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LIME BURNING IN CLAMP KILNS IN SCOTLAND’S WESTERN CENTRAL BELT: PRIMITIVE INDUSTRY OR SIMPLE BUT PERFECTLY ADEQUATE TECHNOLOGY?

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Abstract

Lime is a fundamental component in many industrial, agricultural and chemical processes and is itself produced by an industrial process, namely the heating in kilns (calcining or more colloquially ‘burning’) of calcium carbonate rock or other carbonate material. Research and literature on lime burning in Scotland, based largely on lime production in Scotland’s eastern Central Belt, are dominated by the view that lime burning in draw kilns is the paradigm for Scottish lime production. Other parts of Scotland, however, largely or completely ignored draw kilns in favour of simpler clamp kilns, even in major industrial sites of lime production. This paper reports our map- and field-based surveys in Scotland’s western Central Belt, which clearly point to the enduring importance and almost exclusive use of clamp kilns in that area’s historical lime-burning industry.

KEYWORDS: Clamp kiln; lime; draw kiln; lime burning
Lime is produced by heating (burning or calcining) calcium carbonate (limestone, marble, or marine shells) to ~900°C. Modern production is industrial in scale; whereas historically production technology ranged from all single-use sow kilns to all and multi-use clamp kilns to large shaft kilns with infrastructure and stone-built continuously operating draw kilns (also called shaft kilns). Sow and clamp kilns are relatively simple, elongated U-shaped embayments or more circular (horseshoe-shaped) pits (Figure 1). Elongated pits that are open at both ends have also been observed at one site. Limestone and fuel—generally coal, but wood and peat were also used—were interlayered in the kiln and the fuel ignited. The heat calcined the limestone (CaCO$_3$) to quick lime (CaO), liberating carbon dioxide (CO$_2$). The relative proportions of fuel to limestone—in the case of coal, one part of coal to generally two to four parts of limestone, and occasionally to one part of limestone, all depending on the types and qualities of the coal and limestone—mean that kilns are most sensibly located at the source of the limestone. This locational force is reinforced by the fact that a tonne of limestone produces half a tonne of lime. In the draw kiln (also sometimes called a shaft kiln), the charge (limestone and coal) was loaded continuously at the top of the kiln pot and moved down through the pot as the limestone was calcined and the quick lime was drawn off at the base of the pot. Draw kilns could thus operate continuously for long periods. In a clamp kiln, the contents of the kiln were covered over (clamped) to control the burning. After the clamp kiln cooled, the quick lime was unpacked. The lime produced by both styles of kilns could be transported away as either quick lime or slaked lime (by the addition of water to the quick lime).

Lime has, of course, been used for millennia in building, plastering, and lime washing, and there are reports that lime from Campsie, one of our areas of interest here, was used in building Glasgow’s medieval Cathedral, which was consecrated in the late 12th century. More recently, liming of agricultural soils was critical to Scotland’s agricultural revolution of the 18th and 19th centuries. Indeed, Smout and Fenton have noted that ‘perhaps the most important of the innovations [in Scottish agriculture] sprang from the realization at the turn of the seventeenth century of the value of liming’. Hay recently reiterated the same point and liming of fields remains important for land management in Scotland. Agricultural liming is important in
northern Britain because the region’s high rainfall generally results in acidic, often poorly structured soils and liming both neutralises the soil’s excess acidity and improves the soil’s structure.\(^{10}\) Lime is also an important flux in any industrial processes and demand for lime increased once the industrialisation of western Scotland was under way in the late 18th century and developed much more extensively in the 19th century.

The earliest agricultural liming in Scotland may date at least to the early 17th century and lime was demonstrably being produced in Scotland’s western Central Belt by this time.\(^{11}\) Belsches’ report on agriculture in Stirlingshire, the historical location of our study area, confirms the more widespread use of lime in agriculture by the mid-18th century.\(^{12}\) The incorporation of a distinctive elongated rectangular side embayment (inlet) on the south bank of the Forth and Clyde Canal to service lime draw kilns about 1 km west of Wyndford Lock just outside the southern boundary of Stirlingshire also confirms that lime production was well established in that area by 1773, when water was first let into that part of the canal.\(^{13}\) A map in the University of Glasgow Archives, centred on the study area and dated 1777, annotates the ‘Bankier’ farm label in Baldernock with ‘Coall & Lime’.\(^{14}\) Ross’s 1777 mapping of ‘Coal’ and ‘Lime’ at Culloch a few kilometres to the west of the present study area confirms that to late 18th-century production of lime in that area and an 1805 farm plan for the Dougalston estate depicts two U-shaped clamp kilns (‘Kills’) on Longauld Farm near Culloch.\(^{13}\) An 1812 report on Stirlingshire confirms the widespread use of lime by the first decade of the 19th century.\(^{16}\)

So the production and use of lime in Scotland were well established by the end of the 18th century. In marked contrast to the situation for Yorkshire, however, the technology of Scotland’s early lime production remains sparsely documented.\(^{17}\) Nonetheless, the literature continues to emphasise almost exclusively large masonry-built draw kilns.\(^{18}\) Indeed, Coull’s recent review repeated the common observation that the best surviving evidence of lime production in Scotland is the battery of large lime kilns in Charlestown.\(^{19}\) Likewise, considerable prominence is given to Skinner’s work on large draw kilns in the Lothians to the unhelmed (and inaccessable) extent that the Lothians is thought of as somehow the cradle of the industry in Scotland.\(^{20}\) Indeed, recent work on Johnson’s important work in Yorkshire and the crucial but relatively unknown work in Scotland of Nisbet and MacKay has shed light on
...masonry-built draw kilns. This focus on draw kilns is inconsistent with the widespread remains of clamp kilns in Scotland. Here we examine lime burning in Scotland’s western Central Belt, with a focus on the parishes of Baldernock and Campsie in the area now covered by the 21st century local government area of East Dunbartonshire, formerly in the mid-19th century county of Stirlingshire.

STUDY AREA

The western Central belt of Scotland around Glasgow was the heartland of heavy industrialisation in Scotland, which accompanied, and then supplanted, the growth of weaving, cloth bleaching and printing. The extraction and processing of the western Central belt’s rich endowment of coal and ironstone underpinned the development of iron and steel production and heavy engineering, including the ship building for which Glasgow and neighbouring areas became noted. Scotland’s Central belt coal and ironstone are hosted in a rift valley downfaulted between the Southern Uplands to the south and the Scottish Highlands to the north. The sediments filling this area or sedimentary basin, the Midland Valley, also include limestone, as well as economically important sandstone, fireclay, and oil shale. In any places the geological sequence consists of coal beds (seams) that are interbedded (interstratified) with high-quality limestone and ironstone, facilitating relatively easy extraction of these resources. The key geological unit targeted by the limeburners in both Baldernock and Campsie were the Hurlet Limestone and Coal. There has been much change in geological nomenclature over the last century and in the Campsie area, the target has previously been known as the Campsie Main Coal and Limestone. In Campsie, a shale sandwiched between the coal and the limestone was used for making alum, which explains why the Campsie Alum Works, part of the largest alum works in the United Kingdom, also hosted lime kilns (see below).

Extraction of the coal and limestone for the production of lime is adequate for ore difficult, however, by faulting the deposits. This faulting explains that coal and limestone that were originally continuous across a large area were cut out at a fault, where one block of the Earth’s crust has been moved up or down relative to another. Thus, in any localities, if targeted by parts of the western Midland Valley sequence, the coal and limestone that were worked for lime burning are at different depths in different blocks of ground. Workable coal and limestone are effectively
absent from some blocks of ground either because the geological units containing these materials have been faulted up and eroded away or they have been down faulted and are too deep to have been worked economically and/or safely with 17th and 18th century technology. As well as volcanic intrusions (dykes and sills) locally faulted and/or burned the limestone and coal roasting the extraction and use of these materials.

DATA AND METHODS

Ordnance Survey (OS) mid-19th century first edition maps of Scotland’s Central Belt at scales of 6 inches to the mile and 1:2,500 (colloquially called ‘25 inches to the mile’) are a valuable resource for understanding historical lime burning. OS used any different symbols to map lime kilns but this apparently large number of symbols is easily simplified into two broad classes the clamp kiln and the draw kiln (shaft kiln). Clamp kilns are generally represented by a U symbol or an open-ended or closed rectangle all to some extent mimicking the U-shaped clamp kiln’s plan view or orthophotography (Figure 1). The more complex technology of the draw kiln in which a stone-built structure encloses an internal kiln pot or pots is mapped either using a circle sometimes with a black dot on the circle’s circumference or in a more pictographic style with a circle representing the kiln pot within a surrounding polygon that indicates the edges of the masonry structure that encases and supports the pot.

As part of a wider assessment of the distribution of the lime industry across Scotland in the mid-19th century every mapped occurrence of lime kilns or lime works on OS 1st edition 1:10,560 scale (six-inch) maps of central Scotland covering roadly from west to east and using the mid 19th century county names the Counties of Ayrshire, Renfrewshire, Dunbartonshire, Lanarkshire, Stirlingshire, Linlithgowshire (West Lothian) and Dunfermline (Midlothian), Haddingtonshire (East Lothian), Berwickshire, Berwickshire, Roxburghshire, Clackmannanshire and Fifeshire & Kinross-shire has been documented. All 487 sheets that make up this coverage were examined systematically moving an A4-sized window west to east across each sheet on successive west-east lines down the sheet. Each lime kiln or lime works was noted within that window assisted by a magnifying glass as necessary. The appeared kiln symbols were recorded as well as the location of each lime kiln or
limeworks to a precision of 5 seconds in latitude and longitude, using the latitude and longitude on the map sheets margins. Other information related to the industrial activity was also recorded, including the presence of quarries, tramways, train lines, and so on. We then worked our way through all 487 sheets a second time, checking the accuracy of the recorded information as well as mopping up any limeworks that had been missed in the first pass. We are confident that we have located virtually all of the lime-related features mapped on these 487 sheets.

Here the map data covering the 19th century parishes of Baldernock and Campsie in the former County of Stirlingshire are used to document each OS-mapped occurrence of lime kilns or limeworks (Figure 2). A check of OS 1st edition 2½ inch maps of the area confirmed that the same kilns have been mapped on both series and that the 2½ inch maps do not contain any more data on lime kilns than do the 6 inch maps, although the 2½ inch maps are often more explicitly mapped and label mine shafts, which may be mapped but unlabelled on the corresponding 1st edition 6 inch maps. These mapping data were supplemented by written reports from 1796 and 1812, the 1841, 1851, 1861 and 1871 censuses, and the Old and New Statistical Accounts of the parishes of Baldernock and Campsie. Extensive field checking and mapping of unmapped kilns, guided initially by OS mapping but then ranging more widely, were also undertaken.

Gradiometer surveys of the South Craigend and Boghall kiln fields were undertaken using dual and single fluxgate gradiometer Bartington 601 instruments. Repeated 20 x 20 m survey grids tied into the British grid using a Leica differential GPS were laid out at both sites using marked ropes. The sampling used a traverse spacing of 0.5 m and a 0.125 m sampling interval, with a zigzag survey mode. Forty-two standard 20 x 20 m grids were surveyed at Boghall and four standard grids at South Craigend following English Heritage’s recommendations for magnetometer survey in archaeological practice.

The mapping of kilns also located other infrastructure, including roads from the kiln fields for the carriage of lime for on-site transport to destinations further afield. A rectangular, stone-lined tank at the top of the South Craigend lime road in Baldernock is filled with about 0.5 m of organic-rich sediment overlying a thick clay seal on the bottom of the tank. We cored this sediment with a Russian corer to 0.7 m depth and used X-rays of the core and standard sedimentological
analyses to identify the base of the post-abandonment sediment infill over the basal seal. The cored sediment was sampled at 25 mm depth intervals except for three 0.5 m sampling intervals, and analysed by ICP-MS for total lead (Pb) at the Scottish Universities Environmental Research Centre (SUERC) East Kilbride, using standard SUERC procedures and protocols. These total lead contents were used to estimate the basal age of the sediments infilling as an estimate of the age of post-abandonment of the tank and the onset of its infilling as the lime industry wound down at South Craigend. This depth profile of total Pb above the seal in the South Craigend tank was then wiggle matched to Farmer et al.'s 210Pb-dated profile of total Pb from Loch Lomond, about 25 km NW of the Baldernock area. We carried out the wiggle matching in order (i) to date the South Craigend profile and in particular (ii) to provide a basal age for the infill sediment and hence a suggested age of the onset of the decline of the industry at South Craigend (see below). The dated Loch Lomond profile of total Pb is in effect a record through time of industrial pollution in the West of Scotland. It has already been used successfully to date sediments in a mill dam in Baldernock, in that case by matching by eye the dated peaks and troughs in the Loch Lomond record to the peaks and troughs in the mill dam sediment record of total Pb. Here we used a more rigorous wiggle matching approach derived from radiocarbon dating.

LIME BURNING IN THE BALDERNOCK AREA

SPATIAL DISTRIBUTION

When OS 1st edition and field data are combined, the Baldernock area comprising Baldernock Parish and the immediately adjacent parts of the neighbouring Campsie Parish (Figure 2) has the remains of more than 150 lime clamp kilns (Table 1); there are no draw kilns in the area. That total number of clamp kilns is more than double the number mapped by OS. There appear to be two main patterns of kiln organisation in Baldernock: (i) clusters and/or lines of kilns adjacent to each other in orderly arrangements (Figures 3, 4, 5, 6, and 7) and (ii) single kilns away from the main organised clusters (e.g. Group 8 kilns on Figure 5A). All lime workings are located on occurrences of
limestone and coal in outcrop or at shallow depth, with the discontinuous nature of the area being related to the faulting and disruption of the beds. All clusters of lime kilns are grouped near or around quarries or mine entrances, as at Boghall (Table 1 §1; Figure 3), Hole (Table 1 §3; Figure 4), South Craigend (Table 1 §5; Figure 5), Blairskaithe Trig Point (Table 1 §6; Figure 6), and Glenwynd (Table 1 §7; Figure 7). Indeed, no lime kilns are far from a mine or quarry, even slightly isolated individual kilns, such as the individual Group 8 kilns at South Craigend (Figure 5). Where kilns and mine were separated, even only by a short distance, tramways on narrow linear elevated ridges often connected a kiln and slightly distant mine (e.g., Hole – Figure 4, Blairskaithe Trig – Figure 6). Overall, the pattern is that Baldernock kilns, be they clustered or individual, were essentially always close or well connected to mines.

OPERATION OF THE BALDERNOCK CLAMP KILNS

The clusters and/or lines of clamp kilns presumably facilitated a cycle of loading, burning, cooling, and unloading the kilns in sequence, with each kiln in the cluster being at a different point in the cycle. The kilns adjacent to mine entrances would presumably have been charged with limestone and coal directly from the mines after reading out the limestone and coal to appropriately sized fragments, whether the kilns were individual kilns with adjacent mine shafts or cluster or bank of kilns adjacent to a shaft (e.g., Glenwynd – Table 1 §7; Figure 7).

A mine abandonment plan that includes the South Craigend lime kilns and is based on OS 1st edition mapping shows the kilns clustered around the mine entrance where the kilns would presumably have been serviced by a tramway. The plan indicates that the mine being abandoned was working black-banded ironstone but the explicit identification of areas of 'solid limestone' and 'solid lime' on the plan confirms that the miners were also extracting (or had previously extracted) coal and limestone. The coal and limestone would have fed the kilns clustered around the mine's main entrance, which is still visible as a degraded (in-filled) gully-like feature cutting into the hillside.

The gradiometer survey of the South Craigend kilns indicates subsurface structures apparently present beneath and between kilns (Figure 5). We interpret these structures, which are yet to be excavated, to be subsurface plumbing to aid
the operation of the kilns being similar to the types reported by Radcliffe inpeat-fired clamp kilns in early 19th-century Scotland and by Johnson from excavations in Yorkshire. Carbon dioxide, the by-product in calcining limestone, had to be vented away or else it would have quenched the flame. Thus, it was essential that a kiln be vented while also not allowing too much oxygen to the flame, which could have overheated and vitrified the limestone. A pile of kiln waste adjacent to the South Craigend kilns (Figure 5A) includes lumps of such vitrified and overcooked stone.

OTHER INFRASTRUCTURE

As well as tramways, infrastructure in the Baldernoc lime industry included now-abandoned lanes/roads that connected the kiln fields on the higher ground of the upland moors to transport routes on lower ground (Figures 8 and 9). Each lime road is now flanked on either side by a line of straggly hawthorn trees that have grown on the hedges that lined the roads. The roads were well made with built-up embankments and masonry-lined cuttings to maintain the gradients for (presumably) horse and cart. The detail of the construction of these roads awaits further investigation but they have so far revealed no evidence of tramways. It is speculated that the rectangular, ~1 m deep, stone-lined tank at the top of the South Craigend lime road (Figure 5) provided water for horses at the top of a long climb. Running water at the top of the climb would have met that need for the Glenwynd lime road and the Langshot lime road, the least steep of the three lime roads. A rectangular tank at the bottom of the hillslope that the road serves as evidenced on OS 1st edition 2-inch mapping.

The lime roads were for transporting the lime to lower elevations and then for some of this lime to the north and Clyde Canal that connected Scotland’s west and east coasts and (with the Union Canal) Glasgow and Edinburgh (Figure 9). An 1822 advertisement in the Glasgow Courier advised that Balgrochan Lime (Balgrochan being at the foot of the Glenwynd and Langshot lime roads—Figure 8) was being sold at Hungryside ‘on the canal bank’ as well as at the Balgrochan Lime Shed at Port Dundas—the Glasgow terminus of the canal. The Glasgow Herald advertised the lease of South Craigend farm and its lime and coal works in 1850, noting that the north and Clyde Canal Wharf at Hungryside is within three miles of the Mines.
lime and coal were transported at least three miles by cart to the canal. The link between South Craigend farm and the canal had been an enduring one because the 1836 inventory of an intestate South Craigend farmer included: "two hundred chalders of lime and coal on the hill or at the works and a share of a boat or scow on the canal."41

Other infrastructure associated with lime works included large drains and reservoirs at Blairskaith Trig (Figure 6). The flooded mine entrances in the Trig area confirm that there was a water role in these mines despite the works being on a local high point that was sufficiently elevated to host a trigonometrical survey point. The uphill end of the northern of the two large drains that lead away from the lime kilns area is adjacent to an oval water-filled depression (Figure 6). This depression is interpreted as a collapsed shaft for pumping water resuantly by a steam-powered pump. The location of the shaft and the drain directed to the west from the southern edge of the Trig kiln field is unclear.

AGE OF THE BALLENGOCK KILNS

It is likely that the oldest Ballangock kilns are the two horseshoe-shaped kilns at Boghall that were not mapped by the OS (Figure 3). These kilns now have no surface topographic expression and were almost certainly well and truly defunct by the time of mid-19th century OS mapping.42 These are among the smallest kilns investigated here and they evidently lack the sophistication of the subsurface plumbing seen at South Craigend (Figure 5). Moreover it is clear elsewhere that the horseshoe-shaped clamp kiln is an early form, notably from about 20 km to the northeast of Ballangock in Upper Bannockburn, where the horseshoe-shaped clamp kiln is overwhelmingly numerically dominant and where Harrison has concluded that lime burning was early ("by the late 16th century and perhaps long before").43

Albeit the horseshoe-shaped kiln is likely to be the early clamp kiln form it continued to be used and is present in small numbers among the Ballangock clamp kilns not only at South Craigend (two kilns) and at the Blairskaith Trig kiln field (two kilns). These horseshoe-shaped kilns are side by side with the more usual U-shaped kilns and apparently have the same degree of weathering and post-abandonment degradation pointing to their being of approximately the same age as the U-shaped
It is clear that the Baldernock lime industry operated over a considerable time interval. Kilns in several localities have been backfilled by later activity, leaving kiln remnants with partially infilled ends, notably the South Craigend group 7 kilns (Figure 5A), where only short remnants of the ends of the horns of the seven group 7 horseshoe-shaped clamp kilns are visible at the foot of a slope forming the edge of an extensive and highly modified area that was formerly a work area for later mining. One clamp kiln is also infilled from the back at North Bardowie, an area not discussed here beyond noting that it was revived in the first two decades of the 20th century (see Discussion below).

It is assumed that the sedimentation and infilling of the rectangular, 1 m deep, stone-lined tank at the top of the South Craigend lime road (Figure 5) reflected the decrease in activity in the area and associated lack of maintenance of infrastructure as the industry went into decline. The $\chi^2$ statistic for the best fit for wiggle-matching the stratigraphic sequence of lead in the infill sediments to the dated lead fallout record in Loch Lomond yields a basal age of calendar year 1824.5 (Figure 10). In fact, the values of the $\chi^2$ statistic for basal ages ranging from 1819 to 1843 are all low and most all statistically significant (or at least not statistically significantly different from each other). The wiggle-matching by the Bacon software yields a basal age for the South Craigend sediment infill of calendar year 1828, with a 95% confidence range of calendar years 1831.6 to 1825.5. The match between the two totally independent approaches to wiggle-matching the South Craigend curve to the dated Loch Lomond curve is impressive.

We take these data to mean that the South Craigend water tank started to infill in the second quarter of the 19th century and that the South Craigend lime road pre-dated the second quarter of the 19th century (and probably long pre-dated that date given the scale of the lime workings at South Craigend). This lime-burning locality was nonetheless in decline by the second quarter of the 19th century, but it was not completely defunct: the 1841 census of Baldernock records 14 individuals connected with the production and sale of lime in the parish, including three lime masters, two coal and lime masters, five limestone miners and one lime cutter, two lime burners.
and one lime salesman (Table 2). These were living in South Craigend, Harrastone and Drumcockart and the nearby houses of Linn and Haughhead and Red Kiln (Figure 8). Baldernock coal miners numbered 12 in 1841 all residing in Hole except one in the neighbouring Harrastone. The industry was in decline however because by the 1861 census the number involved in lime had dropped to six all residing in Linn and Drumcockart or Haughhead and in coal to seven living in Harrastone, Red Kiln or Hole. The 1861 census (Table 2) reveals that the decline was continuing with only one person's employment recorded as lime related (a "lime quarrier" living at Haughead – Figure 8). In 1871 there were no lime workers in Baldernock and only seven employed in coal.

The industry's terminal decline by the middle of the 19th century in the area of South Craigend is also signalled by OS 1st edition mapping of all of that area's kilns as "Old Limekilns" which is taken to mean that the kilns were no longer functioning. This decline in the lime industry in Baldernock is also confirmed by advertisements for the lease of South Craigend. The 1850 Glasgow Herald advertisement noted above was not the last time the lease of the farm and the associated minerals were advertised. They were in fact advertised in the Glasgow Herald a rather astonishing 24 times in 13 months in 1857 and 1858 thus:

Mineral fields in the parish of Baldernock, Stirlingshire for sale. To be sold by private bargain – first a lease of the coal, limestone and ironstone in the farm of Hillhead and certain parts of the farms of South Craigend and Bankier; and second a lease of the coal, limestone and ironstone and the pyrites, alums, schistus &c in the lands of Barraston. Both fields are opened up by means of pits, in partial operation.

It seems that the leases were not attractive with three further notices in the Glasgow Herald in 1861 advertising the lease of South Craigend but this time without mention of the coal, limestone and ironstone in the land at Hillhead and certain parts of the farms of South Craigend and Bankier; and second a lease of the coal, limestone and ironstone and the pyrites, alums, schistus &c in the lands of Barraston. Both fields are opened up by means of its in partial operation.
that. The situation in Campsie has similarities to and parallels with that in Baldernock but there are important differences.

LIME BURNING IN THE CAMPSIE AREA

SPATIAL DISTRIBUTION

Figure 2 shows the distribution of the lime-burning areas in the central parts of Campsie Parish. Table 1 indicates the remains of more than 35 kilns, all of the clamp kiln form, as in Baldernock. As also in Baldernock, there are no draw kilns in the Campsie area. The principal areas to be discussed here are Culloch Slap, Baldoran, and Sculliongour (also sometimes confusingly called Balgrochan). The other Campsie area, near Glorat House (Figure 2), is not treated in detail here except to note that the mid-19th century OS 1st edition mapped five clamp kilns that were operating there as the Glorat Lime Works adjacent to a Coal and Limestone Mine. This works had closed by the late 19th century 2nd edition mapping, with the kilns unmapped and the mine being labelled as ‘Old Coal and Limestone Mine’ and the name Glorat Lime Works now applied to the larger lime works nearby, here named Baldoran (see below).

The 1st and 2nd edition OS mapping confirm that the remaining Campsie lime works were characterised by renewal and regeneration rather than the decline observed in Baldernock. In the mid-19th century 1st edition mapping, the Sculliongour Lime and Coal Works had four clamp kilns in a line with a fifth behind those: all immediately adjacent to Mines. The OS 2nd edition shows that by the late 19th century these had been re-organised and rebuilt as three larger clamp kilns in a line with three smaller clamp kilns in a perpendicular line at one end of the line: all served by three tramways to the mid-19th century mine and to distant mines about 200 m from the kilns.

The Culloch Slap Lime works (Figure 11) and lime kilns at the adjacent Campsie Alum Works are treated here together. Clamp kilns were the sole means of lime production mapped in the mid- and late 19th centuries at both Culloch Slap and the Alum Works. Both sites were obviously substantially re-organised in the second half of the 19th century: with Culloch Slap expanding its network of mine tramways.
as well as rebuilding and reducing the number of kilns (seven to five); all clamp kilns; but also apparently enlarging the kilns (Figure 1). The eight Alum Works clamp lime kilns were also connected to their mines by tramways and to the Campsie Branch / Blane Valley Branch Railway by the mid-19th century. The 2nd edition OS mapping indicates that the number of Alum Works kilns remained at eight; but they were rebuilt, substantially re-organised and enlarged in the second half of the 19th century (Table 1).

OS mapping also confirms major re-organisation and expansion of the limeworks at Baldoran in the second half of the 19th century (Figure 12). Mid-19th century OS mapping shows a small Derry Coal & Lime Works operating at Baldoran with two clamp kilns adjacent to a Limestone Mine. A little to the east of these works are mapped eight abandoned clamp kilns named as ‘Old Lime Kilns’ adjacent to an Old Limestone Pit. By the late 19th century, the limeworks had become the Glorat Lime Works and had been reorganised and enlarged (Figure 12). The two mid-19th century clamp kilns had been replaced by five larger clamp kilns that were serviced by tramways one leading from the mine to a flat platform above the tracks of the limeworks from where the kilns were presumably loaded, and one from the fronts of the kilns downhill to the Campsie Branch / Blane Valley Branch Railway (Figure 12). These kilns were now a major industrial operation with a direct connection to the mainline railway system that necessitated a bridge across the Glazert Water to join the railway and with one of the largest clamp kilns that we have seen in this study, about 15m long and more than 2m deep (Figure 12). It is also possible that the small upland works above the Glorat Limeworks that had been mapped as ‘Old’ (abandoned) in the mid-19th century saw late-stage revival. Here, immediately adjacent to a shaft with a second (possibly air) shaft some 75m to the north, three of the eight kilns have had their horns shortened. This ‘robbed-out’ material has evidently been used to renovate one or two kilns, which look fresher and less degraded than the other seven, and may therefore have been used more recently.

INFRASTRUCTURE AND AGENCIES OF THE CAMPSIE KILNS

It has already been noted how the Campsie lime kilns already had substantial infrastructure associated with them by the mid-19th century, including tramways to the mines and to the railway network. It is thus possible (but perhaps unlikely) that the
Balgrochan Lime was noted above as being advertised for sale in the Glasgow Courier advertisement of 23 May 1822 came from the Balgrochan that is near Lennoxtown (i.e., Sculliongour) and had been transported by rail to Glasgow, thence by cart to Port Dundas and canal to the Hungryside Bridge. If that route is unlikely as an explanation for the lime in that particular advertisement, it is nonetheless clear that Campsie lime would have been transported by rail.

OS mapping makes clear that lime production in the Campsie district expanded during the second half of the 19th century. Subsequent OS mapping shows that the Baldoran (Glorat) and Culloch Slap lime works had become defunct by the time of the 1914 revisions of the 6 inch and 25 inch sheets. These 1914 revisions of the 6 inch and 25 inch maps also depict the Campsie Alum Works as 'Disused'. There is disagreement between the two map series on the lime kilns at the alum works. The 1914 revision of the 6 inch mapping maps the lime kilns as 'Limekilns' without the 'Disused' label implying that they were still operating at that time but the corresponding 25 inch map does not show the lime kilns at all and labels the whole area of the alum works including the area where the lime kilns were located as 'Disused'. Taken as a whole, the map data indicate that lime production in the Campsie area had become defunct by the end of the second decade of the 20th century.

The continuing 19th-century vigour of lime burning in Campsie is reflected in the Campsie Parish census data (Table 2), with the more than doubling of employment in lime between the 1861 and 1871 censuses, resulting in the developments noted above and in Table 1. Table 2 also shows that employment in coal mining in Campsie Parish likewise increased throughout the second half of the 19th century, and some of that increase is almost certainly related to the lime industry (i.e., coal miners who were mining coal for lime burning but whose occupations were returned as related to coal).

Discussion

The Campsie lime industry flourished in the second half of the 19th century by which time the Baldernock industry was essentially defunct. Small local operations did continue in Baldernock right up until the early 20th century, with a current resident
recalling his grandfather's leasing and operating of the limestone mine and clamp(s) at North Bardowie in Baldernock parish in the early 1900s. This operation employed two men to produce lime that was taken by horse and cart to Bardowie railway station (Figure 2) for transport on the former North British Railway Kelvin Valley Railway line to Glasgow. To all intents and purposes however the industry in Baldernock faded as the Campsie operations grew. The Campsie industry itself then faded.

The early 20th century revival of the industry in Baldernock and its reliance on the railway for transport perhaps points to why the industry had earlier faded in Baldernock but continued in Campsie. We have argued above that the apparent focus of the Baldernock lime roads on the canal wharf at Hungryside (Figure 9) reflects the importance of canal transport for the lime industry in Scotland's western Central Belt in the late 18th and early 19th centuries. Thus lime kilns were sited on the canal edge (see above), lime was shipped and sold at the Hungryside and Port Dundas wharves, and old clamp limekilns are mapped on the canal-side on OS 1st edition 25 inch maps at Maryhill on Glasgow's north fringe and on a short dead-end spur of the Union Canal near Callendar. Likewise a major canal wharf to the west of the middle of the Central Belt is known as Lime Wharf and connects with a local Lime Road outside the railway's arrival in Scotland's Central Belt in 1842. The railway's arrival in Scotland's Central Belt in 1842 quickly drew traffic away from the canal and must have made it difficult for the major Baldernock lime works to compete with limeworks better situated in relation to emerging transport links. Thus these lime works were already defunct by the mid-19th century OS 1st edition 1 inch maps. One group of kilns at Blairsaith Trig and perhaps the odd one or two other kilns. The Campsie kilns on the other hand were clearly operating in the mid-19th century and had invested in the infrastructure of limekiln connections to the railways and in the case of the Alum Works lime kilns to the mainline railway system. Campsie's major groups of kilns then reorganised and expanded in the second half of the 19th century, installing larger kilns and maintaining Alum Works Lime works or developing Giorat Lime works connections to the railway system. The mid-19th century Giorat House lime works was closed by the late 19th century but the Sculliongour works were distant to the railway was reorganised in the second half of the 19th century. Its lime was carried to the nearby railway by horse and cart.
the small horseshoe-shaped kiln, which is the only kiln type present at Boghall and is occasionally seen elsewhere in Baldernock. It represents the early stages in the evolution of clamp kilns as the comments of Harrison and MacKay indicate, with the technology then evolving into the U-shaped kilns that culminate in large industrial-scale clamp kilns more than 100 long. The burning technology based on clamp kilns in Scotland's western Central Belt evolved over the life of the industry in the Baldernock-Campsie area. An interpretation that the earlier phases of the industry were in Baldernock is supported by Boghall's bank of 17 horseshoe-shaped clamp kilns. Small horseshoe-shaped kilns continued to be used locally in Baldernock at both the South Craigend and Blairsaith Trig kilnfields and only one fossil horseshoe-shaped clamp kiln has been identified in Campsie (at the Old Limestone kilns to the east of Baldoran's Glarat Lime Works – Figure 12). In other words, it can be argued that the Baldernock industry developed earlier than that in Campsie though caution is needed with that interpretation because the widespread redevelopment of the Campsie industry could have obliterated remains of any horseshoe-shaped clamp kilns.

Whatever about that point of detail, the fundamental point to be made here is that clamp kilns remained the sole technology for lime burning in the study area; not one draw kiln has been identified in an area that has evidence of more than 100 clamp kilns. Thus, there is no evidence that tenant John Lochry's undertaking in a letter of July 29, 1813 to John Kincaid, the owner of the Woodhead Estate, that covers the study area, binding Lochry... to build a draw kiln for burning lime in the course of the next year, was ever fulfilled.

The exclusive focus on clamp kiln technology in a major lime-producing area highlights the inappropriateness of the widespread and almost exclusive emphasis on draw kilns as emblematic of the historical lime industry in Scotland. Johnson's remark in relation to Yorkshire – 'It is regrettable that there is no... recognition of the role of clamp kilns in the development of lime burning technology' – evidently applies equally to Scotland.

Remembering that in this area the relevant part of the geological sequence consists of limestone interbedded with coal, it is reasonable to conclude that the dominance of clamp kilns in the Baldernock-Campsie area partly reflects the relative ease of obtaining the limestone and coal with which to charge the
This interpretation is consistent with the siting of kilns immediately adjacent to mine entrances from where the coal and limestone could be loaded directly into kilns. But it must also be remembered that limeburners often referred to clamp kilns. Thus, Carmichael noted in the 1830s:

> These clamp kilns are referred to any to the draw kilns on account of the slow and superior manner in which the stones are calcined whereas the practice of daily removing a quantity of the draw kiln either hurries the operation or defeats it by washing down the limestone before it is thoroughly calcined.\(^7\)

The installation of large clamp kilns at the Glorat Lime Works at Baldoran (Campsie) in the second half of the 19th century is telling in this regard in that the operators of a a major industrial scale lime-burning venture connected by a railway to the mainline railway system installed large (15m long) clamp kilns. OS 2nd edition 25 inch mapping of the Baljaffray area near Milngavie shows that six large clamp kilns up to 16 m long were also installed there about 7 km west-south-west of the Baldernock study area in the second half of the 19th century when draw kilns were not used.\(^8\) This enterprise, labelled 'Baljaffray Work (Coal & Lime)' on OS 2nd edition mapping, was not close to a rail line but the road connections to Glasgow seem to have been reasonable.

The reference to clamp kilns is also evident in other parts of central and western Scotland. It has already been noted that the horseshoe-shaped clamp kilns in upper Cannockurn (Stirlingshire) are likely to be early. Around Braehead in Lanarkshire, to the southeast of the present study area, Ward has georeferenced more than 140 clamp kilns.\(^9\) Similarly, Nisbet documents any tens of clamp kilns in Renfrewshire in western Scotland noting that they were used as in Baldernock and Campsie throughout the life of the lime-burning industry in highly organised industrial scale operations.\(^60\) Nisbet also comments that clamp kilns were often used side by side with draw kilns but notes various reasons for referring the clamp kiln to which can be added the reason noted here namely their ease and simplicity of operation when both limestone and coal occurred together in the geological sequence. Nisbet noted that some of the large clamp kilns in Renfrewshire were more than 20 m in length (i.e. larger than the largest clamp kiln identified in this study) and implied that clamp kilns were often referred to even when the coal had to be brought to the limestone. And finally on this point of the ubiquity of clamp kilns in

\(^{20}\)
western Scotland—a georaphic website ‘Relics of the limestone industry on Dumbarton Muir’ documents any old limestone-related features on Dumbarton Muir including limestone quarries, tracks related to the lime industry and clamp kilns. Incidentally, later draw kilns are also documented for this Dumbarton site.

It is also clear from the historical literature as well as the remains of draw kilns themselves that there was no universally accepted design for draw kilns which were subject to considerable stresses when fully loaded and firing. Common solutions to this issue included the cost construction buttressing of the masonry kilns and/or enclosing of the pot of the draw kiln within a massive (and presumably extensive) masonry structure from the outset (Figure 1). Such solutions were presumably deemed necessary to justify the cost of bringing in the raw material when coal or limestone had to be brought to the lime works and firing of the kiln was (semi)continuous. At the Charlestown wharf-side lime works for example coal was brought in by rail from Dunfermline and the limestone quarried on site. Presumably the cost of transporting coal was offset by being able to fire the draw kilns continuously and then to load the lime directly into ships for transport to markets throughout eastern Scotland as well as by the returns from shipping and selling coal itself. When either coal or limestone had to be brought to the kiln it generally made sense to locate the kilns at the source of limestone because of the 50% weight loss in calcining limestone to lime and the generally higher proportion of lime to coal in the kiln charge (see above).

Thus and notwithstanding any lime burners’ reference for draw kilns and these kilns’ undoubted widespread use in Scotland it remains clear from Cailesie’s Glorat Lime works and Culloch Slab Lime works and the Calairey Works as well as from Nisbet’s works in Renfrewshire that clamp kilns were a perfectly viable and economic technology for industrial-scale production of lime until at least the end of the 19th century. The rebuilding of both of the Glorat and Culloch Lime works in the second half of the 19th century—the considerable size of these works’ largest clamp kilns and the lime works’ connections by tramways both to mines and to the main rail network for shipping of the lime all confirm the scale of the lime works’ infrastructure and economic investment.

The clamp kiln was a low-cost and relatively straightforward way to burn limestone but the method nonetheless needed care and attention. As we have noted the lime burner faced two contrary challenges: clamping the kiln was necessary in
order to control the rate of burning and hence the temperature – too hot and the limestone would have been calcined to useless over-fired clinker stone – calcining limestone produces carbon dioxide which extinguishes the flame if it is not vented and/or oxygen is not supplied to the burning charge. Historical accounts of lime burning in clamp kilns in Baldoran noted the need to supply air to the burning charge: this challenge being met at Baldoran by the kiln carrying three small flues or shelves through the bottom and up the sides and ends of the kiln in order to give them air. Further gradiometer survey and excavation of the Baldermcke clamp kilns reported here will confirm if the sub-surface features tentatively identified in the South Craigend gradiometer survey are indeed plumbing to control the air supply.

STRUCTURE OF INDUSTRY

The Glorat Limeworks demonstrate that the industry was highly organised by the late 19th century but it is equally clear that that degree of organisation had existed for a considerable time as or clusters of kilns around mine openings are common throughout the Baldermcke-Caesie area including at South Craigend, Blairskaith, Trig, Baldoran, Culloch Slap, Boghall, and so on. Equally there were small-scale indeed perhaps lone operators such as at South Craigend but even these small-scale operators generally located their kiln close to a mine.

The newspaper advertisements noted above indicate that the limework operation was by landowners and estates leasing out the mineral rights. Leases only included incentives from the landowner such as those in an 1813 lease between John Kincaid of Kincard (the landowner) and John Lochry (Loughry) in which Kincaid agreed to pay £100 towards the sinking of a pit to the coal – £30 when the pit had reached 15 fathoms, £30 on reaching the coal, and the remaining £40 when the ground works leading to the works were finished. The lease also obliged the landowner to provide the gin (winding gear), gin ropes and hutches, windlass wheel and ropes and other material used for moving materials and men up and down the pit shaft. And thirdly rent was £100 for the first year (presumably as an incentive when there was no production) but then rose to £160 years for the remaining nine years or the lease plus Lordships of one ninth of the gross output of coal, one seventh part of the sale of lime and one shilling per ton of the sale of green (unburnt) limestone.


CONCLUSIONS

Johnson has commented that lime is the Cinderella of industrial archaeology. The results presented here mean that that can be extended to say that clamp kilns are the Cinderella of lime kiln archaeology—rarely investigated and even more rarely excavated. The abundance of clamp kiln remains in the Baldernock–Campsie area provides the opportunity to explore the details of this technology. Thereby to extend Johnson’s intriguing results on clamp kiln structure and function. The exclusive use of clamp kilns in the Baldernock–Campsie area is reasonably explained by a combination of a regional reference for clamp kilns (i.e., local custom and practice) and the possibility of extracting interbedded coal and limestone in the one mine or quarry. That hypothesis must await further archival work but even if both factors are confirmed it remains clear from the historical literature on lime burning and Nisbet’s data from Renfrewshire that some limeburners simply preferred clamp kilns and that clamp and draw kilns operated side by side at the end of lime burning in Scotland’s western Central Belt. In other words, the clamp kiln was itself a sophisticated technology that was not simply a precursor to more sophisticated draw kilns. The skill required to operate a clamp kiln in terms of loading it and then controlling the burn could be rewarded by a higher quality lime as Carmichael pointed out. In short, clamp kilns were not necessarily used simply as a local, small-scale technology that might have been fired only once to produce lime for agriculture but were a central element in a highly organised industry supplying a key ingredient in the development of Scotland’s industry, economy and urban centres.

ACKNOWLEDGMENTS

We thank landowners in Baldernock and Campsie for access to kilns on their properties, especially William and Alec Henderson of ‘Kettlehill’ and David Ralston of ‘Castlehill’, for permission to undertake the geophysical surveys at Boghall and South Craigend respectively, and the Stirlings of Glorat for access to the kiln remains at Baldoran. We also thank staff at East Dunbartonshire’s William Paterson Library for assistance with census data and the National Library of Scotland for permission to use the extracts from Ordnance Survey maps. The
University of Glasgow's School of Geographical & Earth Sciences kindly met the National Library of Scotland's fee for permission to publish these extracts. Kenny Roberts, Field Technician in the University of Glasgow's School of Geographical & Earth Sciences, provided, as always, cheerful and energetic field assistance, and Nicola Brannan, Small Animal Diagnostic Imager at the University of Glasgow School of Veterinary Medicine, kindly produced the X-rays of the South Craigend sediment cores. Mike Helsby of Low Blochairn generously assisted with the coring of this sediment and undertook the careful sedimentological analyses that underpin our interpretation of the core. Valerie Olive of the Scottish Universities Environmental Research Centre analysed the South Craigend core samples for Pb content, for comparison with the dated total lead profile from Loch Lomond kindly provided by Dr John Farmer of the University of Edinburgh. Professor Marian Scott, University of Glasgow School of Mathematics and Statistics, gave thoughtful advice on wiggle matching, and Dr Maarten Blaauw, Queen's University Belfast, was generous with his time in undertaking the wiggle matching using his Bacon software and in explaining the results. We are grateful to all of these individuals for their essential assistance and advice.
NOTES AND REFERENCES


5. Carmichael, ref. 4.


10. The application of calcareous marl (a muddy clay rich in lime) could achieve the same effect but required very substantially greater quantities of marl (400-600 cartloads per acre) compared to lime (10-80 carts per acre). Dodgshon, R., Land improvement in Scottish farming: Marl and lime in Roxburghshire and Berwickshire in the eighteenth century, The Agricultural History Review, 24 (1978): 114.

11. Fenton, A., Scottish Country Life (Edinburgh: John Donald, 1976); White, T., Agriculture and Society in Seventeenth-Century Scotland (Edinburgh: John Donald, 1979); Harrison, R., Life partly in the Stirling area from the 14th to the 18th centuries, Forth Naturalist and Historian, 16 (1993): 83-9; Hay, ref. 9; Smout and Fenton, ref. 8, 73; for example, a feu contract of 1630 between the Earl of Montrose and three persons in Easter Balgrochan (Stirlingshire) gives them the privilege of winning coal and lime through the lieve and a half of land of Carlestone and Easter and Wester Balgrochan as of old; [AS GD220/6/330/1; L1/01/49/01830/1]. The Balgrochan referred to here is in the central part of the Baldernock-Campsie study area.
Belsches, R., *General View of the Agriculture of the County of Stirling With Observations on the Means of its Improvement* (Edinburgh: Board of Agriculture and Internal Improvement, 1796).


"Explanation of Mr Barry's plan of Survey of Craigmaddie Muir 1775", University of Glasgow Archives UGD 152/6 Bundle 2.

Ross, C., 'A Map of the Shire of Dumbarton' (1777); National Archives of Scotland RHP 5302/20.

Graham, P., *General View of the Agriculture of Stirlingshire* (Edinburgh: Board of Agriculture and Internal Improvement, 1812).

Johnson, ref. 6.


Mitchell and Bishop, ref. 3.

Graham, ref. 16.


Ibid., *Figure 3.*

Ibid., *Figure 22.*
Unless otherwise stated, we use the term ‘Baldernock’ to cover Baldernock Parish and the immediately adjacent parts of Campsie Parish on the northeastern edge of Baldernock Parish. ‘Campsie’ then means the more central parts of Campsie Parish.

This approach is sensible in that lime kilns in immediately adjacent parts of Baldernock and Campsie Parishes (South Craigend in Baldernock Parish and Glenwynd in Campsie Parish) are working the same limestone and coal seams. The respective full names are used (e.g., Campsie Parish) when the individual Parishes are being referenced.


Each sediment sample was dissolved using a standard triacid (HF, HNO₃, HCl) dissolution procedure with added 0.2 ml HClO₄. All samples were then diluted so that their measured concentrations fell within the 5ppb-40ppb calibration line. Bismuth was used as an internal standard and BCR-2 geostandard was used as a quality check, with repeatability set at 5%. Analyses were done on an Agilent 7500ce ICP-MS fitted with a self-aspirating PFA concentric nebuliser tuned at 0.1 ml/min. Three points per peak and 15 or 20 per analysis were used to acquire the data. The same standard solution of BCR-2 was analysed every five samples as an internal check, to check for instrumental drift that was not compensated for by the internal standard.

The wiggle-matching was undertaken in two separate ways. The first used a version of the chisquared ($\chi^2$) test (following Ramsey, C.B., van der Plicht, J. and Weninger, B. ‘Wiggle matching’ radiocarbon dates, Radiocarbon, 43 (2001), 381-9) to assess the fit between the 17 data points of the South Craigend total lead profile (the $\chi^2$ test’s Observed values) and every profile of 17 contiguous data points (the $\chi^2$ test’s Expected values) moving progressively down through the dated Loch Lomond data. The match between the Loch Lomond Expected profile and the South Craigend Observed profile that gave the lowest $\chi^2$ value was judged to be the best fit and the basal age of that particular Loch Lomond 17 data point profile gave the basal age of the South Craigend infill. The second approach to the wiggle-matching used the Bacon software to...
match the South Craigend Pb profile to the dated Loch Lomond profile (Blaauw, M. and J.A. Christen, Flexible paleoclimate age-depth models using an autoregressive gamma process, Bayesian Analysis, 6 (2011): 457-74). This was undertaken by Dr Maarten Blaauw, the author of the Bacon software, who used the Bacon default settings except for a section thickness of 10 mm, a prior accumulation rate with mean 3 and shape 5, and using the dated Loch Lomond record as a tailor-made calibration curve against which the South Craigend Pb measurements were wiggle-match (Pers. comm. Dr Maarten Blaauw, January 6, 2017).

37 Pers. comm. email to David Lawrence, British Geological Survey Edinburgh, 06 May 2010, who also noted that the black-banded ironstone occurs as the topmost part of the coal seam, confirming that the coal would almost certainly have been extracted to obtain the ironstone.
39 Glasgow Courier, 23 May 1822.
40 Glasgow Herald, 4 March 1850.
42 The lack of surface morphological evidence for these kiln remnants primarily also partly reflects decades, and perhaps centuries, of re-ploughing, over that topography as well as the 19th century dumping of Glasgow city rubbish on the agricultural land on Glasgow’s periphery. (McGuire: D. Go west for a wife: Family farming in West Central Scotland 1850-1930, University of Glasgow PhD thesis (2012)). Many solid items from household waste can still be found around the kilns in the Boghall field, including broken porcelain dolls, other broken ceramic figurines, and fragments of what appears to be 19th century domestic pottery. The dumping of rubbish has largely served to raise the ground surface around and in the kilns, and hence to subdue the kiln floor (Figure 5).
43 See Figure 3 of Mackay, ref. 2.
44 We have not yet seen any mapping that shows Red Kiln, but the order of data in the census implies that it was close to Carron.
45 Six of the Hole coal miners were from the same family, namely John Marshall and five of his sons, the youngest aged only 9 years old.
46 Bishop and Thomson, ref. 22.
47 Ibid.
48 Ibid.
49 A Royal Commission on the Ancient and Historical Monuments of Scotland image of the Sculliongour (Balgrochan) clamp kilns is given on Scran with the following ID: 000_000_18_187C.
50 The 1630 lease noted in ref. 11 makes it clear that Balgrochan is a long-standing name in the caldernock lime industry. The lease names Carlestoun which is in the area treated here as
Baldernock is adjacent to Easter and Wester Balgrochan (though technically these areas are in Campsie Parish).

1. Mr Reid Harrison pers. comm. December 2014.
2. Lanark Sheet 6.2 (Maryhill), surveyed 1858, published 1865; Stirling Sheet 30.6 (Balfron), surveyed 1860, published 1864.
4. Harrison ref. 11; McKay ref. 21.
7. Car Michael ref. 4.
8. OS 2nd edition 1:2,000 mapping, Dumbartonshire sheet 23.11, revised 1896, published 1898.
10. Nisbet ref. 20.
12. Scottish Lime Centre Trust ref. 19.
17. Johnson ref. 1.
18. Johnson ref. 6.
19. Car Michael ref. 4.
Table 1. Numbers of kilns in Baldernock and Campsie in OS mapping supplemented by field checking. All kilns reported here are clamp kilns and no draw kilns have been either mapped by OS or identified in our field checking. Refer to Figure 2 for locations.

<table>
<thead>
<tr>
<th>Locality; guide GR and Fig reference (if relevant)</th>
<th>Area (Parish)</th>
<th>Number of kilns</th>
<th>Other lime-related features from OS mapping, field checking, census data, archives etc</th>
</tr>
</thead>
</table>
| §1. Boghall; NS 7974 figure 3                     | Baldernock     | 17              | 1. No kilns or mines mapped by OS.  
2. Small horse shoe shaped kilns revealed by gradiometer survey (Figure 3A and B).  
3. Heat reddened (baked) clay and vitrified stone on ground surface and similar colouration visible on colour enhanced Google Earth image (Figure 3C).  
4. Kilns are adjacent to a tree covered depression (Figure 3B) in which the Baldernock Limestone is filmed as cropping out. Local knowledge confirms that the depression is the remain of a coal and/or limestone quarry/mine. |
| §2. Nth Bardowie; NS 81749                        | Baldernock     |                 | 1. Remains of a group of four clamp kilns (not mapped by OS) plus one (now destroyed) kiln mapped by OS on mid-19th century 1st ed. adjacent to ‘Coal Mine’;  
2. No kilns mapped on OS 2nd ed. (late 19th century) but ‘Airshaft’ mapped on 2nd ed. is adjacent to the group of four kilns noted in 1.;  
3. Local information confirms that one or more of the group of four kilns was operating in the early 1900s, with the lime going by horse and cart to local railway for transport (presumably for the 10km or so into Glasgow; see text). |
| §3. Hole; NS 607 2 figure 4                       | Baldernock     | 11              | 1. All OS mapped kilns labelled as ‘Old Limekilns’ (Figure 4).  
2. Multiple mines (‘Old Pit’; ‘Old Pit Coal & Limestone’; ‘Limestone Pit’; ‘Coal & Limestone Pit’[the latter two labels, lacking ‘Old’, implying active mining when OS surveyed the area in 1860]).  
3. Remains of elevated (constructed) ridge for tramway from mine entrance to kilns (Figure 4).  
4. Downhill terminus of ‘South Craigend Lime Road’ (Figures 4 and 9). |
| §4. Linn; NS 907 6                               | Baldernock     | 1               | 1. Single kiln adjacent to a (presumably limestone) quarry or mine;  
2. Unlabelled on OS 1st ed. 6” mapping, but ‘Old Limekiln’ on OS 1st ed. 25” and OS 2nd ed. 6” mapping.  
3. A pit or underground limestone mine (the Baldernock Linn Mine) is also adjacent;  
4. House ‘Linn’ mapped adjacent to the quarry and kiln on OS 1st ed.; this is presumably the ‘Linn Bank’ occupied by a lime miner and his family in the 1851 census. Unroofed house filmed on OS 2nd ed. |
| §5. South Craigend; NS 602760 figure 9            | Baldernock     | 37              | 1. All kilns labelled as ‘Old Limekilns’ on OS 1st and 2nd eds.  
2. Subsurface ‘plumbing’ connecting clamp kilns indicated on gradiometer survey (Figure 9).  
3. Multiple mine shafts (identified in field and not mapped by OS; central mine entrance filmed on mine abandonment plan [Figure 8]).  
4. Uphill terminus of ‘South Craigend Lime Road’ (Figure 9). |
Bishop et al., Lime burning in clamp kilns: Scotland’s western Central Belt

6. Blairskaith
Trig
S. 96767
Figure 6

- Cause this area to be highly disturbed by later forestry activities.

26

1. OS mapped only three kilns: all labelled ‘Kilns’ indicating that they were still functioning in the 19th century also identified by the buildings adjacent to the kilns being marked as roofed, and the fact that the labels on the mines do not include the descriptor ‘Old’; 23 kilns not mapped by OS.

2. Multiple mines, two of which mapped by OS (‘Coal & Limestone Mine’; ‘Coal & Limestone Pit’); other (unmapped) shafts very obvious on the ground including two substantial water-filled shafts one of which is in plan view 20 m long and 5 m wide.

3. Remains of constructed ridge or tramway (not mapped by OS) from mine entrance towards kilns and a different tramway marked on OS 1st but not located on the ground.

4. Large drains running downhill away from (pumping?) shafts.

7. Glenwynd
S. 606761
Figure 7

- Map kilns labelled as ‘Old Limekilns’;

24

1. All OS mapped kilns labelled as ‘Old Limekilns’;

2. Nine mines (all ‘Old Pit Coal & Limestone’) mapped by OS in area immediately surrounding these kilns, with other unmapped shafts or airshafts located in field checking and/or mapped by OS as small circular ponds.

3. Glenwynd Farm house is uphill terminus of ‘Glenwynd Lime Road’ (Figure 9).

8. Langshot
S. 61778
Figure 8

- Map kilns as ‘Old Limekilns’;

6

1. All OS mapped kilns labelled as ‘Old Limekilns’;

2. On side branch of ‘Langshot Lime Road’ (Figure 9).

9. Culloch Slap
S. 622773
Figure 12

- Map kilns as ‘Limekilns’ on OS 1st ed 6” and 25” maps;

1st ed.: 7

2nd ed.: 8

OS 1st edition:

1. Mapped as ‘Limekilns’ on OS 1st ed 6” and 25” maps;

2. Two tramways connecting kilns to mines: one 500 m long to ‘Culloch Slap Old Mine Coal & Limestone’.

OS 2nd edition:

3. Kilns rebuilt;

4. Mapped as ‘Limekilns’ and therefore assumed to be operating;

5. 150 m long tramway still present and a second tramway 960 m long to ‘Tarfin Mine (Alum Coal & Limestone)’.

10. Caithie Alum Works
S. 632770

- Map kilns as ‘Limekilns’ on OS 1st ed 6” and 25” maps;

1st ed.: 8

2nd ed.: 8

OS 1st edition:

1. Mapped as ‘Limekilns’ on OS 1st ed 6” and 25” maps;

2. Two tramways connecting kilns to mines: one 960 m long to ‘Coal & Limestone Mine’ and the other 960 m long to ‘Tarfin Mine (Alum Coal & Limestone)’.

OS 2nd edition:

3. Kilns rebuilt and enlarged (two chained as being 17 m long);

4. 960 m long tramway still connecting to first mine noted under 1st edition, now called ‘Boydsburn Mine’.

S. 610772
Figure 13

- Map kilns as ‘Old’ or ‘Limekilns’;

Derry: 11

Glorat: 13

OS 1st edition: Derry Coal & Lime Works

1. Eight kilns adjacent to ‘Old Limestone Pit’ mapped as ‘Old Limekilns’, and three mapped as ‘Limekilns’, adjacent to ‘Coal Pit’ and ‘Limestone Mine’ (with a further ‘Old Limestone Pit’ adjacent);

2. Unmapped pit shafts or airshafts identified in field mapping.

OS 2nd edition: Glorat Lime Works

3. The eight ‘Old’ kilns and adjacent ‘Old Limestone Pit’ as chained in 1st ed. (see 1.) are relocated in 2nd ed.
<table>
<thead>
<tr>
<th>No.</th>
<th>Site Description</th>
<th>OS 1st edition</th>
<th>OS 2nd edition</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.</td>
<td>Glorat House Coal &amp; Lime Works (1st ed.)</td>
<td>1. Kilns of different sizes and slight differences in plan, view, or sholly (one with rounded end, the remainder with squared-off ends).</td>
<td>2. ‘Coal &amp; Limestone Mine’, with two roofed buildings adjacent.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. ‘Old Coal Pits’.</td>
<td>4. ‘Old Coal &amp; Limestone Mine’, with no buildings; ‘Old Quarries’.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. ‘Levels’.</td>
<td>4. More than 800 m of tramways between levels and kilns.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5. Roofed building adjacent to kilns.</td>
</tr>
</tbody>
</table>
Table 2. Numbers employed in the lime and coal industries in Baldernock and Campsie parishes according to various 19th century censuses

<table>
<thead>
<tr>
<th>Census</th>
<th>Baldernock Parish</th>
<th>Campsie Parish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lime</td>
<td>Coal</td>
</tr>
<tr>
<td>1841</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>1851</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>1861</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>1871</td>
<td>0</td>
<td>7</td>
</tr>
</tbody>
</table>

Note: The 1841 and 1851 census data were obtained from www.freecen.org.uk and the data for the 1861 and 1871 censuses were derived from the microfilm copies of the original census enumerator books held by the East Dunbartonshire Leisure and Culture Trust at William Patrick Library, Kirkintilloch. The microfilm reader at the William Patrick Library was provided by the Newspaper 2000 Project, the Heritage Lottery Fund, and the Regional Newspaper Industry.
Lime burning in clamp kilns: Scotland’s western Central Belt

Figures:

Figure 1. A. Sketch of clamp kiln redrawn by Bishop from Nisbet, S., ref. 3, Figure 1. B. Degraded remains of clamp kilns at Blairskaith Trig, Baldernock (left: horseshoe-shaped kiln and right: adjacent horseshoe-shaped kiln). Both at centre left of Figure 6 (see Figure 2 for location and detail).

Figure 2. Map of the principal lime kiln sites in Baldernock and Campsie Parishes. The South Craigend kilns lie in Baldernock Parish. The adjacent Glenwynd and Langshot kilns are in Campsie.
Lime burning in clamp kilns, Scotland's western Central Belt

Parish but they are treated here together as part of the Baldernock lime kilns because they are clearly working the same occurrence of the Baldernock Limestone and its associated coal.

Figure 3. Boghall lime kilns. A. Gradiometer survey showing the remains of 17 horseshoe-shaped clamp kilns. B. The Boghall kilns as revealed by gradiometer survey in context, highlighting the kilns.'
Lime burning in clamp kilns on Scotland’s western Central Belt

closeness to the adjacent mine in the Baldernock Limestone and associated coal measures. Colour and contrast-enhanced aerial photograph highlighting the circular reddened burnt ground remnants corresponding to the magnetic anomalies in A and B.

Figure 4. OS 1st edition 25-inch mapping of lime industry remains at Hole (Stirling Sheet 32.4 (Baldernock parish); survey date 1860, publication date 1864). The elevated ridge at upper right is interpreted to have carried a tramway from old pit in upper right-hand corner. A second unmarked elevated ridge (i.e., second tramway) ran from the southern end of the first tramway (at spot height 260) WSW along the mapped track to the crossroad in the middle of the figure (marked M2.3.3). That tramway would have then continued on to the kilns adjacent to the buildings (miners' cottages) at Hole. The road coming in from the north-west immediately to the west of Hole is the downhill terminus of the South Craigend Lime Road (see also Figure 9). (Reproduced by permission of the National Library of Scotland)
Lime burning in clamp kilns: Scotland's western Central Belt

Figure 5. A. Remains of the lime industry at South Craigend based on field mapping. At least one further kiln and adjacent mine shaft occur just to the south of the area mapped here. B. South Craigend gradiometer survey of Groups 2 and 3 kilns (allowing numbering in A at left): the blank area between Group 2 kiln 4 and Group 3 kiln 1 corresponds to a tree where it was not possible to survey. Note the possible subsurface structures ('plumbing?') in the floor of kiln 3 in Group 2 (centre of figure) and possible connection between that kiln and the adjacent kiln 2.

Figure 6. The area of Blairskaith Trig station showing kilns and mines. OS mapping shows only the three kilns at centre right and no mine entrances or drains.

Figure 7. OS 1st edition 2\text{\textprime} inch mapping of 24 clamp kilns near Glenwynd (Stirling Sheet 27.16 (Caithness parish); surveyed 1860, published 1865). Ground survey confirms this mapping as
Lime burning in clamp kilns: Scotland's western Central Belt

accurate and as complete as it is possible to assess, given the considerable disturbance by current forestry activities of the northern half of the area in this figure. (Reproduced by permission of the National Library of Scotland)

Figure 8. Lime roads in Baldernock naming various localities mentioned in the text as the 19th century OS 1st edition 6” map (upper portion: Stirlingshire sheet 27; surveyed 1860, published 1864); (lower portion: Stirlingshire sheet 32; surveyed 1860, published 1864). SCLR: South Craigend Lime Road; GLR: Glenwynd Lime Road; LLR: Langshot Lime Road. (Reproduced by permission of the National Library of Scotland)

Figure 9. Baldernock Lime Roads in relation to the wharf at Hungryside on the Forth and Clyde Canal (see Figure 9 for details and names of Lime Roads).

A. B.
Figure 10. Plots of $\chi^2$ values for the lead (Pb) sequences in the South Craigend water tank (Figure 5A) and the dated sequence in Loch Lomond. (A) $\chi^2$ values for the goodness of fit between the 17-point South Craigend profile and all possible 17-point profiles moving progressively down through the dated Loch Lomond sequence. (B) Part enlarged in (A). The minimum $\chi^2$ gives the basal age of 1824.5, say 1825 for the onset of sedimentation in the South Craigend water tank sequence (and hence the assumed age of the decline of the South Craigend lime operations).

Figure 11. OS 2nd edition 6" mapping of Culloch Slap lime works showing rebuilt kilns and new tramway (Stirlingshire Sheet 27, revised 1896, published 1899). The elevated ridge that carried this second tramway is still clear in the field. (Reproduced by permission of the National Library of Scotland)

Figure 12. OS 2nd edition 6" mapping of the former Derry Lime Works at Baldoran redeveloped in the second half of the 19th century as the Glorat Lime works showing tramways connecting kilns to the mine north of the kilns and to the mainline railway to the south. (Reproduced by permission of the National Library of Scotland)

Figure 13. Google Earth image of the draw kiln at the former Cults Lime works at Pitlessie (eastern Scotland). Note the massive square masonry structure surrounding and supporting the kiln pot (the central circular feature).