Indigenous stone resources for Scotland's Built Heritage

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Abstract: Stone forms a major component of Scotland's pre-1919 building stock and is being increasingly used as a new-build cladding material. Stone has also been used traditionally for roofing, streets, pavements and bridges and all forms of walling, and is now being used in large volumes for new city streetscapes.

From the acme of building with stone during the mid- to late-1800s when Scotland had over 700 working quarries supplying local, national and international needs, by the end of the 20th century the country was left with approximately 20 quarries supplying exclusively building and pavement stone. There was a concomitant decline in the skills required to work and use these materials. New supplies of indigenous slate, principally for roofing, have not been available since the 1950s.

Concern for the repair and maintenance of the stone-built heritage has grown in the last decade with the recognition of the importance of local character to the Scottish economy in terms of value to tourism and to architectural, historical, cultural identity. The coincidental increasing influence of global markets has hindered attempts to revive the Scottish stone industry. But the increasingly urgent need to meet international and government sustainability targets has encouraged a fresh examination of the benefits of using local resources, for example the reduction of transport and processing energy requirements. Likewise, the importance, particularly for the repair and conservation sector, of selecting appropriate replacement stone is being recognised by architectural and conservation professionals.

This paper outlines current research, together with the use of GIS, to enable the assessment of Scottish stone resources and properties. In turn, these activities should assist informed decision-making regarding repair and maintenance, selection of stone for new build and new streetscapes and the planning for the reopening of former quarries to supply the growing needs of Scotland's cities.

Résumé: La pierre forme un composant important des materiaux de construction de l'Ecosse avant 1919. Maintenant elle est employée de plus en plus comme revetement des batiments nouveaux. La pierre également a été employée traditionnellement pour la toiture, les rues, les trottoirs et les ponts et toutes les formes de maçonnage, et maintenant est employée dans de grands volumes pour de nouveaux streetscapes de ville.

Au point culminant de la construction en pierre dans la derniere moitie du 19e siecle, l'Ecosse comptait plus de 700 carrieres en exploitation, pour l'approvisionement local, national et international, Au fin du 20e siecle il n'en restaient qu'approximativement 20 carrières qui fournissaient exclusivement la construction et la pierre de trottoir. Il y avait un déclin concomitant dans les habiletés exigées pour travailler et employer ces matériaux. Les nouveaux approvisionnements en ardoise indigène, principalement pour la toiture, n'ont pas été disponibles depuis les années 50.

Le souci pour la réparation et l'entretien de l'héritage de construction en pierre s'est développé dans la dernière décennie avec l'identification d'importance de caractère local à l'économie écossaise en termes de valeur au tourisme et à l'identité architecturale, historique, culturelle. L'influence croissante coïncidente des marchés globaux a gêné des tentatives de rétablir l'industrie en pierre écossaise. Mais la nécessité de plus en plus pressante d'atteindre les objectifs internationaux et gouvernementaux de sustainability a encouragé un examen nouveau des avantages d'employer les ressources locales, par exemple la réduction du transport et de traiter des besoins en énergie. De même l'importance, pour le secteur de réparation et de conservation en particulier, de choisir la pierre appropriée de rechange est identifiée par les professionnels en architecture et en conservation.

Cet article raconte la recherche qui continue ainsi que l'utilisation de GIS de permettre l'évaluation des ressources et des qualités en pierre écossaises. Ces activités devraient aider la prise de décision au courant concernant la réparation et l'entretien, le choix de la pierre pour la nouvelle construction et les nouveaux streetscapes, et la planification pour rouvrir d'anciennes carrières pour assurer les exigences croissants des villes de l'Ecosse.

Keywords: Geographic information systems, geomaterials, natural resources, quarries, sandstone, urban geoscience

INTRODUCTION

Stone has had a profound influence on the Scottish built heritage through its varied use and its influence on design and architectural style through the centuries. With the resurgence of interest in stone for repair, conservation and for new build in the 21st century, there are pressing needs both to understand this complex material and to use it appropriately. The report published by Historic Scotland (1997), *A future for Stone in Scotland*, assessed the

fragmented state of the industry, the potential for exploiting the resource and the prospects for encouraging appropriate research, education and training. With the launch in 2000 of the Scottish Stone Liaison Group (SSLG) - a network of representatives of a wide range of organisations (industry, agency, academia) with interests in building stone - (Historic Scotland 2000), a number of partnership and research initiatives have enabled a more proactive approach towards the questions of stone resources and use. This network has also initiated the long overdue assessment of the indigenous skills required to work and use stone effectively.

As part of the drive to encourage best practice in the use of stone, the Natural Stone Institute (NSI), spawned from the SSLG, was established as a company in 2001. The NSI was charged with providing a better understanding of all aspects of natural stone and its use for public benefit. It is encouraging good practice through:

- Education
- Training
- Research
- Technical innovation
- Information coordination

Educational initiatives of the NSI include continuing professional development (CPD), lectures and field events, literature for the professional and developing a web resource aimed at assisting a range of practitioners. To alert the architectural, planning and building professionals to the value and use of indigenous stone, a volume on *Building with Scottish Stone* was published in 2005 (Natural Stone Institute, 2005) and a volume describing stone resources in Scotland is due to be published jointly by UNESCO, IAEG, Historic Scotland and the British Geological Survey (BGS) in 2006 (Hyslop *et al*., in press).

In outline, this paper addresses how the indigenous geology has influenced local and national building character, how global changes in building practice and introduction of manufactured materials influenced the huge decline in the skills base and use of stone during the 20th century and how we are relearning lessons from the past to ensure best practice for the future. Market forces in a global economy have meant that for the best part of a century the decline in the indigenous industry has been accompanied by major importation of stone from all over the world. Decision-making for repair work is influenced by availability of material leading to examples of the use of inappropriate material. Trends in the use of imported stone in new build spill over into the repair and conservation sectors and can also influence decision-making about the selection of stone. Yet, set against this, the economic value of the built heritage for tourism is well documented. Both 'sense of place' and sustainable development arguments can be used to influence decisions, be they design or planning. Thus, today's city streetscapes need to reflect the aspirations of both visitor and indigenous populations not only for aesthetic purposes but also for historical and cultural reasons.

With this background the paper examines the ability of Scotland to provide a higher proportion of its own stone needs. The paper outlines research into indigenous stone resources and into the mineralogy and properties of local stone types to allow decisions to be made on quality of material and also on repair needs. These issues are currently being addressed by projects in some Scotland's major cities but the principle of the research has universal application.

GEOLOGICAL INFLUENCES ON NATIONAL AND LOCAL BUILDING CHARACTER

Scotland's geological heritage dates back to some 3.1 billion years. The Scottish landmass is underlain by a variety of sedimentary, igneous and metamorphic rocks which rival that of any similar sized portion of the earth's surface. A wide range of these rocks has been exploited for building materials and the local character of Scotland's stone-built heritage reflects the local geology. Glacial processes during the last 2.6 million years (Quaternary) have redistributed surface materials and scoured the landscape providing ready sources of sands, gravels and clays for building purposes.

Stone in early building

Man's use of bedrock and superficial deposits either directly or as component raw materials can be traced over the last 5000 years. Thus, Scottish stone-building pedigree can be traced back to the earliest days of prehistoric construction in Orkney, Shetland and Caithness (in northern Scotland) in which the natural bedding and joints of the Devonian Caithness Flagstones were expertly exploited and the resultant buildings of chambered tombs and dwellings constructed using dry stone techniques that mimicked the geological structure (Maxwell, 1992). Masonry construction from 500 to 200 BC also utilised the natural properties of thin-bedded sandstone slabs to great advantage. The dry stone built broch and external buildings contain architectural features composed of vertical slabs in addition to well-constructed walls which display fluidity in their conception and construction.

In the 1st to 3rd centuries AD the Romans introduced new building techniques including the use of ashlar masonry in the form of square dressed stones of uniform course height together with lime mortar. Local materials continued to be the primary source for building. In areas where suitable rock cropped out, small quarries were developed and stone became established as the local building material.

In medieval times local stone was extracted from easily exploited sites for domestic and farm use and for larger buildings. Much of the material was used with little, if any, dressing to form random rubble walls. Scottish castles employed a mixture of dry stone rubble build and Roman lime mortar technologies. The size of available stones, determined by geological factors such as bedding and joints in the original rock, affected the form of the building. The relatively small dimensions of available stones dictated that walls were mainly constructed with small openings, a

feature suited for the purpose of defence. The availability of large stones determined whether wide openings could be spanned. Thus, large blocks of dressed stone were often transported from further afield for use as lintels and corbels of window and door openings. The form, colour and design of a building were determined, therefore, by the use of geologically different stones. Stones used for tombstones and slabs, crosses and effigies also utilised local stone of metamorphic and sedimentary origin that could be easily worked and sculpted.

Dry stone wall construction

During the late 18th and early 19th centuries, stone was gathered manually from the land as part of field clearance work and was set aside to make for easier use of ploughs and other equipment. Thus, there was a ready source of rounded, weathered boulders suitable for the building of field drains, enclosures and march dykes. The character of the dykes depended on the geological nature of the stones. In western Scotland weather-worn, rounded field boulders of a range of rock types were utilised to produce ill-fitting constructions. In the Lowlands early 18th century buildings utilised mainly glacially rounded, weathered sandstones and igneous rocks retrieved from the fields with exposed face height to length ratios of 1:1 or 1:2. These required the use of thick mortar beds and levelling up slip-stone pinnings to course the wall's construction. Galloway dykes used mainly hard greywacke sandstones (traditionally referred to as 'whin' or 'whinstone') of irregular shape and size. Inward inclining double walls were stabilised using small stones in the middle hearting, which enabled free use of the irregularly shaped face stones. Quarried greywacke sandstones of the Southern Uplands typically have a face dimension height to length ratio ranging from 1:3 to 1:5 (Maxwell 1996). The irregular profile of such material demanded highly skilled mason work for effective coursing. Tightly packed small face slip-stones and pinnings were commonly used to make up course bed height. In contrast, when laid horizontally in walls, these parallel sided, regular shaped, Devonian flagstones of northern Scotland with slab height to length ratios of between 1:4 and 1:8 produced a brick-like wall (Maxwell 1996). Alternatively, when they were set in the ground on edge they produced a tight fitting fence arrangement.

Stone in the evolving architecture of the central belt of Scotland

As architectural styles started to change from the mid 15th century onwards, so there was a developing trend to more sophisticated classical architecture manifested in the mid 17th century with the building of country mansions with well cut ashlar for facades. This culminated in formal designs being applied to Scottish town and city street facades from the late 18th century onwards, stimulated by the building of Edinburgh's New Town from the 1760s (Youngson 1966).

During the industrial revolution that fed on the age of scientific enlightenment, Scotland's central belt (geologically the Midland Valley bounded to the north by the Highland Boundary Fault and to the south by the Southern Upland Fault) became the hotbed of mineral production (Bremner 1869). Ironstone, limestone and coal together with oil-shale were the principal industrial minerals worked from Ayrshire in the west to Fife in the east. As villages and towns grew to support this growing industry and the increasing population, so the requirement for building materials increased and many building stone quarries were opened up. Initially, local sources of stone were utilised except for the most important buildings and monuments. This continued to be the case well into the 19th century. Not only was it costly to transport large quantities of building materials over large distances but often the local sources yielded abundant, good quality stone. Not surprisingly, therefore, many of the 18th and 19th century buildings in major Scottish cities are constructed of local stone.

In the Midland Valley a major resource was good quality sandstone suitable for constructional and monumental purposes, particularly, but not exclusively, from the Carboniferous period (MacGregor 1945). For example, as the 18th to 19th Century New Town of Edinburgh developed Early Carboniferous sandstones were utilised. The most famous quarries west of the city included those of Craigleith, which supplied exceptionally durable, thickly bedded quartz arenite sandstone (Figure 1) (McMillan *et al*., 1999; Hyslop, 2004). Glasgow also had Carboniferous sandstone available on its doorstep (Lawson, 1981). Dundee used local Devonian sandstone. Intrusive igneous rocks and volcanic lavas of Devonian and Carboniferous age were used locally often in rubble-built constructions in East Lothian and to the north and south of Glasgow.

Figure 1. Columns cut from single beds of Craigleith Sandstone, Old College, the University of Edinburgh. Each column measures 6.8 m long by 0.98 m diameter. Photo A.A.McMillan.

Not all building materials for the cities could be obtained locally. Roofing slates, for example, were transported from the Argyllshire slate belt (Richey & Anderson 1944, Walsh 2000). Thinly riven sandstone from Angus was also used as a roofing material. Flagstones (laminated, fine-grained sandstones suitable for paving) of excellent quality were brought from Caithness (McMillan 1997). They were exported to Europe, North America and Australia (Sinclair 1988). Angus, too had a thriving 'pavement' quarry industry from the 17th to 19th centuries which exported its products not just to Scottish cities but to destinations around the world (Bremner 1869, Mackie 1980).

With the development of the canal and railway networks, Scottish cities utilized stone from further afield (Figure 2) (McMillan *et al*. 1999). During the middle of the 19th century, the famous West Lothian and Angus sandstone quarries came into their own, supplying much stone both for prestigious public buildings and tenements. In addition, as local sources of the pale coloured Carboniferous sandstones dwindled supplies began to be imported from northern England, particularly Northumberland. By the end of the 1800s sources of Permian to Triassic red sandstone from Dumfries and Galloway, Ayrshire and Arran became popular (Boyle 1909). Utilising the different sedimentary characteristics and the striking colour contrasts compared with the local pale yellow Carboniferous stone, Glasgow and Edinburgh received large quantities of this building material. Together with similar sandstones quarried in Cumbria (e.g. St Bees) the red sandstones reached North America often as ship ballast. Corsehill Quarry near Annan, Dumfriesshire, was favoured because it was particularly adaptable to fine carving.

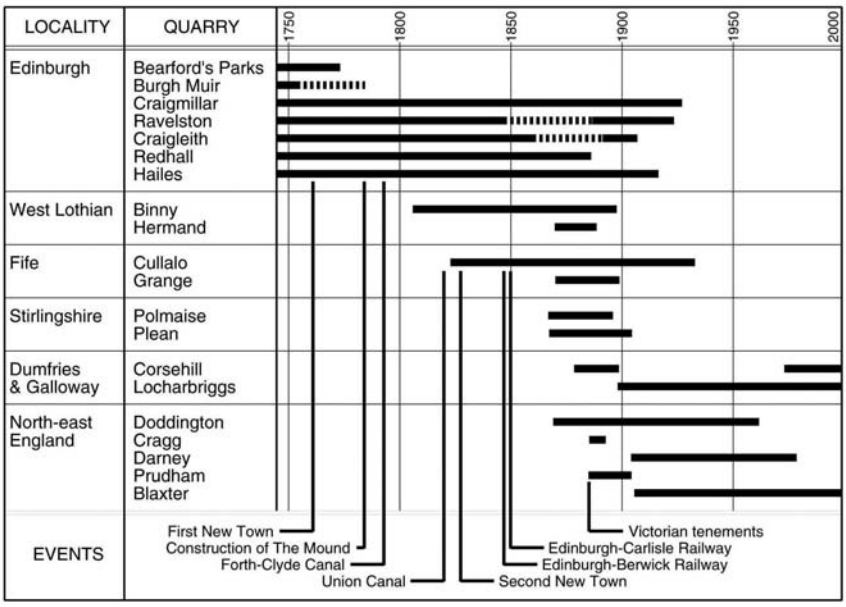

Figure 2. The influence of historic events and development of transport upon the selection of stone for Edinburgh's buildings (McMillan *et al*. 1999).

Use of stone in the Scottish Highlands and Islands

North of the Highland Boundary Fault, Scotland is dominated by Precambrian (Dalradian, Moine and Lewisian) crystalline metamorphic rocks including metasandstone, quartzite, schist, gneiss and, less commonly, marble. NW Scotland and the Outer Hebrides comprise the Lewisian rocks interspersed, on the mainland and on Skye, with the Precambrian Torridonian sedimentary rocks, which are hard semi-crystalline purple coloured metasandstones. Many of the rock types in the Highlands are difficult to work using traditional methods and have been used only locally for building purposes. The metamorphosed mudrocks of major Dalradian slate belts of the Grampian Highlands (e.g. Ballachulish) have been exploited on a major scale (Richey & Anderson 1944, Walsh 2000). Last worked in the 1950s, these slate quarries may have future potential as sources of West Highland slates (see below).

Igneous rocks are widespread in the Highlands, with major granite intrusions of largely Devonian and Carbonierous age throughout the Grampian Highlands and Aberdeenshire, and older Precambrian intrusions in the Northern Highlands. The granite of Aberdeenshire was widely used in the county, including Aberdeen 'The Granite City', and developed a major export market to other parts of the UK and abroad during the 19th century (Anderson 1939, Diack 1940-42). A group of younger (Neogene) intrusions underlie western coastal areas (e.g. Ardnamurchan) and the Inner Hebrides, forming large granite and related igneous areas in the islands of Skye, Mull and Arran. Several of these granite bodies, particularly in coastal locations, were quarried and exported to many parts of the United Kingdom and beyond.

Devonian lacustrine sandstones and flagstones are present in Caithness and Orkney. Both flagstones material and thickly bedded strata have been long exploited as pavement and building stone respectively (see above for references). Younger Mesozoic sandstones occur in coastal areas of the Moray Firth, Mull and Arran have also been locally used as building stone.

Use of stone of the Southern Uplands and Scottish Borders

South of the Southern Upland Fault, the land is mainly underlain by folded strata of Ordovician and Silurian age. The main rock types are sedimentary greywacke sandstone (colloquially known as whinstone), siltstone and mudrocks. The greywacke sandstones are difficult to work and were generally used only locally as building stone for rubble walling or roughly dressed dimension stone (Figure 3).

Figure 3. Coursed squared rubble of greywacke sandstone with dressed red sandstone window surrounds a building in Selkirk, the Scottish Borders. Photo A.A.McMillan.

Locally, the fissile siltstones provided reasonable stone slates for roofing. Building stone for the towns of Dumfries and Annan was supplied from the local sources of Permian to Triassic red sandstone. Devonian and early Carboniferous sandstones of Annandale, Eskdale and the eastern Scottish Borders were used in all of the local towns and villages. The large granite masses of Galloway were exploited for building (e.g. Dalbeattie) and monumental purposes and exported for major structural schemes such as harbour construction (e.g. Liverpool). Smaller bodies of Devonian and Carboniferous basic intrusive and volcanic rocks are locally present, particularly in the north and east of the Southern Uplands, and were mainly used for local construction.

STONE RESOURCES

Quarry sources

From the acme of building with stone during the mid- to late- 19th century when Scotland had over 700 working quarries (Hunt 1859) supplying local, national and, in some cases, international needs, by the end of the 20th century the country was left with approximately 20 quarries supplying exclusively building and pavement stone (McMillan 1997). There was a concomitant decline in the skills required to work and use these materials. Of around 25 quarries in production in Scotland in 2002 about ten produced sandstone, nine were in granite, four in flagstone and two in limestone (Cameron *et al*. 2002). As the quarries were abandoned during the 20th century some were re-used as sources of hard rock aggregate but many were abandoned, later to be infilled in a variety of ways (e.g. with colliery spoil, domestic refuse and other landfill schemes), and particularly in urban settings some became sites for new housing or retail development (e.g. Craigleith, Edinburgh). Other quarries lie dormant, either water-filled or open vegetated holes. Some have significant biodiversity and/or geodiversity interest, and others, in recent years, have been recognised for their recreational potential (e.g. rock climbing).

In Scotland the increasing use of stone for both repair and new build has occasionally encouraged the opening of new quarries and the re-opening of long abandoned workings. A major success, in recent years, has been the reopening of a former quarry at Cullalo, Fife (Figure 4). Carboniferous sandstone from this quarry was recognised in the 19th century as an alternative to Craigleith Sandstone and modern petrographic research demonstrates the similarity of the two sandstones (Hyslop & McMillan 2004). Through the intervention of the SSLG a stone producer was encouraged to reopen the quarry in 2003 and it is now being routinely used for repair work in Edinburgh.

Other research sponsored by Historic Scotland and managed by the SSLG includes the assessment of Highland slate resources. Following initial research by Walsh (2000), a targeted study of a quarry at Ballachulish, one of the original principal slate producing districts (Richey & Anderson, 1944, Walsh, 2000) is ongoing to assess the potential resource. A source of West Highland slate is crucial to meet conservation needs to repair roofs of similar material

(Emerton 2000). Scottish roofs were traditionally slated using slates of diminishing size upwards and each fixed with a single peg. These features, together with the rough textures typical of West Highland slates, make such roofs aesthetically unique. Currently, the alternatives are to use a slate of different character and properties either from England and Wales or from abroad, or to re-use slates from another roof with the resultant potential damage to that property.

Sometimes, planning restrictions may constrain a quarry or a new excavation adjacent to old workings to be opened only for a short interval to supply material for specific building project. An example of this practice (known as 'snatch' quarrying) was at Binny in West Lothian in the 1990s to supply material for repairs to Scott Monument (originally built of sandstone from the same source) in Edinburgh. Other quarries have a long history of more or less continuous working.

Figure 4. Recently reopened sandstone quarry at Cullalo, Fife, supplying stone for repair work in the City of Edinburgh. Photo A.A.McMillan.

Historical stone resource surveys and building stone assessments

Ever since the early days of the Geological Survey in the 1830s when the demand for stone in the UK was reaching its peak, there have been studies focussing on new resources and selection. One of the most celebrated building stone resource assessments was that conducted by a Select Committee set up to recommend stone for the building of the Houses of Parliament (1839 –c.1852) (Barry *et al*. 1839). This account was the first published detailed survey of the building stone industry of Britain (Lott & Richardson 1997).

General interest in the sources of stone grew during the 19th century as architects and builders started to look for new material which matched the colour and physical properties of stone in existing buildings. In Edinburgh, the first detailed published account of the city's building sandstones was written by George Craig (c.1852-1928), architect to the Leith School Board. His paper (1893) showed that, even then, when natural stone was much more widely used, it was difficult to ascertain the source of many of the stones used in older buildings. Aware, as he was, of the incompleteness of his results, Craig hoped that his work would be a useful "first contribution to a branch of practical local geology that has been but little investigated, though full of both economic and scientific interest". For today's generation the problems that faced Craig are still with us. Much knowledge was lost during the huge decline in the use of natural stone following the First World War as concrete started to gain the ascendancy. Even now, few detailed records are kept of modern uses of stone or markets and reference is usually in the form of reports in trade journals or in statistics published, for example, by the Office of National Statistics.

Strategic interest in stone resources (and many other indigenous minerals) was awakened in the 1930s with the result that several assessment surveys were carried out in Scotland. These studies resulted in publications by the then Geological Survey of Great Britain over the period 1930-49 specific to stone including Scottish slate (Richey & Anderson 1944), resources of the Lothians (MacGregor 1945), granite (Anderson 1939) and limestone (Robertson *et al*. 1949). A photographic record of quarries recorded at that time was featured in a recent Historic Scotland technical advice note (McMillan 1997). Many other Survey publications on the coalfield resources reported on stone quarries within each district. All these publications are a valuable resource today informing new generations about the declining industry and location of the resources of that period.

By the 1950s, in a government survey of building sandstone in Scotland, Broughton *et al*. (1953) concluded that "it is unlikely that the cost of building in stone can be reduced to a level that would be competitive with that of building in alternative materials". These authors also noted the serious reduction in masonry skills that had attended the decline in the stone industry. Furthermore, traditional masonry skills were no longer deemed a requirement for modern buildings where, if stone was used at all, it was as thin panel cladding to concrete structural frameworks.

Modern resource assessments

Sourcing of indigenous stone is vital particularly as conservationists and architects are increasingly conscious of the need to use natural stone appropriately both for repair and for new building. Recent publications have aided the initial evaluation of the resource process, for example the first *Building Stone Resources Map of Britain* (British Geological Survey 2001). This map, underpinned by databases, outlines the principal sources of stone and links them to geological formation and lithology. Such data, when used with other sources (e.g. BGS resource publications, archival data and Historic Scotland Technical Advice Notes), are valuable aids for a range of building stone enquiries.

The BGS is developing UK-wide databases to assist in accessing information on quarry sources, building stone samples and stone used in buildings. One of these, BritPits – an abbreviation of British Pits, contains over 2400 entries covering active mineral workings in the UK, together with approximately 15000 entries for inactive and former sites (Cameron *et al*. 2005). The number of workings in the UK currently producing building stone, however, is much smaller, about 440 of which some 50 are active in Scotland (British Geological Survey 2005). Many historically important building stones are not available at present and matching an existing stone can be problematic. BritPits is an invaluable tool in identifying both the probable original source for a building and the most appropriate replacement stone from working sites. Importation of these datasets into a Geographical Information System (GIS) enables resource data to be immediately linked to geological map data and other records (Figure 5). Summary data are available for a range of minerals (including building stone) on the Minerals-GIS Online Service for the regions of England and Wales under the www.mineralsuk.com website. In Scotland, funding to allow similar development has not yet been secured.

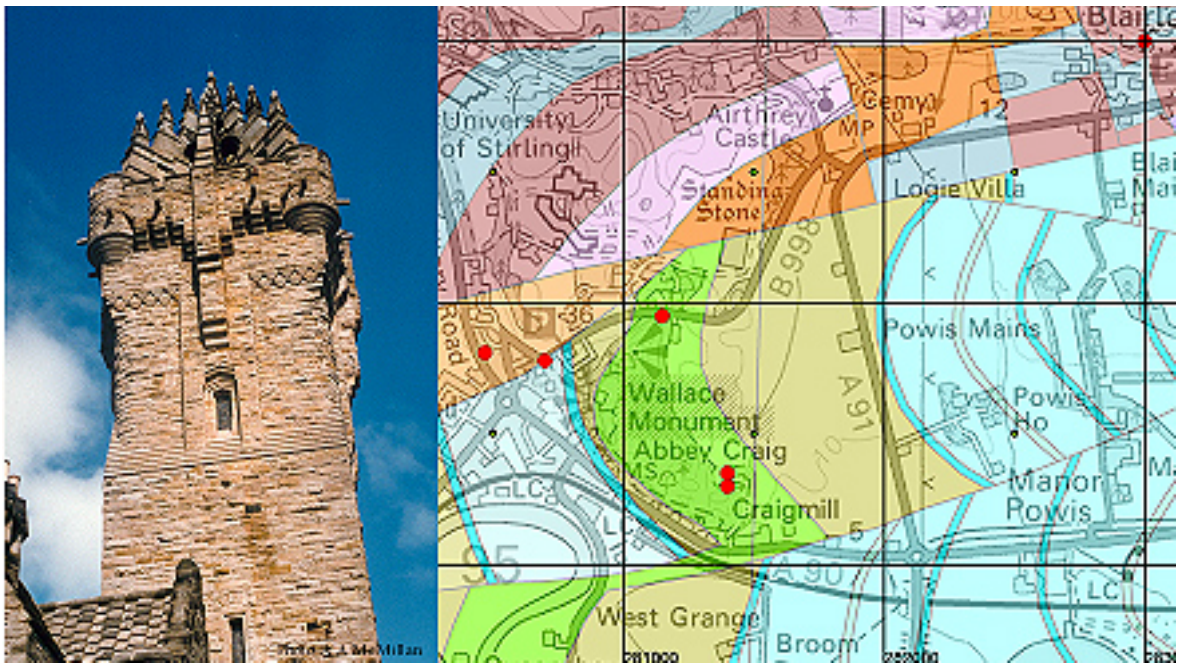

Figure 5. Extract from a GIS of former quarry sources (red dots) and geological map layer. The figure also shows the Wallace Monument on Abbey Craig, Stirling, constructed during the period 1859-69 of locally quarried sandstone. Copyright BGS©NERC.

Initial field assessment of former quarries includes measurement of available sections, determination of bed thickness and continuity of bed, joint mapping, together with sampling for mineralogical analysis and physical testing. In sandstones, it is important to note bedding characteristics such as lamination. Lamination, a characteristic which aided the splitting of stone, both for pavement and roofing material, is now not sought after as widely since stone can be easily cut with modern saws. Yet laminated stone is still in demand for repair work to buildings where such stone forms the original fabric.

KNOWLEDGE AND SKILLS

Selecting stone for repair – stone properties

The importance, particularly for the repair and conservation sector, of selecting appropriate replacement stone is being recognised by architectural and conservation professionals (Hyslop 2004). Concern for the repair and maintenance of the stone-built heritage has grown in the last decade with the recognition of the importance of local character to the Scottish economy in terms of the value to tourism and to architectural, historical, cultural identity. The coincidental increasing influence of global markets has hindered attempts to revive the Scottish stone industry. However, the increasingly urgent need to meet international and government sustainability targets has encouraged a fresh examination of the benefits of using local resources, for example by a reduction in transport and processing energy requirements.

Geological factors which determine the use of stone

The decision to select a particular stone type is dependant upon the ability of that stone to fulfil a number of criteria. Major factors are the functional suitability of the material in terms of its physical characteristics such as strength, durability, uniformity and dimensional aspects such as bed height (for sedimentary rocks) and block size. The stone must also be capable of being worked, sawn, dressed and tooled in the required manner. Specific functional requirements demand particular criteria, such as that for slip resistance for natural stone paving, or particular structural engineering characteristics required for use as stone cladding panels. Many of the requisite criteria relating to laboratory testing are given in the appropriate British and European Standard documents relating to a particular product. Testing methods are being harmonised under the European Committee for Standardization (CEN). Although laboratory tests are an important guide to the predicted performance of a stone type, valuable lessons can be learnt from the past performance of a stone type in a structure which may have been exposed to the weathering environment for long periods of time, in many cases over hundreds of years.

Issues such as colour and texture are of great importance in the selection of building stone. Natural stone has to look good as well as perform its physical function. The aesthetics of natural stone have always been an important factor but today they are some of the main reasons why stone is preferred to synthetic building materials in new build projects. For purposes of conservation and repair of historic stone buildings, colour and texture are equally crucial if a like-for-like conservation philosophy is to be adopted for the selection of replacement stone. The natural weathering of stone can also add to its aesthetic characteristics.

Local materials and skills

The recognition that one half of the annual expenditure of the construction industry may be attributed to the repair and maintenance sector reinforces the need for stone to be used in traditional ways and by appropriately skilled personnel (e.g. stonemasons, slaters). A significant issue is the sourcing of appropriate material for repairs. Because the vast majority of building stone quarries are no longer working, it is rarely possible to obtain a particular historic stone type without reopening the original quarry. Rarely has it been possible to reopen quarries to supply repair needs (see above). Most stone used for the repair of Scotland's historic buildings is imported. Whilst this may be satisfactory if the alternative replacement stone has identical characteristics to the original stone, recent studies (e.g. Hyslop 2004) have shown that this is not always the case and that the methods used for selection of stone have not always resulted in the most appropriate material being used for repairs resulting in damage to adjacent masonry. Reliance upon criteria such as physical laboratory test data is not sufficient to identify matching stone types where subtle differences in mineral composition, microscopic texture and porosity characteristics can exist. The consequences of using inappropriate replacement stone could be serious, both in terms of changing the appearance of the built heritage and causing accelerated damage to the original historic fabric. Increased availability of indigenous stone would alleviate this problem.

For modern building, architects and designers need to know both advantages and limitations of using stone. Modern designs have sometimes sacrificed functional features resulting in, for example, failure to allow a building to efficiently shed rainwater. In consequence, more or less constantly saturated porous stone has been rapidly disfigured, thus defeating the object of making the exterior of a building more aesthetically pleasing.

Linking materials to skills – an example from Glasgow

A Scottish Stone Liaison Group project, funded by Scottish Enterprise Glasgow, the City of Glasgow, the National Heritage Training Group and the Construction Industry Training Board (CITB) Construction Skills, is providing, for the first time, a systematic assessment of building stone resource requirements for the City of Glasgow. The BGS won the first part of the project which involves an assessment of the city's stone façades. A representative selection of 200 buildings have been photographed and building stone from the façades of about 100 have been sampled. These samples allow the petrographic description of the stone, the identification of the source and the investigation of any decay. From this database the type and quantity of stone required in both the short and long term is determined, thus providing the planning authorities with a precise figure of how much stone will be required to maintain the city centre over the next 20 years. The second part of the study, conducted by the Construction Industry Training Board, is to quantify the stone masonry skills across Scotland, which will alert authorities to the available skilled workforce needed for repair work within the city and elsewhere in Scotland. It is expected that the results of these studies will be published during 2006.

CHANGING PERCEPTIONS

In recent years there has been a steadily increasing recognition that the natural product is not only aesthetically more pleasing and durable but also compares favourably with other building materials in terms of life cycle cost analysis (Historic Scotland 1997, Natural Stone Institute 2005).

Particularly with the growth in tourism in Britain, public interest in the natural and built environment has increased in recent years. Consistently 'exit poll' surveys indicate that over 90% of all visitors to Scotland cite 'beautiful scenery', a combination of its landscape and history as a major reason for visiting. A significant proportion of the home population also appreciates the surroundings on their doorsteps, choosing to take holidays in Scotland. The appeal of Scotland's stone-built heritage is powerful and many organisations such as Historic Scotland, The National Trust for Scotland and Visit Scotland (the national tourist authority) recognise the need to feed this enthusiasm and interest which, in turn, may influence future sustainable planning strategies.

With the establishment of the Scottish Parliament in 1999 came an opportunity for the people to voice a collective view on the nation's architectural policy. The launch of the SSLG in May 2000 and the NSI in 2001 have provided a focus for initiatives to reawaken and develop the indigenous stone industry. Materials now feature in government policy literature (e.g. Scottish Executive, 2001) and planning policy statements. Organisations including the Built Environment Forum for Scotland and the Historic Environment Advisory Council for Scotland are expressing recognition of stone as a vital component of the built heritage and there are encouraging signs of support of the need for a modern assessment of Scottish stone resources.

Through a range of projects, some of which have been outlined in this paper, Scotland is addressing its stone materials and skills needs of the 21st century. A joined up approach of this kind will be crucial if the nation's stone built heritage, famous throughout the world and visited by a significant proportion of the UK's overseas tourists, is to be sustained for future generations.

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REFERENCES

ANDERSON, J.G.C. 1939.The Granites of Scotland. *Special Report of the mineral resources of Great Britain*, **32**. Memoirs of the Geological Survey of Great Britain. Edinburgh:HMSO.

BARRY, C., De La BECHE, H.T., SMITH, W. & SMITH, C.H. 1839. *Report (addressed to the Commissioners of Her Majesty's Woods, Forests, Land Revenue, Works, and Buildings) as the result of an inquiry, undertaken under the authority of the Lords Commissioners of Her Majesty's Treasury with reference to the selection of stone for building the new Houses of Parliament.* London: The Treasury.

BOYLE, R. 1909. The economic and petrographic geology of the New Red Sandstones of the south and west of Scotland. *Transactions of the Geological Society of Glasgow*, **13**, 344-383.

BREMNER, D. 1869. *The Industries of Scotland*. Adam and Charles Black, Edinburgh.

BRITISH GEOLOGICAL SURVEY. 2001. *Building Stone Resources Map of Britain* (1: 1 000 000). LOTT, G. K. British Geological Survey, Keyworth, Nottingham.

BRITISH GEOLOGICAL SURVEY. 2005. *Building and roofing stone.* Mineral Planning Factsheet. British Geological Survey, Keyworth, Nottingham for the Office of the Deputy Prime Minister. Available for download from www.mineralsUK.com.

BROUGHTON, H.F., ILLINGWORTH, J.R. & RICE, G.G. 1953. *Survey of building in sandstone in Scotland*. *National Building Studies Special Report*, Number 20. Department of Scientific and Industrial Research (Building Research Station). Her Majesty's Stationery Office, London.

CAMERON, D.G., BARTLETT, E.L., COATS, J.S., HIGHLEY, D.E., LOTT, G.K., FLIGHT, D., HILLIER, J.A., & HARRISON, J. 2002. *Directory of Mines and Quarries 2002: 6th Edition*. British Geological Survey, Keyworth, Nottingham.

CAMERON, D.G., BARTLETT, E.L., HIGHLEY, D.E., LOTT, G.K. & HILL, A.J. 2005. *Directory of Mines and Quarries 2005: 7th Edition*. British Geological Survey, Keyworth, Nottingham.

CRAIG, G. 1893. On the building stones used in Edinburgh: their geological sources, relative durability, and other characteristics. *Transactions of the Edinburgh Geological Society*, **6**, 254-273.

DIACK, W. 1940-42. Rise and progress of the granite industry of Aberdeen. *The Quarry Managers' Journal*, Series of articles

EMERTON, G. 2000. *The pattern of Scottish roofing*. Historic Scotland Research Report. Historic Scotland, Edinburgh.

HISTORIC SCOTLAND. 1997. A Future for Stone in Scotland. *Historic Scotland Research Report*. Edinburgh: Historic Scotland.

HISTORIC SCOTLAND. 2000. *Scottish Stone Liaison Group Launch Abstracts*. Historic Scotland, Edinburgh.

HUNT, R. 1859. *Mineral statistics of the United Kingdom of Great Britain and Ireland (for the year 1858), Part 1*. Memoir of the Geological Survey of Great Britain. Geological Survey of Great Britain.

HYSLOP, E.K. 2004. *The performance of replacement sandstone in the New Town of Edinburgh*. Historic Scotland Research Report. Historic Scotland, Edinburgh.

HYSLOP, E. & McMILLAN, A. 2004. Replacement sandstone in the Edinburgh World Heritage Site: problems of source and supply. *In: Proceedings of the 10th International Congress on Deterioration and Conservation of Stone*, *Volume 2*, KWIATKOWSKI, D & LÖFVENDAHL, R. (eds). Stockholm: ICOMOS, Sweden, 777-784.

HYSLOP, E., McMILLAN, A., & MAXWELL, I. 2006.. *Stone in Scotland*. Earth Science Series. UNESCO Publishing (Paris), The International Association for Engineering Geology and the Environment (IAEG), The Crown, the British Geological Survey and the Natural Environment Research Council.

LAWSON, J. 1981. *The building stones of Glasgow*. Geological Society of Glasgow, Glasgow.

LOTT, G.K, & RICHARDSON, C. 1997. Yorkshire stone for building the Houses of Parliament (1839-c.1852). *Proceedings of the Yorkshire Geological Society,* **51**, 265-272.

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

MACKIE, A. 1980. Sandstone quarrying in Angus - some thoughts on an old craft. *The Edinburgh Geologist*, **8**, 14-25.

McMILLAN, A.A. 1997. *Quarries of Scotland*. Historic Scotland Technical Advice Note, Number 12. Historic Scotland, Edinburgh.

McMILLAN, A.A., GILLANDERS, R.J. & FAIRHURST, J.A. 1999. *Building stones of Edinburgh*. 2nd edition. Edinburgh Geological Society, Edinburgh.

MAXWELL, I. 1992. Stone: the changing perception of traditional build. *In*: RICHES, A. & STELL, G. (eds) *Materials and Traditions in Scottish Building*. Regional and Thematic Studies, Number 2. Scottish Vernacular Buildings Working Group, Edinburgh.

MAXWELL, I. 1996.*Building materials of the Scottish farmstead*. Scottish Vernacular Buildings Working Group, Edinburgh.

NATURAL STONE INSTITUTE, 2005. *Building with Scottish stone*. Edinburgh: Arcamedia, Edinburgh. 64pp.

RICHEY, J.E. & ANDERSON, J.G.C. 1944. *Scottish slates*. Wartime Pamphlet, Number 40. Geological Survey of Great Britain.

ROBERTSON, T., SIMPSON, J.B. & ANDERSON, J.G.C. 1949. *The limestones of Scotland*. Special Report of the mineral resources of Great Britain, Volume 35. Memoirs of the Geological Survey of Great Britain. His Majesty's Stationery Office, Edinburgh.

SCOTTISH EXECUTIVE 2001. *A policy on architecture in Scotland.* Scottish Executive, Edinburgh.

SINCLAIR, A. 1988. *Spittal, Caithness. Home of the World's finest flagstone*. Thurso, Caithness: Spittal Village Hall.

WALSH, J.A. 2000. *Scottish slate quarries*. Historic Scotland Technical Advice Note, Number 21. Historic Scotland, Edinburgh.

YOUNGSON, A.J. 1966. *The making of classical Edinburgh 1750-1840*. Edinburgh University Press, Edinburgh.