southwards for 5km via the Knock [NS 991 712], to just east of East Kirkton Quarry [NS 990 690]. At Craigs [NS 995 703] a NNW-SSE-trending sill dips moderately steeply ENE and cuts across bedding within the overlying tuffaceous rocks with minor limestones of the Bathgate Hills Volcanic Formation. These rocks are disturbed and show signs of a weak thermal metamorphic overprint. A similar transgressive relationship is observed at the Knock, where a NNW-SSE-trending sill, dipping at approximately 60 degrees ENE, cuts basaltic lavas. Binny Craig RIGS is an example of a sill and NS- trending dyke step where the sill is chaning horizon within the sedimentary country rocks. Craigton Quarry shows discordant, stepped contacts of the sill roof with the country rocks of the Strathclyde Group (West Lothian Oil-shale Formation).

Quartz-dolerite dykes

The quartz-dolerite dykes generally form narrow, steeply inclined bodies which can be traced laterally for up to 10km. The dykes were intruded along the prominent set of east-west-trending faults, with in many instances emplacement occurring more or less contemporaneously with fault movement. The Lenzie-Torphichen Dyke is intruded along the Avonbridge Fault and the Midland Valley Sill is present at different stratigraphical levels on either side of the fault. Individual dykes are up to 50 m thick and are commonly offset in an en-echelon manner. Contacts with the country rocks are typically sharp. Fine-grained margins are usually present. Country-rock xenoliths are rare within the dykes. Characteristic of the quartz-dolerites throughout the district are zones of alteration to 'white trap'. These zones of hydrothermal alteration are commonly closely associated with faults and frequently show traces of mineralisation (including calcite, pyrite, baryte and occasional chalcopyrite), and are commonly accompanied by an impregnation of hydrocarbons. It has been suggested that the alteration has been produced by volatiles released during the distillation of oil shales by the heat of the intrusions. These dykes are well seen at Beecraigs Quarry (climbing wall), Parkley Fisheries and Ochiltree Mill quarries.

Appendix 4 Potential sites from desk study

Site Name	MB Score	MB No	AM No	Lithostratigraphy	Page No	SW corner	NE corner	Accuracy (m)	Easting	Northing	Notes	Reference
Auchinoon Quarry	4	156	3	dolerite, metamorphic qT	277	NT 0905 6170	NT 0920 6180	100	309125	661750		Edin Mem 1910, p277; Hardrock Aggrgate Resources, p62
Beecraigs quarry	4	140	10	columnar dyke qD		NT 0080 7390	NT 0085 7393	100	300825	673915		Loth geol, Excur Guide
Binny Craig	4	161	12	sill, step, dyke, hydrocarbon, crag and tail, scree	283	NT 0420 7330	NT 0470 7400	100	304450	673650		Edin Mem 1910, p283, 328
Binny Quarry (golf)	4	53	13	Binny Sandstone	10	NT 0565 7310	NT 0580 7340	100	305725	673250		Oil-Sh of the Lothians 3rd edit p10
Coalheugh Head, Torphin Bridge	4	22	32	Dalmahoy Shale?	34	NT 0340 6100	NT 0370 6160	100	303550	661300		Oil-Sh of the Lothians 3rd edit p34
Cockleroy	4	136	33	qD sill transgressing	91	NS 9875 7425	NS 9915 7480	100	298950	674525		Cent Coalfield Area III, p91; Edin Mem
Craigton (Hill) Quarry	4	162	40	qD sill faulted off, contacts	283	NT 0745 7675	NT 0770 7697	100	307575	676860		Edin Mem 1910, p283; Wartime Pamphlet 45, p24
Easter Inch Moss and Seafield Law	4	185	55	basin peat workings; artificial crag and tail from bing	34	NT 9910 6610	NT 0090 6690	100	300000	666500		Wartime Pamphlet 45 p34
Harwood Water Calder Rd	4	72	66	Fells Limestone	93	NT 0250 6250	NT 0265 6275	100	302575	662625		Edin Mem 1910 p93
Hilderston Silver Mine	4	131	71	limestone, minerals, qD, tuff, limestone,	122, 123	NS 9890 7150	NS 9925 7170	100	299075	671600		Area VI Cent Coalfield p122, 123; Hilderston Mine, WL:mining history
Hillhouse Quarry & Mine	4	97	72	Petershill Limestone, dolerite, Hillhouse Basalt type sec, sedis	34, 35, 89, 113	NT 0040 7485	NT 0060 7525	100	300500	675050		Cent Coalfield Area III p34, 35, 89, 113; Edin Mem 1910 p112, 113, 282; Loth geol, Excur Guide p216
Levenseat quarries	4	117	85	silica sandstones	71, 113	NS 9400 5730	NS 9455 5855	100	294275	657925		Area VI Cent Coalfield p71, 113; Falkirk Mem 1998 p30; Special Sand resources
Levenseat quarries & mines	4	112	86	Castlecary Limestone	43, 44	NS 9440 5770	NS 9485 5840	100	294625	658050		Area VI Cent Coalfield p43, 44; Edin Mem 1910 p137; The Limestones of
Levenseat quarries & mines	4	113	87	Curdly Ironstone/Roman Cement, Glenboig	69, 70	NS 9450 5910	NS 9460 5940	100	294550	659250		Area VI Cent Coalfield p69, 70; Area VI Cent Coalfield p71
Linhouse Water (Calderwood RIGS)	4	63, 172	89	Broxburn Shale & Marl, Calder Fault,	49	NT 0790 6705	NT 0800 6735	100	307950	667200		Oil-Sh of the Lothians 3rd edit p49, 50; Edin Mem 1910 p87
Linhouse Water (Calderwood RIGS)	4	173	89	Calder Fault branch 2 seen; Langton Ft	50	NT 0775 6660	NT 0780 6663	100	307775	666615		Oil-Sh of the Lothians 3rd edit p50
Linhouse Water above Carstairs Rail Viaduct	4	6	90	Cementstone Group sandy top unit; lava	41	NT 0700 6400	NT 0760 6450	100	307300	664250		Edin Neighbourhood 1962 p41
Linhouse Water, Linhouse; Corston	4	9	93	Corston Hill volcanics, waterfalls	84, 85	NT 0640 6300	NT 0650 6320	100	306450	663100	repetitions	Edin Mem 1910 p84, 85
Longford Burn	4	124	100	LSC Woodmuir Smithy Coal		NS 9825 6075	NS 9835 6090	100	298300	660825		map
Midhope Burn to Hopetoun shores	4	24	102	Pumpherston Shale, BDH, Camps, Dunnet, Broxburn	79, 80	NT 0815 7915	NT 0930 7960	100	308725	679375		Oil Shales of the Lothians 3rd edit p79, 80
Midhope Society shore	4	41	102	Dunnet Sandstone, Shale & Marl	99	NT 0965 7910	NT 1000 7920	100	309825	679150		Edin Mem 1910 p99

Page 1

Site Name	MB Score	MB No	AM No	Lithostratigraphy	Page No	SW corner	NE corner	Accuracy (m)	Easting	Northing	Notes	Reference
Petershill quarries	4	91	117	Petershill Limestone etc	195	NS 9845 6935	NS 9865 6990	100	298550	669625		The Lsts of Scot p195; Area VI Cent Coalfield p22, 23; Edin Mem 1910 p109, 111; Falkirk Mem 1998 p17, 18; Lst Res
River Almond (Almondell RIGS)	4	31	126	Burdiehouse Limestone	48	NT 0850 6825	NT 0865 6845	100	308575	668350	Camps	Oil-Sh of the Lothians 3rd edit p48; The Limestones of Scot p142, 195
Upper Uphall	4	67	138	Grey Shale sitts		NT 0530 7215	NT 0570 7235	100	305500	672250		
Wairdlaw quarry	4	99	139	Wairdlawlimestone, TOHO, SHLS	23	NS 9950 7305	NS 9960 7335	100	299550	673200		Area VI Cent Coalfield p23; Edin Mem 1910 p111; Falkirk Mem 1998 p18
Wallace's Cave	4	178	140	natural arch in sdst		NS 9455 7300	NT 9460 7310	100	294575	673050		map
Witch Craig viewpoint	4	152	151	qD, wall		NS 9870 7245	NS 9915 7300	100	298925	672725		map
Binny Quarry (burn)	3	54	13	Binny Sandstone	10	NT 0590 7310	NT 0595 7315	100	305925	673125		Oil-Sh of the Lothians 3rd edit p10
Bowden Hill mines	3	111	18	Castlecary Limestone, striae, qD sill, glacial striae	194	NS 9760 7430	NS 9795 7460	100	297775	674450		The Limestones of Scot p194; Cent Coalfield Area III p113; Cent Coalfield Area III p99
Braehead quarries	3	130	19	glacial till, LCMS sandstones 1939	119	NS 9190 6035	NS 9220 6075	100	292050	660550		Area VI Cent Coalfield p119; Wartime Pamphlet 45 p20; Building Stones of
Breich Mines and river	3	114	20	Curdly Ironstone/Lower		NS 9510 6055	NS 9540 6090	100	295250	660700		map
Brox Burn Bangour Resvr, The Gullet	3	77	26	Ashes, lavas BHV and WLO	101	NT 0135 7125	NT 0200 7160	100	301675	671425		Edin Mem 1909 p101
Carribber mine, Muiravonside	3	109	29	Calmy Limestone	113	NS 9685 7515	NS 9695 7520	100	296900	675175		Cent Coalfield Area III p113; The Limestones of Scot p194; Edin Mem
Carsie Hill	3	142	30	vents in the landscape, HHL	93	NT 0140 7540	NT 0180 7555	100	301600	675475		Cent Coalfield Area III p93
Clifton Hall, R Almond, canal	3	155	31	qD sill/dyke, Pumpherston Shale	87	NT 1040 7040	NT 1070 7100	100	310550	670700		Edin Mem 1910 p87
Cockleroy	3	190		landslip, head		NS 9870 7435	NS 9885 7470	100	298775	674525		map
Craigton quarry & rail cutting	3	59	41	Binny Sandstone	72	NT 0670 7665	NT 0690 7675	100	306800	676700		Oil-Sh of the Lothians 3rd edit p72
East Kirkton Quarry	3	82	54	EKL	109	NS 9895 6892	NS 9944 6926	10	299250	669080		Edin Mem 1910 p109; Falkirk Mem 1998 p10-13; Loth geol, Excur Guide p209;
Gormyre burn	3	110	62	Calmy Limestone, tuff		NS 9780 7315	NS 9790 7350	100	297850	673325		map
Harwood Water bed	3	68	66	Broxburn Marl, Fells Shale	27	NT 0250 6250	NT 0265 6275	100	302575	662625		Oil-Sh of the Lothians 3rd edit p27; Edin Mem 1910 p93; Oil-Sh of the Lothians
Harwood Water Limefield House	3	36	66	Camps Shale	30	NT 0330 6420	NT 0335 6430	100	303325	664250		Oil-Sh of the Lothians 3rd edit p30
Harwood Water Murray's Pool Bridge	3	62	66	Broxburn Shale waste	27	NT 0250 6250	NT 0285 6315	100	302675	662825		Oil-Sh of the Lothians 3rd edit p27
Harwood Water north of Hermand	3	48	66	Dunnet Shale	30	NT 0275 6360	NT 0285 6370	100	302800	663650		Oil-Sh of the Lothians 3rd edit p30
Harwood Water north of Hermand	3		66	Dunnet Shale, also dunnet marl	92	NT 0275 6360	NT 0285 6370	100	302800	663650		Edin Mem 1910 p92

Page 2

Site Name	MB Score	MB No	AM No	Lithostratigraphy	Page No	SW corner	NE corner	Accuracy (m)	Easting	Northing	Notes	Reference
Harwood Water S of Langside	3	45, 177	66	Langside-Blackburn Fault, 'under' Dunnet, Langside Fault	37	NT 0295 6500	NT 0325 6550	100	303100	665250	Barracks Ash	Oil-Sh of the Lothians 3rd edit p37
Harwood Water, Limefield	3	30	66	Burdiehouse Limestone &	92	NT 0330 6380	NT 0350 6445	100	303400	664125		Edin Mem 1910 p92; Oil-Sh of the Lothians 3rd edit p30
Harwood Water, Limefield House	3	39	66	Dunnet Sandstone	30	NT 0330 6380	NT 0345 6460	100	303375	664200		Oil-Sh of the Lothians 3rd edit p30
Hermand Quarry	3	52	68	Binny Sandstone	10, 30	NT 0280 6340	NT 0295 6355	100	302875	663475		Oil-Sh of the Lothians 3rd edit p10, 30;
Hilderston Silver Mine Quarry	3	94		Petershill Limestone etc		NS 9905 7125	NS 9925 7170	100	299150	671475		
Hopetoun limestone quarries	3	33	74	Burdiehouse Limestone		NT 0820 7795	NT 0835 7840	100	308275	678175	dark, Lingula	map
Hopetoun Obelisk Quarry	3	42	75	Dunnet Sandstone	7	NT 0940 7860	NT 0950 7875	100	309450	678675		SL80/6; Sdst Res of western part Lothian Region p7; Building Stones of
Hopetoun White Quarry	3	61	76	Binny Sandstone, boulder clay	55	NT 0730 7730	NT 0740 7740	100	307350	677350		Building Stones of Edin p55; Oil-Sh of the Lothians 3rd edit p72
Kettlestoun Braehead Quarry	3	133	80	sedi breccia with qD, spotted shale, qD sill, fine, top and raft contacts WAR notebook A	92, 115	NS 9875 7590	NS 9885 7605	100	298800	675975	? Loc	Cent Coalfield Area III p92, 115; Cent Coalfield Area III p91; Edin Mem 1910 p359; Wartime Pamphlet 45 p24
Kildimmery Quarry = Nancy's Hill Quarry	3	144	81	qD dyke	93, 115	NT 0275 7595	NT 0295 7600	100	302850	675975		Cent Coalfield Area III p93, 115
Linhouse Water	3	20	89	Granton Sandstones	55	NT 0740 6600	NT 0800 6700	100	307700	666500		Edin Neighbourhood 1962 p55
Linhouse Water Carstairs Rail Viaduct	3	5	90	Cementstone Group	141, 193	NT 0750 6450	NT 0800 6490	100	307750	664700		The Limestones of Scot p141, 193
Linhouse Water, Blackraw	3	4	90	Cementstone Group	50	NT 0770 6545	NT 0780 6562	100	307750	665535		Oil-Sh of the Lothians 3rd edit p50; Edin Neighbourhood 1962 p41; Edin Mem
Linhouse Water, Camilty Mill	3	160	91	sill, qT contact at Red Craig	277	NT 0620 6165	NT 0625 6190	100	306225	661775		Edin Mem 1910 p277
Linhouse Water, Corston	3	10	92	Corston Hill volcanics (inc Markle)	51	NT 0700 6400	NT 0735 6430	100	307175	664150		Edin Neighbourhood 1962 p51
Linhouse Water, Glasgow Rail Viaduct	3	17	89	Abbeyhill Shales	85, 86	NT 0730 6560	NT 0770 6620	100	307500	665900		Edin Mem 1910 p85, 86
Linhouse Water, Glasgow Rail Viaduct	3	159	89	unclassed sill basal contact		NT 0760 6550	NT 0785 6575	100	307725	665625		map
Linhouse Water, Mid Calder	3	8	90	Corston Hill volcanics?	50	NT 0730 6605	NT 0735 6615	100	307325	666100		Oil-Sh of the Lothians 3rd edit p50
Linhouse Water, Oakbank	3	176	89	Murieston Fault (context)	87	NT 0765 6655	NT 0780 6680	100	307725	666675		Edin Mem 1910 p87
Midhope to Banks shore	3	34	102	white trap, sandstone dyke or intrusive tuff at Camps	67	NT 1000 7865	NT 1135 7910	100	310675	678875	CEC?	map; Edin Neighbourhood 1962 p67

Page3

Site Name	MB Score	MB No	AM No	Lithostratigraphy	Page No	SW corner	NE corner	Accuracy (m)	Easting	Northing	Notes	Reference
Midhope Burn	3	78		Raeburn Shale, ash, Houston Marl		NT 0560 7780	NT 0620 7815	100	305900	677975		map
Midhope to Society shore	3	35	102	Burdiehouse Limestone	98	NT 0870 7930	NT 0945 7915	100	309050	679225		Edin Mem 1910 p98
Midhope, Abercorn and Queensferry	3	32	102	Burdiehouse Limestone	195, 196	NT 0815 7915	NT 1000 7960	100	309075	679375	>	The Limestones of Scot p195, 196
Murieston Water	3	64	106	Broxburn Shale &	49	NT 0740 6690	NT 0775 6770	100	307575	667300		Oil-Sh of the Lothians 3rd edit p49
Murieston Water	3	174	106	Calder Fault branch 2 seen; Langton Ft	50	NT 0730 6657	NT 0745 6660	100	307375	666585		Oil-Sh of the Lothians 3rd edit p50
Murieston Water Skivo	3	175	107	Murieston Fault, BLLS, ASV	34	NT 0500 6360	NT 0525 6410	100	305125	663850		Oil-Sh of the Lothians 3rd edit p34
Murieston Water, Calderwood	3	11	106	Corston Hill volcanics (tuff only)	51	NT 0720 6650	NT 0735 6660	100	307275	666550		Edin Neighbourhood 1962 p51
Murieston Water,	3	7	107	Corston Hill volcanics	51	NT 0510 6350	NT 0520 6390	100	305150	663700		Edin Neighbourhood 1962 p51; Oil-Sh of
Murieston Water, Skivo	3	16	107	Abbeyhill Shales (fault seen), Abbeyhill Shales (as Cementstone Group)	34, (50)	NT 0500 6310	NT 0530 6370	100	305150	663400	(Linhouse Water)	Oil-Sh of the Lothians 3rd edit p34, (50); Edin Mem 1910 p85
Murieston Water; Torphin-Annetscross bridges	3	21	108	(GullaneFm) coarse sandstones etc	34	NT 0375 6170	NT 0500 6310	100	304375	662400		Oil-Sh of the Lothians 3rd edit p34
Ochiltree Mill quarry	3	132	114	sill cut by qD dyke	281	NT 0300 7405	NT 0325 7415	100	303125	674100		Edin Mem 1910 p281; Cent Coalfield
Priestinch Rail Cutting taken as Craigton Quarry	3			Binny Sandstone	64	NT 0670 7665	NT 0690 7675	100	306800	676700	(black)	Oil-Sh of the Lothians 3rd edit p64
Rifle Range Quarries	3	92	125	Petershill Limestone	212	NS 9835 7015	NS 9900 7095	100	298675	670550		Loth geol, Excur Guide p212
Rusha quarry	3	153	128	picrite (soles of baker's ovens)	117	NS 9945 6080	NS 9955 6095	100	299500	660875		Area VI Cent Coalfield p117; Edin Mem 1910 p280, 281, 359; Falkirk Mem 1998
Skolie Burn SSSI	3	100	132	Hosie limestones, Johnstone Shell-bed, Slingstane	106	NS 9850 6190	NS 9890 6280	100	298700	662350		Edin Mem 1910 p106; Area VI Cent Coalfield p34, 35; Falkirk Mem 1998 p16; GCR Lower Carboniferous p58, 59;
The Knock	3	137	135	qD dyke?, BHV, viewpoint, qD sill, dyke?= step up	55	NS 9900 7100	NS 9915 7120	100	299075	671100		Falkirk Mem 1998 p55; Edin Mem 1910 p284; Loth geol, Excur Guide p213, 214
West Torphin	3	23	144	Pumpherston Shale? & curious brecciated limy kingle	35	NT 0300 6040	NT 0345 6105	100	303225	660725		Oil-Sh of the Lothians 3rd edit p35
Woodmuir Burn	3	123	152	sandy marine band		NS 9703 6129		10	297030	661290		map
Airngath Hill Red Coal crop	2	104	2	Limestone CoalFm/BHV pillows	86	NT 0045 7898		10	300450	678980		Cent Coalfield Area III p86
Baad Park Burn	2	3	5	Cementstone Group,		NT 1095 6010	NT 1125 6050	100	311100	660300		map
Bangour Knowes	2	151	8	qD	117	NT 0255 7085	NT 0265 7095	100	302600	670900		Area VI Cent Coalfield p117
Binny Quarry (east)	2	56	13	Binny Sandstone	8	NT 0580 7290	NT 0595 7305	100	305875	672975		SL80/6; Sdst Res of western part
Blackburn, River	2	89	15	Main and Foul Hosie	34	NS 9865 6525	NS 9895 6535	100	298800	665300		Area VI Cent Coalfield p34, 35
Breichdykes	2	76	21	Two Foot Coal	32	NT 0020 6315	NT 0055 6325	100	300375	663200		Oil-Sh of the Lothians 3rd edit p32

Page 4

Site Name	MB Score	MB No	AM No	Lithostratigraphy	Page No	SW corner	NE corner	Accuracy (m)	Easting	Northing	Notes	Reference
Bridgend quarry	2	66	23	Broxburn Shale		NT 0440 7515	NT 0465 7530	100	304525	675225		map
Broomyknowes	2	84	25	marine shale with goniatites		NT 0190 7427		10	301900	674270		map
Cockmuir quarry by canal	2	60	34	Binny Sandstone	72	NT 0665 7656		10	306650	676560		Oil-Sh of the Lothians 3rd edit p72
Colzium East and West burns junction	2	14	35	Corston porph lavas as well; cornstone	51	NT 0855 5875	NT 0940 5890	100	308975	658825		Edin Neighbourhood 1962 p51
Colzium East and West burns junction	2	180		boulder clay	51	NT 0855 5875	NT 0870 5890	100	308625	658825		Edin Neighbourhood 1962 p51
Crosswood Burn	2	18	43	top Cementstone arenaceous, LOSG and volcs, coal	85, 86	NT 0615 5640	NT 0630 5665	100	306225	656525		Edin Mem 1910 p85, 86
Crosswood Reservoir	2	15	44	pebbly sandstone, (coal) LOSG	5	NT 0535 5760	NT 0565 5775	100	305500	657675		SL80/6; Sdst Res of western part Lothian Region p5
Dean Burn quarry	2	170	46	Seafield-Deans Ash		NT 0110 6615	NT 0120 6640	100	301150	666275		Map
Dechmont House	2	171	48	Seafield-Deans Ash and lava		NT 0260 6915	NT 0280 6935	100	302700	669250		Map
Dechmont Law, RockviewQuarry?	2	163	49	qD sill, leaves, baked mudstone	28	NT 0310 6960	NT 0345 6995	100	303275	669775		Wartime Pamphlet 45 p28
Duntarvie (Bailies Muir) freestone quarry	2	58	52	Binny Sandstone	64	NT 0895 7680	NT 0928 7690	100	309115	676850		Oil-Sh of the Lothians 3rd edit p64
Dykefoot stream	2	47	53	Under, Dunnet, Broxburn, Fells	27	NT 0225 6225	NT 0285 6315	100	302550	662700		Oil-Sh of the Lothians 3rd edit p27
Ecclesmachan burn	2	74	57	Houston Marls & Broxburn Marls	68	NT 0515 7370	NT 0570 7410	100	305425	673900	(Oatridge)	Oil-Sh of the Lothians 3rd edit p68; Cent Coalfield Area III p16
Harburn Mine landfilled	2	25	64	Burdiehouse Limestone, sitts	142, 143, 193	NT 0340 5935	NT 0370 5990	100	303550	659625		The Limestones of Scot p142, 143, 193
Harburnhead	2	27	65	Burdiehouse Limestone, sitts	9, 21	NT 0380 5850	NT 0430 5910	100	304050	658800		Oil-Sh of the Lothians 3rd edit p9, 21
Harwood Water Limefield House	2	40	66	sandstone above Camps	6	NT 0338 6388		10	303380	663880		SL80/6; Sdst Res of western part Lothian Region p6
Harwood Water, Dykefoot	2	44	66	Under, Dunnet, Broxburn, Fells	27	NT 0280 6340	NT 0295 6355	100	302875	663475		Oil-Sh of the Lothians 3rd edit p27
Hilderston Farm Sandstone Quarry infilled	2	106	70	sandstone and mined ground		NS 9795 7135	NS 9825 7175	100	298100	671550		map
Hillhouse Sdst Quarry	2	101	73	LLGS sdst	111	NT 0105 7525	NT0120 7540	100	301125	675325		Cent Coalfield Area III p111; Edin Mem
Houston House, Brox Burn	2	75	77	Houston Marls		NT 0515 7140	NT 0540 7145	100	305275	671425		map
Little Vantage Quarry	2	2	96	Cementstone Group		NT 1010 6300	NT 1030 6315	100	310200	663075		map
Longford Burn	2	103	99	Black Metals Marine		NS 9698 5945	NS 9732 5995	10	297170	659700	two locs	map
Midhope Burn	2	65	103	Broxburn Shale (&Marl)	72, 79, 80	NT 0750 7860	NT 0805 7920	100	307775	678900		Oil-Sh of the Lothians 3rd edit p72, 79, 80

Page 5

Site Name	MB Score	MB No	AM No	Lithostratigraphy	Page No	SW corner	NE corner	Accuracy (m)	Easting	Northing	Notes	Reference
Muldron Farm burn	2	118	104	fault, marine band,		NS 9225 5810	NS 9225 5835	100	292250	658225		map
North Cobbinshaw Reservoir burn	2	50	111	Dunnet Shale, pebbly sandstones		NT 0265 5950	NT 0275 5975	100	302700	659625		map
North Couston sagr pit	2	183	112	glaciofluvial sagr	81	NS 9515 7115	NS 9555 7160	100	295350	671375		Falkirk Mem 1998 p81
Parkly Craigs quarries	2	143	116	qD dyke	93	NT 0100 7590	NT 0135 7595	100	301175	675925		Cent Coalfield Area III p93
Raven Craig	2	139	122	qD contacts, limestone, tuff	285	NS 9900 7010	NS 9960 7065	100	299300	670375		Edin Mem 1910 p285; Loth geol, Excur Guide p211
Riccarton farm	2	83	123	Under limestone	17	NT 0215 7525	NT 0220 7530	100	302175	675275		Cent Coalfield Area III p17; Oil-Sh of the
Riccarton streamlet	2	79	124	(Raeburn Shale?)/ash/(TwoFoot Coal)	74	NT 0235 7450	NT 0240 7460	100	302375	674550		Oil-Sh of the Lothians 3rd edit p74
River Almond Ponds, west of Livingston	2	46	127	Under Dunnet	38	NT 0208 6619	NT 0222 6640		302200	666200	Barracks Ash & Limestone	Oil-Sh of the Lothians 3rd edit p38
Selms quarries	2	1	129	cornstone, (qD); CYD, BGN, KNW??	50	NT 0830 6600	NT 0885 6617	100	308575	666085		Oil-Sh of the Lothians 3rd edit p50; The Limestones of Scot p141, 193; Edin
Shear Burn	2	19	131	top Cementstone arenaceous, LOSG and volcs, coal	85, 86	NT 0570 5770	NT 0665 5870	100	306175	658200		Edin Mem 1910 p85, 86
Torphin Quarry landfill	2	26	136	Burdiehouse Limestone	142, 143, 193	NT 0280 5980	NT 0320 6000	100	303000	659900		The Limestones of Scot p142, 143, 193
Whitebaulks quarries & Carsie Hill	2	98	146	Petershill;Hurlet/Tartraven?	112	NT 0020 7435	NT 0045 7480	100	300325	674575		Edin Mem 1910 p112; Cent Coalfield Area III p32, 33, 113
Addiewell	1	88	1	(Hurlet Limestone & Coal)	143	NS 9920 6275	NS 9950 6240	100	299350	662575		The Limestones of Scot p143; Area VI Cent Coalfield p33
Baad's Mill	1	189	6	Chalybeate Well, HON, coal		NT 0000 5915	NT 0030 5960	100	300150	659375		map
Blackburn, Hopefield, River Almond	1	86	15	(Hurlet)	33	NS 9905 6525	NS 9910 6530	100	299075	665275		Area VI Cent Coalfield p33
Breich Water	1	72	21	Houston Coal	31	NT 0055 6325	NT 0070 6340	100	300625	663325		Oil-Sh of the Lothians 3rd edit p31
Breich Water below Breichdykes	1	73	21	Houston Marls (poor)	32	NT 0020 6315	NT 0055 6325	100	300375	663200		Oil-Sh of the Lothians 3rd edit p32
Broxburn north	1	187	27	meltwater channels		NT 0640 7250	NT 0780 7325	100	307100	672875		
Cairnpapple	1	138	28	qD step, BHV, qD sill dyke	284	NS 9840 7145	NS 9895 7190	100	298675	671675		Edin Mem 1910 p284; Hardrock Aggregate Resources p39
Corston Hill	1	12	36	porphyritic lavas	84	NT 0937 6350		10	309370	663500		Edin Mem 1910 p84
Corston Hill	1	13	37	basalts & mugearites	46	NT 0800 6380		10	308000	663800		Hardrock Aggrgate Resources p46
CrowMoss	1	186	45	hagged peat		NT 0800 5700	NT 0900 5750	100	308500	657250		map
Dedridge Quarry pond	1	37	50	Camps Shale (BDH)	47	NT 0505 6580	NT 0520 6595	100	305125	665875		Oil-Sh of the Lothians 3rd edit p47
Galabraes Quarry	1	93	59	Petershill Limestone		NS 9855 6990	NS 9870 7010	100	298625	670000		
Glenbare Quarry	1	96	60	Petershill Limestone		NS 9845 6900	NS 9855 6910	100	298500	669050		map
Glendevon quarries	1	57	61	Binny Sandstone	64	NT 0765 7505	NT 0777 7512	10	307710	675085		Oil-Sh of the Lothians 3rd edit p64
Harburn House	1	169	63	Crosswood Ash		NT 0440 6067		10	304400	660670		map
Harwood water Mossend stream (HW)	1	69	67	Broxburn Marl	29	NT 0110 6080	NT 0140 6100	100	301250	660900		Oil-Sh of the Lothians 3rd edit p29

Page 6

Site Name	MB Score	MB No	AM No	Lithostratigraphy	Page No	SW corner	NE corner	Accuracy (m)	Easting	Northing	Notes	Reference
Howden Quarry	1	158	78	qD sill in contact nearby with tD		NT 0515 6575	NT 0520 6585	100	305175	665800		map
Kettleston Avontoun Quarry	1	134	79	qD sill, 12m partly pegmatitic	70	NS 9840 7595	NS 9855 7610	100	298475	676025		Hardrock Aggregate Resources p70; Cent Coalfield Area III p115
Kipps Hill, Cathlaw	1	108	83	BHV lavas, qD dyke	30	NS 9845 7365	NS 9890 7400	100	298675	673825		Area VI Cent Coalfield p30
Langcraig Quarry	1	149	84	qD dyke, South CathlawDyke	117	NS 9755 7197	NS 9770 7205	100	297625	672010		Area VI Cent Coalfield p117
Linhouse quarry	1	147	88	qD sill	116	NS 9060 7115	NS 9075 7130	100	290675	671225		Area VI Cent Coalfield p116
Linlithgow Bridge	1	107	94	Index Limestone/lava-ash	139	NS 9855 7800	NS 9870 7810	100	298625	678050		Edin Mem 1910 p139; Cent Coalfield Area III p58
Livingston Mill	1	181	98	terrace on till	336	NT 0300 6680	NT 0350 6700	100	303250	666900		Edin Mem 1910 p336
Mid Calder area	1	188	101	meltwater channels	114, plate IV	NT 0400 6300	NT 0500 6500	100	304500	664000		Edin Neighbourhood 1962 p114, plate IV
Muldron Quarry landfill	1	119	105	sandstone PGP		NS 9145 5745	NS 9165 5780	100	291550	657625		map
Newpark & Murieston Mines pond	1	28	109	Burdiehouse Limestone	9, 35	NT 0440 6360	NT 0530 6450	100	304850	664050		Oil-Sh of the Lothians 3rd edit p9, 35
North Cobbinshawold quarries	1	87	110	(Hurlet Limestone & Coal)		NT 0105 5750	NT 0130 5775	100	301175	657625		map
North Mine Quarry	1	95	113	qD dyke, sandstone, lava, baked limestone, Petershill		NS 9925 7175	NS 9950 7220	100	299375	671975		Loth geol, Excur Guide p215
Pilgrim's Hill, east Linlithgow	1	141	118	vents in the landscape	93, 115	NT 0120 7695	NT 0165 7720	100	301425	677075		Cent Coalfield Area III p93, 115
quarry south of Kipps	1	167	121	lava with augite	148	NS 9897 7325		10	298970	673250	possible loc	Edin Mem 1910 p148
Selms; Rowanbrae Quarry	1	164	130	qD sill		NT 0915 6623	NT 0922 6629	10	309185	666260		map
Tartraven quarries	1	90	134	Blackhall Limestone	16, 17, 18	NT 0060 7250	NT 0080 7270	100	300700	672600		Falkirk Mem 1998 p16-18
West Foulshiels quarry	1	120	142	Glenboig Lower	5.2.5;	NS 9635 6370	NS 9655 6385	100	296450	663775		Fireclay Resources CSMP 5.2.5
Auldcathie Rail Bridge Cutting	0	70	4	Broxburn Marl	64	NT 0800 7620	NT 0820 7630	100	308100	676250		Oil-Sh of the Lothians 3rd edit p64
Balbardie rail cutting	0			(Index Limestone)	137	NS 97 69		1000	297000	669000	no location	Edin Mem 1910 p137; Area VI Cent
Ballencrieff Mine	0	116	7	Glenboig Lower	83	NS 9635 6945	NS 9640 6955	100	296375	669500		Falkirk Mem 1998 p83; Fireclay
BarbauchlawBurn quarries	0	126	9	sandstone below Mill Coal	105	NS 9290 6905	NS 9295 6910	100	292925	669075		Area VI Cent Coalfield p105
BarbauchlawQuarry	0	125	9	sandstone above Mill Coal	105	NS 9180 6820	NS 9190 6830	100	291850	668250		Area VI Cent Coalfield p105
Binns Hill	0	166	11	vents in the landscape, 2 plugs		NT 0480 7835	NT 0600 7885	100	305400	678600		map
Binny Quarry (landfill)	0	55	13	Binny Sandstone	148, 149, 150, 198	NT 0565 7275	NT 0585 7300	100	305750	672875		Building Stones of Edin p148, 149, 150, 198

Page 7

Site Name	MB Score	MB No	AM No	Lithostratigraphy	Page No	SW corner	NE corner	Accuracy (m)	Easting	Northing	Notes	Reference
Blackburn Mains infilled quarry	0	154	14	picrite (soles of baker's ovens)	38	NS 9850 6525	NS 9855 6530	100	298525	665275		Hardrock Aggrgate Resources p38
Blackmire Rail Cutting	0	29	16	Burdiehouse	30	NT 0375 6400	NT 0400 6415	100	303875	664075		Oil-Sh of the Lothians 3rd edit p30; Edin
Blowshennie Quarry	0	135	17	qD sill, some coarse		NS 9720 7515	NS 9730 7525	100	297250	675200		map
Bridgend old claypits	0	184	22	drift?		NT 0415 7500	NT 0425 7510	100	304200	675050		map
Broompark quarry	0	148	24	qD sill, a few metres	117	NS 9605 7210	NS 9610 7215	100	296075	672125		Area VI Cent Coalfield p117
Camps	0			Buckie fake	48	NT 1010 6805		100	310100	668050	approx	Oil-Sh of the Lothians 3rd edit p48
Camps brickworks	0			till worked for brick	350	NT 1040 6810		100	310400	668100		Edin Mem 1910 p350
Couston (Broompark) former claypits	0	182	38	brick clay (no sec)	120	NS 9560 7160	NS 9600 7180	100	295800	671700		Area VI Cent Coalfield p120
Craigs quarries, Livingston; Broxburn sill, prob built over	0	157	39	dolerite, teschenitic	277	NT 0545 6845	NT 0595 6860	100	305700	668525		Edin Mem 1910 p277
Deans Barracks quarry infilled	0	43	47	Barracks Limestone	44	NT 0180 6780	NT 0215 6790	100	301975	667850		Oil-Sh of the Lothians 3rd edit p44
Drum , Whitburn	0			opencast LCMS	5.3.3;	NS 957 660		100	295700	666000		Fireclay Resources CSMP 5.3.3
Drumbowie quarry	0	146	51	qD sill infilled	116	NS 9070 6980	NS 9090 6990	100	290800	669850		Area VI Cent Coalfield p116
Eastfield Quarry ex-landfill	0	128	56	LCMS sandstones	114	NS 9345 6180	NS 9365 6195	100	293550	661875		Area VI Cent Coalfield p114
Fallahill Quarry	0	129	58	LCMS sandstones	114	NS 9205 6075	NS 9220 6100	100	292125	660875		Area VI Cent Coalfield p114
Hilderston farm infilled quarry	0	105	69	(Index Limestone)	29	NS 9780 7110	NS 9785 7120	100	297825	671150		Area VI Cent Coalfield 29; Edin Mem 1910 p139
Kingscavil Quarry infilled	0	81	82	sandstone of LinlithgowPalace;	102, 356	NT 0265 7630	NT 0280 7660	100	302725	676450		Edin Mem 1910 p102, 356; Cent Coalfield Area III p17; Wartime
LinlithgowPalace	0	179	95	glacial sagr mounds, kettle, Avon buried	103	NS 9965 7715	NT 0085 7790	100	300250	677525		Cent Coalfield Area III p103
Pardovan Quarry, infilled	0	80	115	sandstone above Fells, belowHouston	17	NT 0380 7725	NT 0400 7735	100	303900	677300		Cent Coalfield Area III p17; Wartime Pamphlet 45 p18
Porterside Quarry east of Linlithgow	0	102	119	LLGS sdst	111	NT 0175 7660		100	301750	676600	possible site	Cent Coalfield Area III p111
PottishawMine former	0	121	120	Glenboig Lower		NS 9690 6630	NS 9695 6635	100	296925	666325		map
Tar Hill	0	165	133	vents in the		NT 0590 7380	NT 0635 7410	100	306125	673950		map
Triangulation Point, Rifle Range Quarries	0	168	137	lavas	212	NS 9875 7115		100	298750	671150	trig point	Loth geol, Excur Guide p212
Wallhouse Fireclay Mine former	0	115	141	Glenboig Lower Fireclay		NS 9550 7250	NS 9560 7255	100	295550	672525		no ref
West Kirkton Quarry infilled	0	85	143	Hurlet &BHV	22	NS 9880 6870	NS 9890 6895	100	298850	668825		Area VI Cent Coalfield p22; Edin Mem 1910 p108, 109, 146, 147
Wester Hillhouse infilled (Torphichen)	0	150	145	qD sill	38	NS 9170 7065	NS 9190 7090	100	291800	670775		Hardrock Aggrgate Resources p38
Whitrigg Mine former	0	122	147	Glenboig Lower		NS 9615 6515	NS 9670 6525	100	296425	665200		map
Winchburgh brickpit pond	0	49	148	Dunnet Shale, till worked for brick, Broxburns?, glacial till	63	NT 0875 7510	NT 0900 7545	100	308875	675275		Oil-Sh of the Lothians 3rd edit p63; Edin Mem 1910 p350; Resources of Clay and Mudstone for Brickmaking 6.5.1b.1;

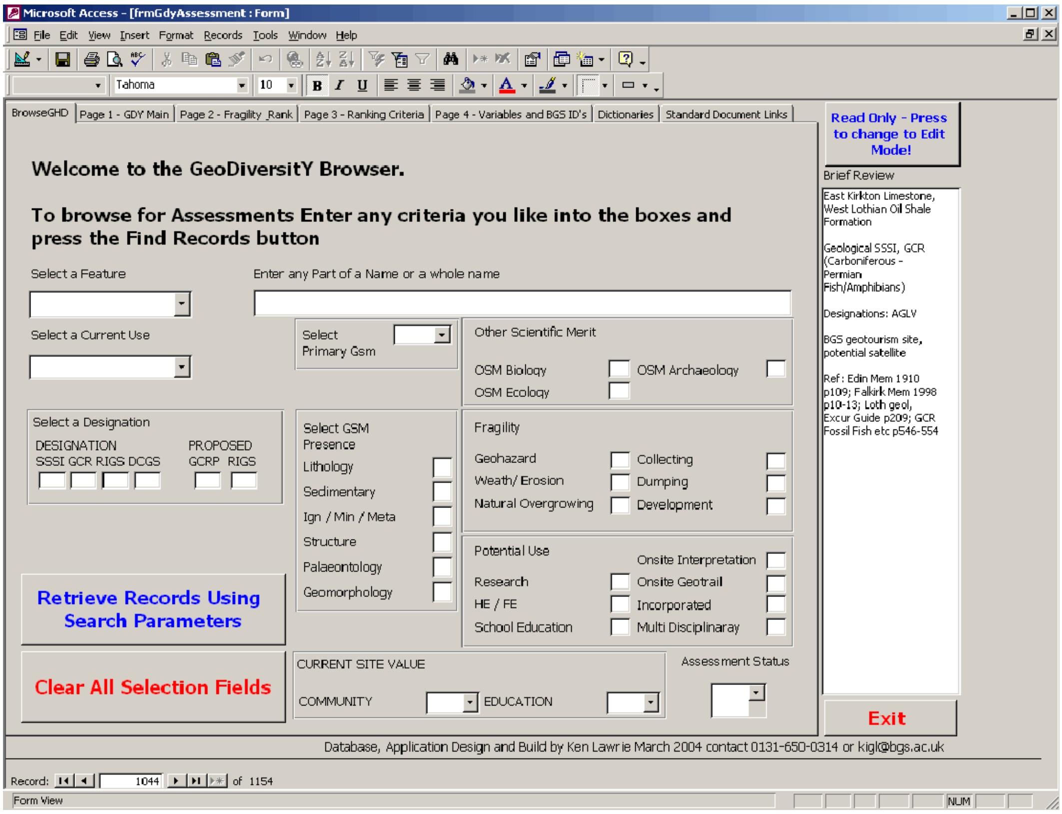
Page 8

Site Name	MB Score	MB No	AM No	Lithostratigraphy	Page No	SW corner	NE corner	Accuracy (m)	Easting	Northing	Notes	Reference
Winchburgh Quarry, Swineburn; fishery	0	51	149	Binny Sandstone	8	NT 0965 7590	NT 0975 7605	100	309700	675975		SL80/6; Sdst Res of western part Lothian Region p8
Winchburgh-Philpstoun Rail Cutting	0	71	150	Broxburn Marl	61, 62	NT 0550 7706	NT 0605 7610	100	305775	676500		Oil-Sh of the Lothians 3rd edit p61, 62
Banks shore	2			raised beach features		NT 1000 7865	NT 1135 7910	100	310675	678875		map
Binny Quarry	0			Binny Sandstone	148, 149, 150, 198	NT 0575 7328		10	305750	673280	infilled	Building Stones of Edin p148, 149, 150, 198
Cockmuir quarry by canal	2			Binny Sandstone	55	NT 0660 7645	NT 0670 7660	100	306650	676525		Building Stones of Edin p55
Craigton quarry	2			Binny Sandstone	55, 151, 152, 199	NT 0678 7674		10	306780	676740		Building Stones of Edin p55, 151, 152, 199
Hermand Quarry	1			Binny Sandstone	8	NT 0287 6350			302870	663500		SL80/6; Sdst Res of western part
Kildimmery Quarry nr Kingscavil; fishery	3	145		qD dyke, Nancy's Hill neck, qD dyke & agglomerate	114	NT 0215 7600	NT 0240 7610	100	302275	676050		Cent Coalfield Area III p114; Hardrock Aggregate Resources p60; Wartime Pamphlet 45 p29
Linhouse Water	3			cornstone, (qD); CYD, BGN, KNW??	141, 193	NT 0830 6600	NT 0885 6617	100	308575	666085		The Limestones of Scot p141, 193
Livingston Burn (? Loc)	1	38	97	Dunnet Sandstone	43	NT 0310 6715	NT 0355 6755	100	303325	667350	Barracks Limestone	Oil-Sh of the Lothians 3rd edit p43
Midhope Society shore	3		102	anticlinal fold	100	NT 0815 7915	NT 1000 7960	100	309075	679375		Edin Mem 1910 p100
Niddry Castle	3			vents in the		NT 0935 7410	NT 0965 7450	100	309500	674300		map
Westfield quarries	0			qD dyke	117	NS 967 720		100	296700	672000		Area VI Cent Coalfield p117
South Couston opencast?	0			LCMS base		NS 950 699			295000	669900	no locality	Fireclay Resources CSMP

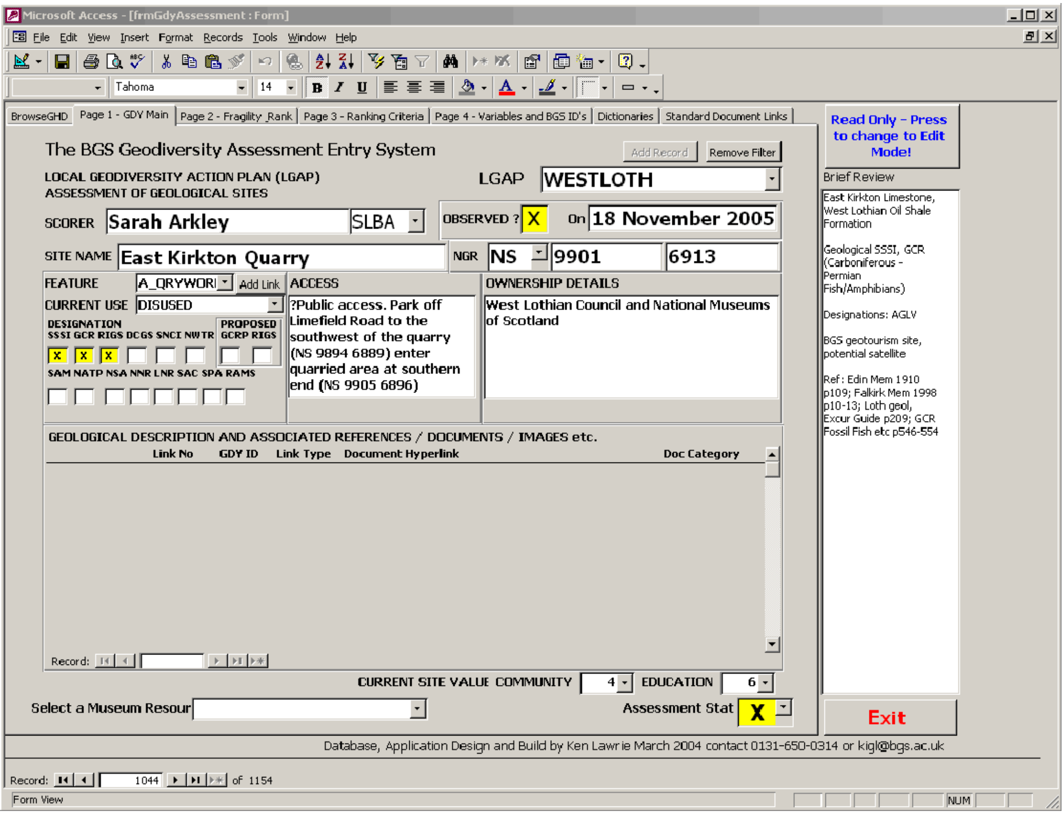
Page9

Note: See Figure 6 for a plot of these sites.

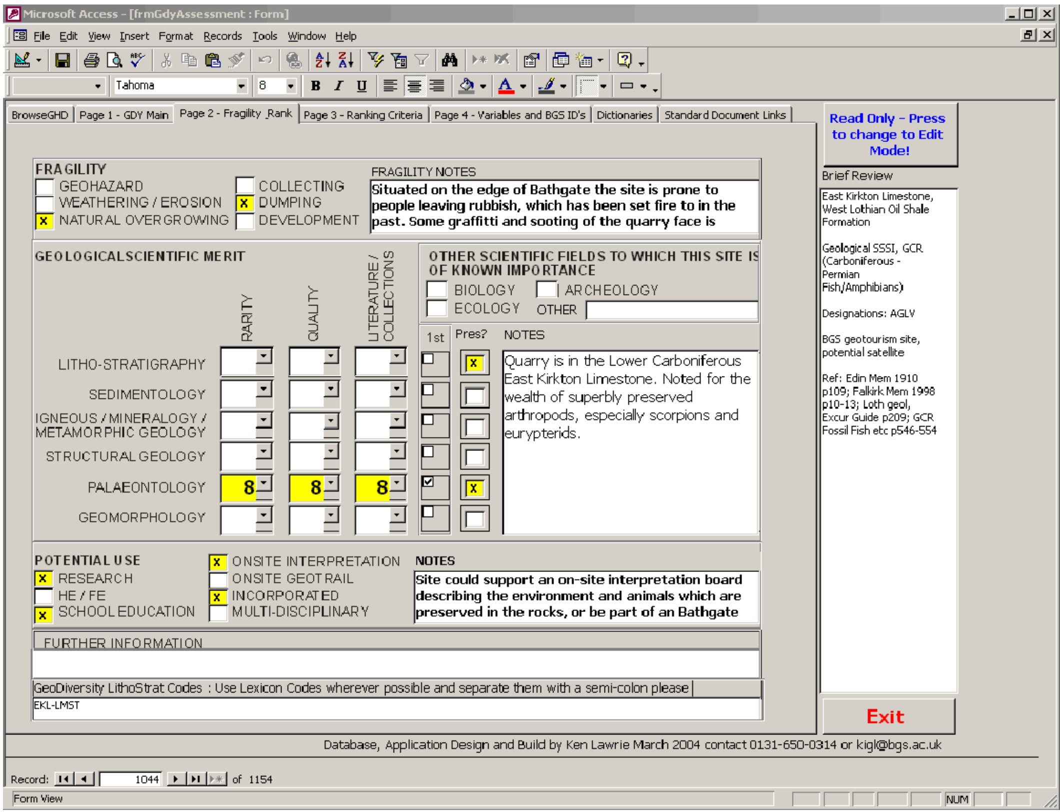
Appendix 5 GeoDiversitY Database



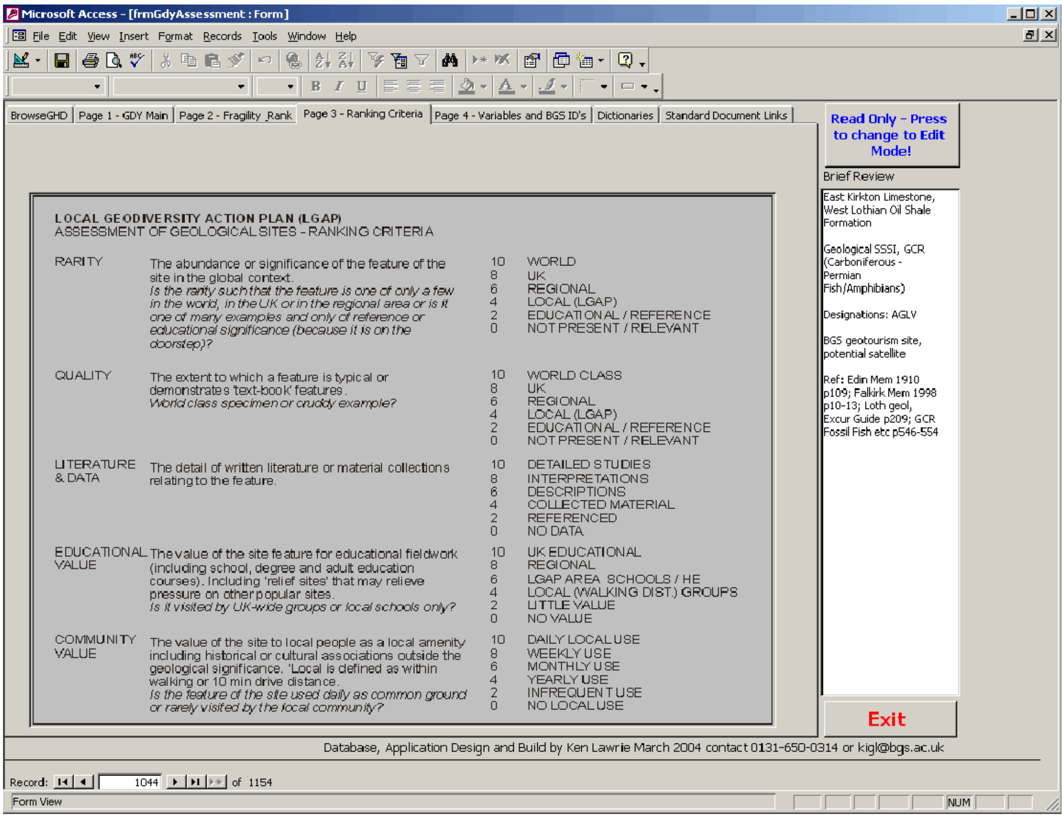
GeoDiversitY database – browser window



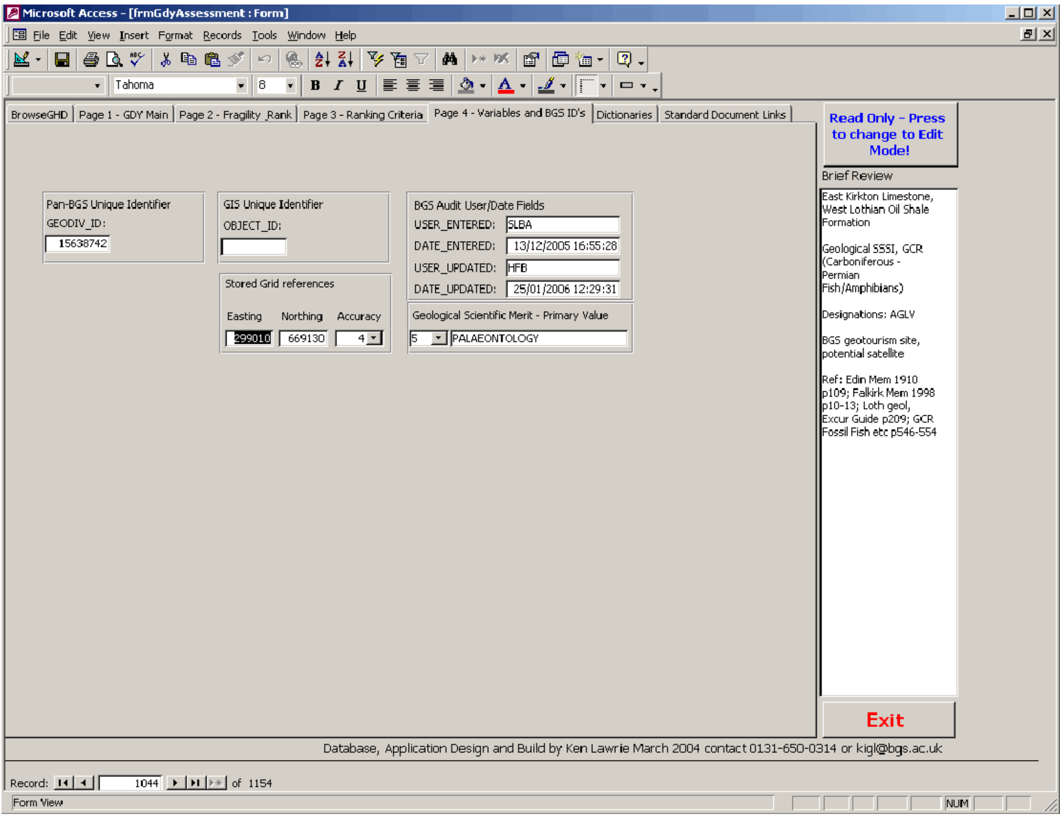
GeoDiversitY database – locality data entry window



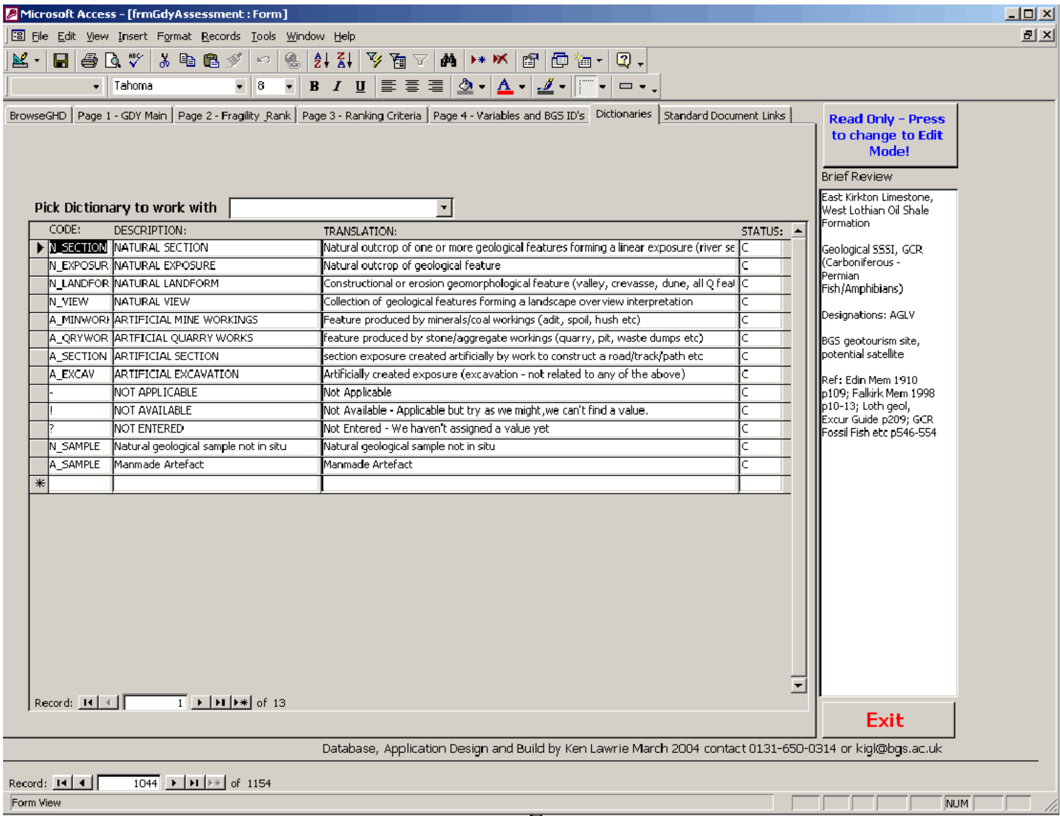
GeoDiversitY database – main geodiversity data entry window



GeoDiversitY database – ranking criteria window



GeoDiversitY database – variables and ID window



GeoDiversitY database – dictionary window

LOCAL GEODIVERSITY ACTION PLAN (LGAP)
ASSESSMENT OF GEOLOGICAL SITES

LGAP

SCORER DATE OBSERVED?

SITE NAME BNG

FEATURE
CURRENT USE
CURRENT DESIGNATION
DESIGNATED FOR

ACCESS

OWNERSHIP DETAILS

GEOLOGICAL DESCRIPTION

PHOTO

REFERENCES

CURRENT SITE VALUE
EDUCATIONAL
COMMUNITY

FRAGILITY
- ☐ GEOHAZARD
- ☐ WEATHERING / EROSION
- ☐ NATURAL OVERGROWING
- ☐ COLLECTING
- ☐ DUMPING
- ☐ DEVELOPMENT

NOTES

GEOLOGICALSCIENTIFIC MERIT

	RARITY	QUALITY	LITERATURE / COLLECTIONS	1st
LITHO-STRATIGRAPHY				
SEDIMENTOLOGY				
IGNEOUS / MINERALOGY / METAMORPHIC GEOLOGY				
STRUCTURAL GEOLOGY				
PALAEONTOLOGY				
GEOMORPHOLOGY				

OTHER SCIENTIFIC FIELDS TO WHICH THIS SITE IS OF KNOWN IMPORTANCE
- ☐ BIOLOGY
- ☐ ARCHEOLOGY
- ☐ ECOLOGY
- ☐ OTHER

NOTES

POTENTIAL USE
- ☐ RESEARCH
- ☐ HE / FE
- ☐ SCHOOL EDUCATION
- ☐ ONSITE INTERPRETATION
- ☐ ONSITE GEOTRAIL
- ☐ INCORPORATED
- ☐ MULTI-DISCIPLINARY

NOTES

FURTHER INFORMATION

GeoDiversitY database – Form for field use at geodiversity sites, page1

LOCAL GEODIVERSITY ACTION PLAN (LGAP)
ASSESSMENT OF GEOLOGICAL SITES - RANKING CRITERIA

RARITY	The abundance or significance of the feature of the site in the global context. *Is the rarity such that the feature is one of only a few in the world, in the UK or in the regional area or is it one of many examples and only of reference or educational significance (because it is on the doorstep)?*	10 8 6 4 2 0	WORLD UK REGIONAL LOCAL (LGAP) EDUCATIONAL / REFERENCE NOT PRESENT / RELEVANT
QUALITY	The extent to which a feature is typical or demonstrates 'text-book' features. *World class specimen or cruddy example?*	10 8 6 4 2 0	WORLD CLASS UK REGIONAL LOCAL (LGAP) EDUCATIONAL / REFERENCE NOT PRESENT / RELEVANT
LITERATURE & DATA	The detail of written literature or material collections relating to the feature.	10 8 6 4 2 0	DETAILED STUDIES INTERPRETATIONS DESCRIPTIONS COLLECTED MATERIAL REFERENCED NO DATA
EDUCATIONAL VALUE	The value of the site feature for educational fieldwork (including school, degree and adult education courses). Including 'relief sites' that may relieve pressure on other popular sites. *Is it visited by UK-wide groups or local schools only?*	10 8 6 4 2 0	UK EDUCATIONAL REGIONAL LGAP AREA SCHOOLS / HE LOCAL (WALKING DIST.) GROUPS LITTLE VALUE NO VALUE
COMMUNITY VALUE	The value of the site to local people as a local amenity including historical or cultural associations outside the geological significance. 'Local is defined as within walking or 10 min drive distance. *Is the feature of the site used daily as common ground or rarely visited by the local community?*	10 8 6 4 2 0	DAILY LOCAL USE WEEKLY USE MONTHLY USE YEARLY USE INFREQUENT USE NO LOCAL USE

GeoDiversitY database – Form for field use at geodiversity sites, page2

Appendix 6 GIS data layers supplied to West Lothian Council and SNH

File name	Format	File date	Description
BGS_Geodiversity_sites-23Mar06.shp	ESRI shape, point	23-Mar-06	122 geodiversity audit sites for West Lothian
BGS GD sites by value.lyr	ESRI layer	23-Mar-06	122 geodiversity audit sites for West Lothian – by site value
BGS GD sites by type.lyr	ESRI layer	23-Mar-06	122 geodiversity audit sites for West Lothian – by site type
BGS GD sites by staff.lyr	ESRI layer	23-Mar-06	122 geodiversity audit sites for West Lothian – by field auditor name
BGS_Audit_Sites.shp	ESRI shape, point	8-Mar-06	Sites selected from West Lothian desk study as potential targets for the geodiversity audit
BGS_Audit_Sites.lyr	ESRI layer	10-Mar-06	122 geodiversity audit sites for West Lothian
Inverclyde Gp Sites.shp	ESRI shape, point	26-Jan-06	6 geodiversity audit sites for the Inverclyde Group, West Lothian
Inverclyde Gp Sites.lyr	ESRI layer	10-Feb-06	6 geodiversity audit sites for the Inverclyde Group, West Lothian
Strathclyde Gp Sites.shp	ESRI shape, point	26-Jan-06	68 geodiversity audit sites for the Strathclyde Group, West Lothian
Strathclyde Gp Sites.lyr	ESRI layer	10-Feb-06	68 geodiversity audit sites for the Strathclyde Group, West Lothian
Bathgate Gp Sites2.shp	ESRI shape, point	2-Mar-06	5 geodiversity audit sites for the Bathgate Group, West Lothian
Bathgate Gp Sites2. lyr	ESRI layer	2-Mar-06	5 geodiversity audit sites for the Bathgate Group, West Lothian
Clackmannan Gp Sites2.shp	ESRI shape, point	2-Mar-06	18 geodiversity audit sites for the Clackmannan Group, West Lothian
Clackmannan Gp Sites2. lyr	ESRI layer	2-Mar-06	18 geodiversity audit sites for the Clackmannan Group, West Lothian
Coal Measures Gp Sites.shp	ESRI shape, point	26-Jan-06	4 geodiversity audit sites for the Coal Measures Group, West Lothian
Coal Measures Gp Sites. lyr	ESRI layer	10-Feb-06	4 geodiversity audit sites for the Coal Measures Group, West Lothian
Vents and Plugs Sites.shp	ESRI shape, point	26-Jan-06	2 geodiversity audit sites for the volcanic vents and plugs of West Lothian
Vents and Plugs Sites. lyr	ESRI layer	10-Feb-06	2 geodiversity audit sites for the volcanic vents and plugs of West Lothian
Alkali dolerite sills Sites.shp	ESRI shape, point	26-Jan-06	6 geodiversity audit sites for the alkali dolerite sills of West Lothian
Alkali dolerite sills Sites. lyr	ESRI layer	10-Feb-06	6 geodiversity audit sites for the alkali dolerite sills of West Lothian
Quartz dolerite sills Sites.shp	ESRI shape, point	26-Jan-06	13 geodiversity audit sites for the quartz dolerite sills of West Lothian
Quartz dolerite sills Sites.lyr	ESRI layer	10-Feb-06	13 geodiversity audit sites for the quartz dolerite sills of West Lothian
WL_Quat_landscape_char.shp	ESRI shape, polygon	14-Dec-05	BGS Quaternary Landscape Characterisation
WL Quat landscape char.lyr	ESRI layer	8-Mar-06	BGS Quaternary Landscape Characterisation