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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

Li□e is a □unda□ental co□ □onent in □any industrial□agricultural and che□ical □rocesses and is itsel□□roduced □y an industrial □rocess□na□ely□the heating in □ilns (calcining□or □ore collo□uially □□urning□) o□calciu□ car□onate roc□or other car□onate □aterial. Research and literature on li□e □urning in Scotland□□ased largely on li□e □roduction in Scotland□s eastern Central □elt□are do□inated □y the view that li□e □urning in draw □ilns is the □aradig□ □or Scottish li□e □roduction. Other □arts o□Scotland□however□largely or co□ □letely ignored draw □ilns in □avour o□si□ □ler cla□ □ □ilns□even in □a□or industrial sites o□li□e □roduction. This □a□er re□orts our □a□□and □ield□□ased surveys in Scotland□s western Central □elt□which clearly □oint to the enduring i□ □ortance and al□ost e□clusive use o□cla□ □ □ilns in that area□s historical li□e□□urning industry.

□□YWORDS: *Clamp kiln; lime; draw kiln; lime burning*

INTRODUCTION

Lime is produced by heating (burning or calcining) calcium carbonate (limestone, marble or marine shells) to 900°C.[1] Modern production is industrial in scale whereas historically production technology ranged from small single-use sow kilns to small and medium sized multi-use clamp kilns, large clamp kilns with infrastructure and stone built continuously operating draw kilns (also called shaft kilns).[2] Sow and clamp kilns are relatively simple elongated or shaped embankments or more circular (horseshoe shaped) pits (Figure 1). Elongated pits that are open at both ends have also been observed at one site.[3] Limestone and fuel (generally coal but wood and peat were also used) were interlayered in the kiln and the fuel ignited.[4] The heat calcined the limestone ($CaCO_3$) to quicklime (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.[5] 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 quicklime 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.[6] After the clamp kiln cooled the quicklime was unpacked. The lime produced by both styles of kilns could be transported away as either quicklime or slaked lime (by the addition of water to the quicklime).

Lime has of course been used for millennia in building, plastering and lime washing and there are reports that lime from Cambusie one of our areas of interest here was used in building Glasgows Medieval Cathedral which was consecrated in the late 12th century.[7] More recently liming of agricultural soils was critical to Scotlands agricultural revolution of the 18th and 19th centuries. Indeed Stout and Fenton have noted that perhaps the most important of the innovations in Scottish agriculture strang from the realization at the turn of the seventeenth century of the value of liming.[8] Hay recently reiterated the same point and liming of fields remains important for land management in Scotland.[9] Agricultural liming is important in

northern □ritain □ecause the region□s high rain□all generally results in acidic□o□ten □oorly□structured soils□and li□ ing □oth neutralises the soil□s e□cess acidity and i□ □roves the soil□s structure.[10] Li□ e is also an i□ □ortant □u□in □any industrial □rocesses□and de□ and □or li□ e increased once the industrialisation o□western Scotland was under way in the late 18th century and develo□ed □uch □ore e□tensively in the 19th century.

The earliest agricultural li□ ing in Scotland □ ay date □ro□ at least the early 17th century and li□ e was de□onstra□ly □eing □roduced in Scotland□s western Central □elt □y this ti□ e.[11] □elsches□re□ort on agriculture in Stirlingshire□the historical location o□our study area□con□ir□ s the □ore wides□read use o□li□ e in agriculture □y the □id□18th century.[12] The incor□oration o□a distinctive elongated rectangular side e□ □ay□ ent (inlet) on the south □an□o□the □orth and Clyde Canal to service li□ e draw □ilns a□out 1 □□ west o□Wynd□ord Loc□□ust outside the southern □oundary o□Stirlingshire□also con□ir□ s that li□ e □roduction was well esta□lished in that area □y 1773□when water was □irst let into that □art o□the canal.[13] A □lan in the □niversity o□Glasgow Archives□centred on the study area and dated 177□□annotates the □□an□ier□□ar□ la□el in □aldernoc□with □Coall □ Li□ e□.[14] Ross□s 1777 □a□□ing o□□Coal□and □Li□ e□at Culloch□a □ew □ilo□etres to the west o□the □resent study area□con□ir□ s □id□to late 18th□century □roduction o□li□ e in that area□ and an 180□ □ar□ □lan □or the Dougalston □state de□icts two □□sha□ed cla□ □ □ilns (□□ills□) on Long□auld □ar□ near Culloch.[15] An 1812 re□ort on Stirlingshire con□ir□ s the wides□read use o□li□ e □y the □irst decade o□the 19th century.[16]

So□the □roduction and use o□li□ e in Scotland were well esta□lished □y the end o□the 18th century. In □ar□ed contrast to the situation □or Yor□shire□however□ the technology o□Scotland□s early li□ e □roduction re□ ains s□arsely docu□ ented.[17] □onetheless□the literature continues to e□ □hasise□al□ ost e□clusively□large □ asonry□□uilt draw □ilns.[18] Indeed□Coull□s recent review re□eated the co□ □on o□servation that the □est surviving evidence o□li□ e □roduction in Scotland is the □attery o□large li□ e□ilns in Charlestown□□i□e.[19] Li□ewise□considera□le □ro□ inence is given to S□inner□s wor□on large draw □ilns in the Lothians□to the unhel□□ul (and ina□□ro□riate) e□tent that the Lothians is thought o□as □so□ ehow the □radle o□the industry□in Scotland□.[20] Indeed□e□ce□t □or □ohnson□s i□ □ortant wor□in Yor□shire□ and the crucial□□ut □erha□s not widely □nown□wor□in Scotland o□□is□et and Mac□ay□□u□lished wor□in □ritain□even the very local□generally □ocuses on

□asonry□□uilt draw □ilns.[21] This □ocus on draw □ilns is inconsistent with the wides□read re□ains o□cla□ □ □ilns in Scotland.[22] Here□we e□a□ine li□e □urning in Scotland□s western Central □elt□with a □ocus on the □arishes o□□aldernoc□and Ca□ □sie in the area now covered □y the 21st□century local govern□ent area o□□ast Dun□artonshire□□ut □or□erly in the □id□19th century county o□Stirlingshire.

ST□DY AR□A

The western Central □elt o□Scotland around Glasgow was the heartland o□heavy industrialisation in Scotland□which acco□ □anied□and then su□□lanted□the growth o□ weaving□cloth □leaching and □rinting. The e□traction and □rocessing o□the western Central □elt□s rich endow□ent o□coal and ironstone under□inned the develo□□ent o□ iron and steel □roduction and heavy engineering□including the shi□ □uilding □or which Glasgow and neigh□ouring areas □eca□e noted. Scotland□s Central □elt coal and ironstone are hosted in a ri□t valley down□aulted □etween the Southern □□lands to the south and the Scottish Highlands to the north. The sedi□ents in□lling this □a□or sedi□entary □asin □the Midland Valley □also include li□estone□as well as econo□ically i□ □ortant sandstone□□ireclay□and oil shale. In □any □laces the geological se□uence consists o□coal □eds (sea□s) that are inter□□edded (interstrati□ied) with high □uality li□estone and ironstone□□acilitating relatively easy e□traction o□these resources.[23] The □ey geological unit targeted □y the li□e □urners in □oth □aldernoc□and Ca□ □sie were the Hurlet Li□estone and Coal.[24] There has □een □uch change to geologucal no□enclature over the last century and in the Ca□ □sie area□the target has □reviulsy □een □nown as the Ca□ □sie Main Coal and Li□estone.[2□] In Ca□ □sie□a shale sandwiched □etween the coal and the li□estone was used □or □a□ing alu□ □which e□□lains why the Ca□ □sie Alu□ Wor□s□□art o□the largest alu□ wor□s in the □nited □ingdo□ □also hosted li□e □ilns (see □elow).[26]

□□traction o□the coal and li□estone □or the □roduction o□li□e is □ade □ore di□□icult□however□□y □aulting o□these de□osits. This □aulting □eans that coal and li□estone that were originally continuous across a large area a□ru□tly cut out at a □ault□where one □loc□o□the □arth□s crust has □een □oved u□or down relative to another. Thus□in □any localities□ty□i□ied □y □arts o□the western Midland Valley se□uence□the coal and li□estone that were wor□ed □or li□e □urning are at di□□erent de□ths in di□□erent □loc□s o□ground. Wor□a□le coal and li□estone are e□□ectively

absent from some locks 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 volcanic intrusions (dykes and sills) locally baked and/or burned the limestone and coal compromising 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 1:2500 (colloquially called 25 inches to the mile) are a valuable resource for understanding historical lime burning. OS used many 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).[27] Clamp kilns are generally represented by a dot symbol or an open-ended or closed rectangle—all to some extent mimicking the flat-shaped clamp kiln's plan-view morphology (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.[28]

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 1:10560 scale (six-inch) maps of central Scotland—covering broadly from west to east (and using the mid-19th century county names)—the Counties of Ayrshire—Renfrewshire—Dunbartonshire—Lanarkshire—Stirlingshire—Linlithgowshire (West Lothian)—Edinburghshire (Midlothian)—Haddingtonshire (East Lothian)—Berwickshire—Perthshire—Clackmannanshire—and Fifeshire—Kinross-shire—has been documented.[29] All 487 sheets that make up this coverage were examined—by 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 mapped kiln symbols were recorded—as well as the location of each lime kiln or

li□ewor□s□to a □recision o□□ seconds in latitude and longitude□using the latitude and longitude on the □a□sheets □argins. Other in□or□ation related to the industrial activity was also recorded□including the □resence o□□uarries□□ ines□tra□ ways□train lines□and so on. We then wor□ed our way through all 487 sheets a second ti□e□ chec□ing the □a□ □or the accuracy o□the recorded in□or□ation as well as □ o□□ing u□□any li□e□ilns or li□ewor□s that had □een □issed in the □irst □ass. We are con□ident that we have located virtually all o□the li□e□related □eatures □a□□ed on these 487 sheets.

Here the □a□data covering the 19th century □arishes o□□aldernoc□and Ca□ □sie in the □or□er County o□Stirlingshire are used to docu□ent each OS□ □a□□ed occurrence o□li□e□ilns or li□ewor□s (□igure 2). A chec□ o□OS 1st edition 2□ inch □a□s o□the area con□ir□ed that the sa□e □ilns have □een □a□□ed on □oth series and that the 2□ inch □a□s do not contain any □ore data on li□e□ilns than do the 6 inch □a□s□although the 2□ inch □a□s o□ten □ore e□□licitly □a□ and la□el □ine sha□ts□which □ay □e □a□□ed □ut unla□elled on the corres□onding 1st edition 6 inch □a□s. These □a□□ing data were su□□le□ented □y written re□orts □ro□ 1796 and 1812□the 1841□18□1□1861 and 1871 censuses□and the Old and □ew Statistical Accounts o□the □arishes o□□aldernoc□and Ca□ □sie.[30] □□tensive □ield chec□ing and □a□□ing o□un□a□□ed □ilns□guided initially □y OS □a□□ing □ut then ranging □ore widely□were also underta□en.

Gradio□eter surveys o□the South Craigend and □oghall □iln □ields were underta□en using dual and single □lu□gate gradio□eter □artington 601 instru□ents. Re□eated 20 □20□ survey grids□tied into the □ritish □a□grid using a Leica di□□erential G□S□were laid out at □oth sites using □ar□ed ro□es. The sa□ □ling used a traverse s□acing o□0.□□ and a 0.12□□ sa□ □ling interval□with a □ig□□ag survey □ode. □orty□two standard 20 □20□ grids were surveyed at □oghall and □our standard grids at South Craigend□□ollowing □nglish Heritage□s reco□ □endations □or □agneto□eter survey in archaeological □ractice.[31]

The □a□□ing o□□ilns also located other in□rastructure□including roads □ro□ the □iln □ields □or□we assu□e□the carriage o□li□e □or on□trans□ort to destinations □urther a□ield. A rectangular□stone□lined tan□at the to□ o□the South Craigend li□e road in □aldernoc□is in□illed with a□out 0.□□ o□organic□rich sedi□ent overlying a thic□clay seal on the □otto□ o□the tan□. We cored this sedi□ent with a Russian corer to 0.7□ de□th□and used □□rays o□the core and standard sedi□entological

analyses to identify the base of the most abandonment sediment infill over the basal seal. The cored sediment was sampled at 2cm depth intervals except for three 0.5cm sampling intervals and analysed by ICP-MS for total lead (Pb) at the Scottish Universities Environmental Research Centre (SUERC) Past Pilgride using standard SUERC procedures and protocols.[32] These total lead contents were used to estimate the basal age of the sediments infilling as an estimate of the age of 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 Barber et al.'s ^{210}Pb-dated profile of total Pb from Loch Lomond about 20 km W of the Baldernock area.[33] 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 hill dam in Baldernock—in that case by matching by eye the dated peaks and troughs in the Loch Lomond Pb record to the peaks and troughs in the hill dam sediment record of total Pb.[34] Here we used a more rigorous wiggle-matching approach derived from radiocarbon dating.[35]

LIMESTONE QUARRYING 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 classified kilns (Table 1) there are no draw kilns in the area. That total number of classified 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 often 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 4A). All lime workings are located on occurrences of

li□estone and coal in outcro□or at shallow de□th□with the discontinuous nature o□ the □a□or concentrations o□li□e wor□ings across the area □eing related to the □aulting and disru□tion o□the □eds. All clusters o□□ ulti□le □ilns are grou□ed near or around □uarries or □ine entrances□as at □oghall (Ta□le 1 □1 □□igure 3)□Hole (Ta□le 1 □3□□igure 4)□South Craigend (Ta□le 1 □□□□igure □)□□lairs□aith Trig □oint (Ta□le 1 □6□□igure 6)□and Glenwynd (Ta□le 1 □7□□igure 7). Indeed□no li□e □ilns are □ar □ro□ a □ine or □uarry□even slightly isolated individual □ilns□such as the individual Grou□ 8 □ilns at South Craigend (□igure □). Where □ilns and □ine were se□arated□ even only □y a short distance□tra□ ways on narrow linear elevated ridges o□ten connected □iln and slightly distant □ine (e.g.□Hole □ □igure 4□□lairs□aith Trig □ □igure 6). Overall□then□the □attern is that □aldernoc□ □ilns□□e they clustered or individual□were essentially always close□or well connected□to □ines.

O□□RATIO□ O□ TH□ □ALD□R□OC□ CLAM□ □IL□S

The clusters and/or lines o□cla□ □ □ilns □resu□a□ly □acilitated a cycle o□loading□ □urning□cooling□and unloading the □ilns in se□uence□with each □iln in the cluster □eing at a di□□erent □oint in the cycle. The □ilns ad□acent to □ine entrances would □resu□a□ly have □een charged with li□estone and coal directly □ro□ the □ines□a□ter □rea□ing o□the li□estone and coal to a□□ro□riately si□ed □rag□ents□whether the □ilns were individual □ilns with ad□acent □ine sha□ts□or cluster or □an□s o□□ilns ad□acent to a sha□t (e.g.□Glenwynd □ Ta□le 1 □7□□igure 7).

A □ine a□andon□ent □lan that includes the South Craigend li□e □ilns and is □ased on OS 1st edition □a□□ing shows the □ilns clustered around the □ine entrance □ro□ where the □ilns would □resu□a□ly have □een serviced □y a tra□way[36]. The □lan indicates that the □ine □eing a□andoned was wor□ing □ac□□ □anded ironstone □ut the e□□licit identi□ication o□areas o□□solid li□estone□and □solid li□e□on the □lan con□ir□s that the □iners were also e□tracting (or had □reviously e□tracted) coal and li□estone.[37] The coal and li□estone would have □ed the □ilns clustered around the □ines □ain entrance□which is still visi□le as a degraded (in□illed) gully□li□e □eature cutting into the hillside.

The gradio□eter survey o□the South Craigend □ilns indicates su□□sur□ace structures a□□arently □resent □eneath and □etween □ilns (□igure □□). We inter□ret these structures□which are yet to □e e□cavated□to □e su□□sur□ace □lu□ □ing□to aid

the o□eration o□the □iln□□erha□s □eing si□ilar to the ty□es re□orted □y Radcli□e in □eat□ired cla□ □ □ilns in early 19th□century Scotland and □y □ohnson fro□ e□cavations in Yor□shire[38]. Car□on dio□ide□the □a□or □y□□roduct in calcining li□estone□had to □e vented away or else it would have □uenched the □la□e. Thus□it was essential that a □iln □e vented□while also not allowing too □uch o□ygen to the □la□e□which could have over□heated and vitri□ied the li□estone. A □ile o□□iln waste ad□acent to the South Craigend □ilns (□igure □A) includes lu□ □s o□such vitri□ied and □over□coo□ed□stone.

OTH□R I□□RASTR□CT□R□

As well as tra□ways□in□rastructure in the □aldernoc□li□e industry included now□ a□andoned lanes/roads that connected the □iln □ields on the higher ground o□the u□land □uirs (□oors) to trans□ort routes on lower ground (□igures 8 and 9). □ach li□e road□is now □an□ed on either side □y a line o□straggly hawthorn trees that have □grown□on□□ro□ the hedges that lined the roads. The roads were well□□ade with □uilt□u□e□ □an□□ents and □asonry□lined cuttings to □aintain the gradients □or (□resu□a□ly) horse and cart. The detail o□the construction o□these roads awaits □urther investigation □ut they have so □ar revealed no evidence o□tra□ways. It is s□eculated that the rectangular□□1 □ □dee□□stone□lined tan□at the to□ o□the South Craigend li□e road (□igure □)□□rovided water □or horses at the to□ o□a long cli□ □. Running water at the to□ o□the cli□ □ would have □et that need □or the Glenwynd li□e road□and the Langshot li□e road□the least stee□ o□the three li□e roads□had a rectangular tan□at the □otto□ o□the hillslo□e that the road serves□as evidenced on OS 1st edition 2□ inch □a□□ing.

The li□e roads were □or trans□orting the li□e to lower elevations□and then□□or so□e o□this li□e□to the □orth and Clyde Canal that connected Scotland□s west and east coasts□and (with the □nion Canal) Glasgow and □din□urgh (□igure 9). An 1822 advertise□ent in the *Glasgow Courier* advised that □algrochan Li□e (□algrochan □eing at the □oot o□the Glenwynd and Langshot li□e roads □ □igure 8) was □eing sold at Hungryside □on the canal □an□□as well as at the □algrochan Li□e Shed at □ort□Dundas□the Glasgow ter□inus o□the canal.[39] The *Glasgow Herald* advertised the lease o□South Craigend □ar□ and its li□e and coal wor□in 18□0□noting that □the □orth and Clyde Canal Whar□at Hungryside is within three □iles o□the Mines□.[40] So□

li□e and coal were trans□orted at least three □iles □y cart to the canal. The lin□ □etween South Craigend □ar□ and the canal had □een an enduring one □ecause the 1836 inventory o□an intestate South Craigend □ar□er included: □two hundred chalders o□li□e□the stoc□o□coals□li□e □c u□on the hill or at the wor□s□and a share o□a □oat or scow on the canal□.[41]

Other in□rastructure associated with li□ewor□s included large drains and□ □resu□a□ly □u□ □s□at □lairs□aith Trig (□igure 6). The □looded □ine entrances in the Trig area con□ir□ that there was a water □ro□le□ in these □ines□des□ite the wor□s □eing on a local high □oint that was su□□iciently elevated to host a trigono□etrical survey □oint. The u□hill end o□the northern o□the two large drains that lead away □ro□ the li□e □ilns area is ad□acent to an oval water□illed de□ression (□igure 6). This de□ression is inter□reted as a colla□sed sha□t □or □u□ □ing water□□resu□a□ly □y a stea□ □□owered □u□ □. The location o□the sha□t and □u□ □ □or the drain directed to the west □ro□ the southern edge o□the Trig □iln □ield is unclear.

AG□ O□ TH□ □ALD□R□OC□ □IL□S

It is li□ely that the oldest □aldernoc□ □ilns are the two □an□s o□horseshoe□sha□ed □ilns at □oghall that were not □a□□ed □y the OS (□igure 3). These □ilns now have no sur□ace to□ogra□hic e□□ression and were al□ost certainly well□and□truly de□unct □y the ti□e o□□id□19th century OS □a□□ing.[42] These are a□ong the s□allest □ilns investigated here and they evidently lac□ the so□histication o□the su□□sur□ace □lu□ □ing seen at South Craigend (□igure □□). Moreover□it is clear □ro□ elsewhere that the horseshoe□sha□ed cla□ □ □iln is an early □or□ □nota□ly □ro□ a□out 20□□ to the northeast o□□aldernoc□in □□□er □annoc□□urn□where the horseshoe□sha□ed cla□ □ □iln is overwhel□ingly nu□erically do□inant and where Harrison has concluded that li□e □urning was early (□□y the late 16th century□and □erha□s long □e□ore□).[43]

Al□eit the horseshoe□sha□ed □iln is li□ely to □e the early cla□ □ □iln □or□ □it continued to □e used and is □resent in s□all nu□□ers a□ong the □aldernoc□ cla□ □ □ilns□nota□ly at South Craigend (two □ilns) and at the □lairs□aith Trig □iln□ield (two □ilns). These horseshoe□sha□ed □ilns are side□□y□side with the □ore usual □□sha□ed □ilns and a□□arently have the sa□e degree o□weathering and □ost□a□andon□ent degradation□□ointing to their □eing o□a□□ro□i□ately the sa□e age as the □□sha□ed

□ilns. □otwithstanding the continued use o□the horseshoe□sha□ed □or□ o□□iln□it is nonetheless concluded here that a concentration o□the horseshoe□sha□ed □or□ indicates an early □hase o□the industry.

It is clear that the □aldernoc□li□e industry o□erated over a considera□le ti□e interval. □ilns in several localities have □een □ac□□illed □y later activity□leaving □iln re□nants with □artially in□illed □ac□ends□nota□ly the South Craigend grou□ 7 □ilns (□igure □A)□where only short re□nants o□the ends o□the horns o□the seven grou□ 7 □□sha□ed cla□ □ □ilns are visi□le at the □oot o□a slo□e □or□ing the edge o□an e□tensive and highly □odi□ied area that was □ro□a□ly a wor□ area □or later □ining. One cla□ □ □iln is also in□illed □ro□ the □ac□at □orth □ardowie□an area not discussed here □eyond noting that it was revived in the □irst two decades o□the 20th century (see Discussion□□elow).

It is assu□ed that the sedi□entation and in□illing o□the rectangular□□1 □ □ dee□□stone□lined tan□at the to□ o□the South Craigend li□e road (□igure □) re□lected the decrease in activity in the area and associated lac□o□□aintenance o□ in□rastructure as the industry wet into decline. The χ^2 statistic □or the □est □it □or wiggle□□atching the stratigra□hic se□uence o□lead in the in□ill sedi□ents to the dated lead □all□out record in Loch Lo□ond yields a □asal age o□the in□ill sedi□ents o□ calendar year 1824.□(□igure 10). In □act□the values o□the χ^2 statistic □or □asal ages ranging □ro□ 1819 to 1843 are all low and □ro□a□ly all statistically signi□icant (or at least not statistically signi□icantly di□□erent □ro□ each other). The wiggle□□atching □y the □acon so□tware yields a □asal age □or the South Craigend sedi□ent in□ill o□ calendar year 1828□with a 9□□ con□idence range o□calendar years 1831.6 to 182□.□. The □atch □etween the two totally inde□endent a□□roaches to wiggle□ □atching the South Craigend curve to the dated Loch Lo□ond curve is i□ □ressive.

We ta□e these data to □ean that the South Craigend water tan□started to in□ill in the second □uarter o□the 19th century and that the South Craigend li□e road □re□dated the second □uarter o□the 19th century (and □ro□a□ly long □re□dated that date□given the scale o□the li□ewor□s at South Craigend). This li□e□□urning locality was□nonetheless□in decline □y the second □uarter o□the 19th century□□ut it was not co□□letely de□unct: the 1841 census o□□aldernoc□records 14 individuals connected with the □roduction and sale o□li□e in the □arish□including three li□e □asters□two coal and li□e □asters□□ive li□estone □iners and one li□e □iner□two li□e □urners

and one li□e sales□an (Ta□le 2). These were living in South Craigend□□arraston and Dru□ loc□art and the near□y houses o□Linn□an□□□an□ier□Haughhead and Red □iln[44] (□igure 8). □aldernoc□coal □iners nu□ □ered 12 in 1841□all residing in Hole e□ce□t one in the neigh□ouring □arraston.[45] The industry was in decline□however□ □ecause□□y the 18□1 census□the nu□ □ers involved in li□ e had dro□□ed to si□□all residing in Linn□an□□Dru□ loc□art or Haughhead□and in coal to seven□living in □arraston□Red □iln or Hole. The 1861 census (Ta□le 2) reveals that the decline was continuing□with only one □erson□s e□ □loy□ ent recorded as li□ e□related (a □li□ e □uarrier□living at Haughead □ □igure 8). In 1871□there were no li□ e wor□ers in □aldernoc□and only seven e□ □loyed in coal.

The industry□s ter□inal decline □y the □iddle o□the 19th century in the area o□ South Craigend is also signalled □y OS 1st edition □a□□ing o□all o□that area□s □ilns as □Old Li□ e□ilns□□which is ta□en to □ean that the □ilns were no longer □unctioning.[46] This decline in the li□ e industry in □aldernoc□is also con□ir□ ed □y advertise□ ents □or the lease o□South Craigend. The 18□0 *Glasgow Herald* advertise□ ent noted a□ove was not the last ti□ e the lease o□the □ar□ and the associated □inerals were advertised. They were in □act advertised in the *Glasgow Herald* a rather astonishing 24 ti□ es in 13 □ onths in 18□7 and 18□8□thus:

> Mineral □ields in the □arish o□□aldernoc□□Stirlingshire□□or sale. To □e sold□□y □rivate □argain □ □irst a lease o□the coal□li□ estone and ironstone in the □ar□ o□Hillhead and certain □arts o□the □ar□ s o□South Craigend and □an□eir□and second a lease o□the coal□li□ estone and ironstone□and the □yrites□alu□ □schistus□□c in the lands o□□arraston. □oth □ields are o□ened u□ □y □eans o□□its□in □artial o□eration.[47]

It see□ s that the leases were not attractive□with three □urther notices in the *Glasgow Herald* in 1861 advertising the lease o□South Craigend□□ut this ti□ e without □ ention o□the coal□li□ estone and □lac□□□anded ironstone□□erha□s signalling the □inal de□ ise o□the □inerals activity around South Craigend.[48] In the sa□ e way□the e□ □loy□ ent o□the South Craigend inha□itant in the 18□1 and 1861 censuses is si□ □ly that o□□ar□ er□with no □ ention o□the Li□ e Master e□ □loy□ ent o□two South Craigend inha□itants in the 1841 census. So□the li□ e industry in □aldernoc□was in decline co□ ing u□ to the □ iddle o□19th century and □aded a□ter

that. The situation in Ca□ □sie has si□ilarities to and □arallels with that in □aldernoc□ □ut there are i□ □ortant di□□erences.

LIM□ □□R□I□G I□ TH□ CAM□SI□ AR□A

S□ATIAL DISTRI□□TIO□

□igure 2 shows the distri□ution o□the li□e□□urning areas in the central □arts o□ Ca□ □sie □arish□Ta□le 1 indicates the re□ains o□□ ore than 3□ □ilns□all o□the cla□ □ □iln □or□ □as in □aldernoc□. As also in □aldernoc□□there are no draw □ilns in the Ca□ □sie area. The □rinci□al areas to □e discussed here are Culloch Sla□□□aldoran and Sculliongour (also so□eti□es con□usingly called □algrochan). The other Ca□ □sie area□near Glorat House (□igure 2)□is not treated in detail here□e□ce□t to note that the □id□19th century OS 1st edition □a□□ed □ive cla□ □ □ilns that were o□erating there as the Glorat Li□e Wor□s□ad□acent to a □Coal and Li□estone Mine□. This wor□s had closed □y the late 19th century 2nd edition □a□□ing□with the □ilns un□a□□ed and the □ine □eing la□elled as □Old Coal and Li□estone Mine□□and the na□e □Glorat Li□e Wor□s□now a□□lied to the larger li□e wor□s near□y□here na□ed □aldoran (see □elow).

The 1st and 2nd edition OS □a□□ing con□r□ that the re□aining Ca□ □sie li□ewor□s were characterised □y renewal and regeneration rather than the decline o□served in □aldernoc□. In the □id□19th century 1st edition □a□□ing□the Sculliongour Li□e and Coal Wor□s had □our cla□ □ □ilns in a line□with a □i□th □ehind those□all i□ □ediately ad□acent to □Mines□. The OS 2nd edition shows that □y the late 19th century these had □een re□organised and re□□uilt as a □an□o□□ive larger cla□ □ □ilns in a line□with three s□aller cla□ □ □ilns in a □er□endicular line at one end o□the □ive□all served □y three tra□ways to the □id□19th century □ine and to □ore distant □ines a□out 200□ □ro□ the □ilns.[49]

The Culloch Sla□ Li□e wor□s (□igure 11) and li□e □ilns at the ad□acent Ca□ □sie Alu□ Wor□s are treated here together. Cla□ □ □ilns were the sole □eans o□ li□e □roduction □a□□ed in the □id□and late 19th centuries at □oth Culloch Sla□ and the Alu□ Wor□s. □oth sites were o□viously su□stantially re□organised in the second hal□o□the 19th century□with Culloch Sla□e□□anding its networ□o□□ ine tra□ways□

as well as re□uilding and reducing the nu□ □er o□□ilns (seven to □ive□all cla□ □ □ilns)□ □ut also a□□arently enlarging the □ilns (□igure 11). The eight Alu□ Wor□s cla□ □ li□ e□ilns were also connected to their □ines □y tra□ ways and to the Ca□ □sie □ranch / □lane Valley □ranch Railway □y the □id□19th century. The 2nd edition OS □a□□ing indicates that the nu□ □er o□Alu□ Wor□s □ilns re□ained at eight□□ut they were re□uilt□su□stantially re□organised and enlarged in the second hal□o□the 19th century (Ta□le 1).

OS □a□□ing also con□ir□s □a□or re□organisation and e□□ansion o□the li□ ewor□s at □aldoran in the second hal□o□the 19th century (□igure 12). Mid□19th century OS □a□□ing shows a s□all Derry Coal □ Li□ e Wor□s o□erating at □aldoran with two cla□ □ □ilns ad□acent to a □Li□ estone Mine□. A little to the east o□these wor□s are □a□□ed eight a□andoned cla□ □ □ilns □a□□ed as □Old Li□ e□ilns□ad□acent to an □Old Li□ estone □it□ □y the late 19th century□the li□ ewor□s had □eco□ e the □Glorat Li□ e Wor□s□and had □een reorganised and enlarged (□igure 12). The two □id□19th century cla□ □ □ilns had □een re□laced □y □ive larger cla□ □ □ilns that were serviced □y tra□ ways□one leading □ro□ the □ine to a □at □lat□or□ a□ove the □ac□s o□the □ilns □ro□ where the □ilns were □resu□a□ly loaded□and one □ro□ the □ronts o□the □ilns downhill to the Ca□ □sie □ranch / □lane Valley □ranch Railway (□igure 12). These □ilns were now a □a□or industrial o□eration with a direct connection to the □ainline railway syste□ that necessitated a □ridge across the Gla□ert Water to □oin the railway□and with one o□the largest cla□ □ □iln that we have seen in this study□ a□out 1□□ long and □ore than 2□ dee□ (□igure 12). It is also □ossi□le that the s□all u□land wor□s a□ove the Glorat Li□ ewor□s that had □een □a□□ed as □Old□ (a□andoned) in the □id□19th century saw late□stage revival. Here□i□ □ediately ad□acent to a sha□t□with a second (□ossi□ly air) sha□t so□ e 7□□ to the north□three o□ the eight □ilns have had their horns shortened. This □ro□□ed□out□□aterial has evidently □een used to renovate one or two □ilns□which loo□ □resher and less degraded than the other seven□and □ay there□ore have □een used □ ore recently.

I□□RASTR□CT□R□ A□D AG□ O□ TH□ CAM□SI□ □IL□S

It has already □een noted how the Ca□ □sie li□ e □ilns already had su□stantial in□rastructure associated with the□ □y the □id□19th century□including tra□ ways to □ines and to the railway networ□. It is thus □ossi□le (□ut □erha□s unli□ely) that the

□algrochan Li□e□noted a□ove as □eing advertised □or sale in the *Glasgow Courier* advertise□ent o□23 May 1822 ca□e □ro□ the □algrochan that is near Lenno□town (i.e.□Sculliongour) and had □een trans□orted □y rail to Glasgow□thence □y cart to □ort Dundas and canal to the Hungryside □ridge.[□0] I□that route is unli□ely as an e□□lanation □or the li□e in that □articular advertise□ent□it is nonetheless clear that Ca□ □sie li□e would have □een trans□orted □y rail.

OS □a□□ing □a□es clear that li□e □roduction in the Ca□ □sie district e□□anded during the second hal□o□the 19th century. Su□se□uent OS □a□□ing shows that the □aldoran (Glorat) and Culloch Sla□ li□e wor□s had □eco□e de□unct □y the ti□e o□the 1914 revisions o□the 6 inch and 2□inch sheets. These 1914 revisions o□the 6 inch and 2□inch □a□s also de□ict the Ca□ □sie Alu□ Wor□s as □Disused□□□ut there is disagree□ent □etween the two □a□series on the li□e□ilns at the alu□ wor□s. The 1914 revision o□the 6 inch □a□□ing □a□s the li□e□ilns as □Li□e□ilns□without the □Disused□la□el□i□ □lying that they were still o□erating at that ti□e□□ut the corres□onding 2□inch □a□does not □a□the li□e□ilns at all and la□els the whole area o□the alu□ wor□s including the area where the li□e□ilns were located as □Disused□.Ta□en as a whole□the □a□data indicate that li□e □roduction in the Ca□ □sie area had □eco□e de□unct □y the end o□the second decade o□the 20th century.

The continuing 19th□century vigour o□li□e□□urning in Ca□ □sie is re□ected in the Ca□ □sie □arish census data (Ta□le 2)□with the □ore□than dou□ling o□ e□ □loy□ent in li□e □etween the 1861 and 1871 censuses □resu□a□ly re□ecting the develo□□ents noted a□ove and in Ta□le 1. Ta□le 2 also shows that e□ □loy□ent in coal □ining in Ca□ □sie □arish li□ewise increased throughout the second hal□o□the 19th century□and so□e o□that increase is al□ost certainly related to the li□e industry (i.e.□coal □iners who were □ining coal □or li□e□□urning □ut whose occu□ations were returned as related to coal).

DISC□SSIO□

The Ca□ □sie li□e industry □ourished in the second hal□o□the 19th century □y which ti□e the □aldernoc□industry was essentially de□unct. S□all local o□erations did continue in □aldernoc□right u□until the early 20th century□with a current resident

recalling his grandfather's leasing and operating of the limestone mine and clamp kiln(s) at North Cardowie in Caldernock Parish in the early 1900s. This operation employed two men to produce lime that was taken by horse and cart to Cardowie railway station (Figure 2) for transport on the former North British Railway Kelvin Valley Railway line to Glasgow.[1] To all intents and purposes however the industry in Caldernock faded as the Carmyle operations grew. The Carmyle industry itself then faded.

The brief early 20th century revival of the industry in Caldernock and its reliance on the railway for transport perhaps points to why the industry had earlier faded in Caldernock but continued in Carmyle namely the railway system. We have argued above that the apparent focus of the Caldernock 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 lime kilns are mapped on the canalside 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 Balfron.[2] Likewise a major canal wharf to the west of Balfron in the middle of the Central Belt is known as Lime Wharf and connects with a local 'Lime Road'. But 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 Caldernock limeworks to compete with limeworks better situated in relation to emerging transport links.[3] Thus these limeworks were already defunct by the time of the mid 19th century OS mapping except for one group of kilns at Blairskaith Trig and perhaps the odd one or two other kilns. The Carmyle kilns on the other hand were clearly operating in the mid 19th century and had invested in the infrastructure of tramway connections to the mines and in the case of the Alum Works lime kilns to the mainline railway system. Carmyle's major groups of kilns then reorganised and expanded in the second half of the 19th century installing larger kilns and maintaining Alum Works Limeworks for developing Glorat Limeworks connections to the railway system. The mid 19th century Glorat House limeworks was closed by the late 19th century but the Sculliongour works more distant from the railway was reorganised in the second half of the 19th century. Presumably its lime was carried to the nearby railway by horse and cart.

I□the s□all horseshoe□sha□ed □iln□which is the only □iln ty□e □resent at □oghall and is occasionally seen elsewhere in □aldernoc□□re□resents the early stages in the evolution o□cla□ □ □ilns□as the co□ □ents o□Harrison and Mac□ay indicate□with the technology then evolving into the □□sha□ed □ilns that cul□inate in large industrial□ scale cla□ □ □ilns □ore than 1□□ long□then li□e □urning technology □ased on cla□ □ □ilns in Scotland□s western Central □elt evolved over the li□e o□the industry in the □aldernoc□□Ca□ □sie area.□4 An inter□retation that the earlier □hases o□the industry were in □aldernoc□is su□□orted □y □oghall□s □an□o□17 horsehoe□sha□ed cla□ □ □ilns. S□all horseshoe□sha□ed □ilns continued to □e used locally in □aldernoc□□at □oth the South Craigend and □lairs□aith Trig □iln□ields□and only one □ossi□ly horseshoe□sha□ed cla□ □ □ilns has □een identi□ied in Ca□ □sie (at the Old Li□e □ilns to the east o□□aldoran□s Glorat Li□e Wor□s□ □igure 12). In other words□it can □e argued that the □aldernoc□industry develo□ed earlier than that in Ca□ □sie□though caution is needed with that inter□retation □ecause the wides□read redevelo□□ent o□ the Ca□ □sie industry could have o□literated re□ains o□any horseshoe□sha□ed cla□ □ □ilns.

Whatever a□out that □oint o□detail□the □unda□ental □oint to □e □ade here is that cla□ □ □ilns re□ained the sole technology □or li□e □urning in the study area□not one draw □iln has □een identi□ied in an area that has evidence o□□ ore than 1□0 cla□ □ □ilns. Thus□there is no evidence that tenant □ohn Lochry□s underta□ing in a letter o□□uly 29 1813 to □ohn □incaid□the owner o□the Woodhead □state that covers the study area□□□ind□ing Lochry□... to □uild a draw □iln □or □urning li□e in the course o□the ne□t year□was ever □ul□illed.□□

The e□clusive □ocus on cla□ □ □iln technology in a □a□or li□e □□roducing area highlights the ina□□ro□riateness o□the wides□read and al□ost e□clusive e□ □hasis on draw □ilns as e□ □le□atic o□the historical li□e industry in Scotland. □ohnson□s re□ar□ in relation to Yor□shire □ □It is regretta□le that there is no □ recognition o□the role o□cla□ □ □ilns in the develo□□ent o□li□e □urning technology□□ evidently a□□lies e□ually to Scotland.□6 Re□e□ □ering that in this area the relevant □art o□the geological se□uence consists o□li□estone inter□edded with coal□it is reasona□le to conclude that the do□inance o□cla□ □ □ilns in the □aldernoc□□Ca□ □sie area □artly re□ects the relative ease o□o□taining the li□estone and coal with which to charge the

□ilns. This inter□retation is consistent with the siting o□□ilns i□ □ediately ad□acent to □ine entrances □ro□ where the coal and li□estone could □e loaded directly into □ilns. □ut it □ust also □e re□e□ □ered that li□e□urners o□ten □re□erred cla□ □ □ilns. Thus□Car□ichael noted in the 1830s:

> These □cla□ □□□ilns are □re□erred □y □any to the draw □ilns□on account o□the slow and su□erior □anner in which the stones are calcined□ whereas the □ractice o□daily re□oving a □uantity o□li□e □ro□ the draw □iln□either hurries the o□eration or de□eats it□□ringing down the li□estone □e□ore it is thoroughly calcined.□[7]

The installation o□large cla□ □ □ilns at the Glorat Li□e Wor□s at □aldoran (Ca□ □sie) in the second hal□o□the 19th century is telling in this regard□in that the o□erators o□ a □a□or industrial□scale li□e□□urning venture□connected □y a tra□way to the □ainline railway syste□ □installed large (1□□ long) cla□ □ □ilns. OS 2nd edition 2□ inch □a□□ing o□the □al□a□□ray area near Milngavie shows that si□large cla□ □ □ilns u□ to 16□ long were also installed there□a□out 7 □□ west□south□west o□the □aldernoc□study area□in the second hal□o□the 19th century□again□draw □ilns were not used.□[8] This enter□rise□la□elled □□al□a□□ray Wor□(Coal □ Li□e)□on OS 2nd edition □a□□ing□was not close to a rail line □ut the road connections to Glasgow see□ to have □een reasona□le.

The □re□erence □or cla□ □ □ilns is also evident in other □arts o□central and western Scotland. It has already □een noted that the 4□ horseshoe□sha□ed cla□ □ □ilns in u□□er □annoc□□urn (Stirlingshire) are li□ely to □e early. Around □raehead in Lanar□shire□to the southeast o□the □resent study area□Ward has geo□re□erenced □ore than 140 cla□ □ □ilns.□[9] Si□ilarly□□is□et docu□ents □any tens o□cla□ □ □ilns in Ren□rewshire in western Scotland□noting that they were used□as in □aldernoc□ and Ca□ □sie□throughout the li□e o□the li□e□□urning industry in highly organised□ industrial□scale o□erations[60]. □is□et also co□ □ents that cla□ □ □ilns were o□ten used side□□y□side with draw □ilns□□ut notes various reasons □or □re□erring the cla□ □ □iln□ to which can □e added the reason noted here□na□ely□their ease and si□ □licity o□ o□eration when □oth li□estone and coal occurred together in the geological se□uence. □is□et noted that so□e o□the large cla□ □ □ilns in Ren□rewshire were □ore than 20□ in length (i.e.□larger than the largest cla□ □ □iln identi□ied in this study) and i□ □lied that cla□ □ □ilns were o□ten □re□erred even when the coal had to □e □rought to the li□estone. And □inally on this □oint o□the u□i□uity o□cla□ □ □ilns in

western Scotland□a *geograph* we□site□□Relics o□the li□estone industry on Du□□arton Muir□docu□ents □any old li□e□related □eatures on Du□□arton Muir□ including li□estone □uarries□trac□s related to the li□e industry and cla□□□ilns.[61] Incidentally□later draw □ilns are also docu□ented □or this Du□□arton site.

It is also clear □ro□ the historical literature□as well as the □ro□ re□ains o□ draw □ilns the□selves□that there was no universally acce□ted design □or draw □ilns□ which were su□□ect to considera□le stresses when □ully loaded and □eing □ired.[62] Co□□on solutions to this issue included the □ost□construction □uttressing o□the □asonry □ilns and/or enclosing o□the □ot o□the draw □iln within a □assive (and □resu□a□ly e□□ensive) □asonry structure □ro□ the outset (□igure 13).[63] Such solutions were □resu□a□ly dee□ed necessary to □usti□y the cost o□□ringing in the raw □aterial when coal or li□estone had to □e □rought to the li□ewor□s and □iring o□ the □iln was (se□i□)continuous. At the Charlestown whar□side li□ewor□s□□or e□a□□le□coal was □rought in □y rail □ro□ Dun□er□line and the li□estone □uarried on□site.[64] □resu□a□ly the cost o□trans□orting coal was o□□set □y □eing a□le to □ire the draw □ilns continuously and then to load the li□e directly into shi□s □or trans□ort to □ar□ets throughout eastern Scotland□as well as □y the returns □ro□ shi□□ing and selling coal itsel□.[6□] When either coal or li□estone had to □e □rought to the □iln□it generally □ade sense to locate the □ilns at the source o□li□estone □ecause o□the □0□ weight loss in calcining li□estone to li□e and the generally higher □ro□ortion o□ li□estone to coal in the □iln charge (see a□ove).

Thus□and notwithstanding □any li□e□urners□□re□erence □or draw □ilns and these □ilns□undou□ted wides□read use in Scotland□it re□ains clear □ro□ Ca□□sie□s Glorat Li□ewor□s and Culloch Sla□Li□ewor□s and the □al□a□ray Wor□s□as well as □ro□ □is□et□s wor□in Ren□rewshire□that cla□□□ilns were a □er□ectly via□le and econo□ic technology □or industrial□scale □roduction o□li□e until at least the end o□ the 19th century. The re□uilding o□□oth o□the Glorat and Cullch Sla□Li□ewor□s in the second hal□o□the 19th century□the considera□le si□e o□these wor□s□largest cla□□□ilns□and the li□ewor□s□connections □y tra□ways □oth to □ines and to the □ain rail networ□□or shi□□ing o□the li□e□all con□ir□ the scale o□the li□ewor□s□ in□rastructure and econo□ic invest□ent.

The cla□□□iln was a low□cost and relatively straight□□orward way to □urn li□estone □ut the □ethod nonetheless needed care and attention. As we have noted□ the li□e □urner □aced two contrary challenges: cla□□ing the □iln was necessary in

order to control the rate o□□urning and hence the te□ □erature □too hot and the li□estone would have □een calcined to useless□over□ired clin□er stone □ □ut calcining li□estone □roduces car□on dio□ide which e□tinguishes □la□e i□it is not vented and/or i□o□ygen is not su□□lied to the □urning charge. Historical accounts o□ li□e □urning in cla□ □ □ilns in □aldoran noted the need to su□□ly air to the □urning charge□this challenge □eing □et at □aldoran □y the □iln □carry□ing□three s□all □i□es or □ens through the □otto□ □and u□ the sides and ends o□the □iln□in order to give the□ air.[66] □urther gradio□eter survey and e□cavation o□the □aldernoc□cla□ □ □ilns re□orted here will con□r□ i□the su□□sur□ace □eatures tentatively identi□ied in the South Craigend gradio□eter survey are indeed □lu□ □ing to control the air su□□ly.

STR□CT□R□ O□ I□D□STRY

The Glorat Li□ewor□s de□onstrate that the industry was highly organised □y the late 19th century □ut it is e□ually clear that that degree o□organisation had e□isted □or a considera□le ti□e as □a□or clusters o□□ilns around □ine o□enings are co□ □on throughout the □aldernoc□□Ca□ □sie area□including at South Craigend□□lairs□aith Trig□□aldoran□Culloch Sla□□□oghall□and so on. □□ually□there were s□all□scale□ indeed □erha□s lone□o□erators□such as at South Craigend□□ut even these s□all□ scale o□erators generally located their □iln close to a □ine.

The news□a□er advertise□ents noted a□ove indicate that the li□ewor□s o□eration was □y landowners and estates leasing out the □ineral rights. Leases co□ □only included incentives □ro□ the landowner□such as those in an 1813 lease □etween □ohn □incaid o□□incaid (the landowner) and □ohn Lochry (Loughry) in which □incaid agreed to □ay □100 towards the sin□ing o□a □it to the coal □ □30 when the □it had reached 1□ □atho□s□□30 on reaching the coal□and the re□aining □40 when the a□ove□ground wor□s leading to the wor□s were □inished.[67] The lease also o□liged the landowner to □rovide the gin (winding gear)□gin ro□es and hutches□ windlass wheel and ro□es and other □aterial used □or □oving □aterials and □en u□ and down the □it sha□t. And thirdly□rent was □100 □or the □irst year (□resu□a□ly as an incentive when there was no □roduction)□□ut then rose to □160 years □or the re□aining nine years o□the lease □lus Lordshi□s o□one ninth o□the gross out□ut o□ coal□one seventh □art o□the sale o□li□e and one shilling □er ton o□the sale o□ □green□(un□urnt) li□estone.

Co□cL□sIO□S

□ohnson has co□ □ented that li□e is the Cinderella o□industrial archaeology.[68] The results □resented here □ean that that can □e e□tended to say that cla□ □ □ilns are the Cinderella o□li□e □iln archaeology □rarely investigated and even □ore rarely e□cavated. The a□undance o□cla□ □ □iln re□ains in the □aldernoc□□Ca□ □sie area □rovides the o□□ortunity to e□□lore the details o□this technology□there□y to e□tend □ohnson□s intriguing results on cla□ □ □iln structure and □unction.[69] The e□clusive use o□cla□ □ □ilns in the □aldernoc□□Ca□ □sie area is reasona□ly e□□lained □y a co□ □ination o□a regional □re□erence □or cla□ □ □ilns (i.e.□local custo□ and □ractice) and the □ossi□ility o□e□tracting inter□edded coal and li□estone in the one □ine or □uarry. That hy□othesis □ust await □urther archival wor□□□ut even i□□oth □actors are con□ir□ed□it re□ains clear□□ro□ the historical literature on li□e□urning and □ro□ □is□et□s data □ro□ Ren□rewshire□that so□e li□e□urners si□ □ly □re□erred cla□ □ □ilns□and that cla□ □and draw □ilns o□erated side□□y□side at the □ea□o□li□e□ □urning in Scotland□s western Central □elt. In other words□the cla□ □ □iln was itse□□a so□histicated technology that was not si□ □ly a □recursor to □ore so□histicated draw □ilns. The s□ill re□uired to o□erate a cla□ □ □iln□□oth in ter□s o□loading it and then controlling the □urn□could □e rewarded □y a higher □uality li□e□as Car□ichael □ointed out.[70] In short□cla□ □ □ilns were not necessarily used si□ □ly as a local□ s□all□scale technology that □ight have □een □ired only once to □roduce li□e □or agriculture□□ut were a central ele□ent in a highly organised industry su□□lying a □ey ingredient in the develo□□ent o□Scotland□s industry□econo□y and ur□an centres.

Ac□□owL□dG□M□□TS

We than□landowners in □aldernoc□and Ca□ □sie □or access to □ilns on their □ro□erties□es□ecially Willia□ and Alec Henderson o□□□ettlehill□and David Ralston o□□Castlehill□□□or □er□ission to underta□e the geo□hysical surveys at □oghall and South Craigend□res□ectively□and the Stirlings o□Glorat □or access to the □iln re□ains at □aldoran. We also than□sta□□at □ast Dun□artonshire□s Willia□ □atric□ Li□rary□□ir□intilloch□□or assistance with census data□and the □ational Li□rary o□ Scotland □or □er□ission to use the e□tracts □ro□ Ordnance Survey □a□s. The

□niversity o□Glasgow's School o□Geogra□hical □ □arth Sciences □indly □et the □ational Li□rary o□Scotland's □ee □or □er□ission to □u□lish these e□tracts. □enny Ro□erts□□ield Technician in the □niversity o□Glasgow's School o□Geogra□hical □ □arth Sciences□□rovided□as always□cheer□ul and energetic □ield assistance□and □icola □rannan□S□all Ani□al Diagnostic l□ager at the □niversity o□Glasgow School o□Veterinary Medicine□□indly □roduced the □□rays o□the South Craigend sedi□ent cores. Mi□e Hels□y o□□Low □lochairn□generously assisted with the coring o□this sedi□ent and undertoo□the care□ul sedi□entological analyses that under□in our inter□retation o□the core. Valerie Olive o□the Scottish □niversities □nviron□ental Research Centre analysed the South Craigend core sa□□les □or □□ content□□or co□□arison with the dated total lead □ro□ile □ro□ Loch Lo□ond □indly □rovided □y Dr □ohn □ar□er o□the □niversity o□□din□urgh. □ro□essor Marian Scott□ □niversity o□Glasgow School o□Mathe□atics and Statistics□gave thought□ul advice on wiggle □atching□and Dr Maarten □laauw□□ueen's □niversity □el□ast□was generous with his ti□e in underta□ing the wiggle□□atching using his □□acon□ so□tware□and in e□□laining the results. We are grate□ul to all o□these individuals □or their essential assistance and advice.

□OT□S A□D R□□□R□□C□S

[1] □ohnson□D.□*Limestone Industries of the Yorkshire Dales* (Stroud: Te□ □us□2nd edition□2010)□ Willia□ s□R.□*Lime Kilns and Lime Burning* (Ayles□ury: Shire □oo□s□1989).

[2] □o□ey□G.□A □ote on □Sow□□ilns□□*Journal of the Newcastle upon Tyne Agricultural Society*□20 (1966)□37□8□□is□et□S.□□The 18th Century Li□ e Industry in Scotland□□*Scottish Local History*□□8 (2003)□8□13.

[3] Mitchell□D. and □. □isho□□□Li□ e□ilns □ still a □urning issue□□*Sheetlines (The Journal of the Charles Close Society for the Study of Ordnance Survey Maps)*□107 (2016)□20□2.

[4] Car□ ichael□□. □Account o□the □rinci□al li□ estone □uarries o□Scotland□□*Transactions of the Highland and Agricultural Society of Scotland (New Series)*□□ (1837)□□7□84□□or □eat: Ga□ney□V. *The Lordship of Strathavon: Tomintoul under the Gordons* (A□erdeen: The Third S□alding Clu□□ 1960)□43□Willia□ s□□. □Suggestions □or □ro□ oting □ i□ □roving the □isheries u□on the coasts o□ Highlands and Isles□□*Prize Essays and Transactions of the Highland and Agricultural Society of Scotland*□1 (1799)□2□0□74.

□ Car□ ichael□re□ 4.

[6] *Ibid*.□□ohnson□D.□□The archaeology and technology o□early□□ odern li□ e □urning in the Yor□shire Dales: Develo□ing a cla□ □ □iln □ odel□□*Industrial Archaeology Review*□30 (2002)□127□43.

[7] □is□et□S.□□The Archaeology o□the Li□ e Industry in Ren□rewshire□□*Renfrewshire Local History Forum Journal*□13 (200□)□41□□8

[8] S□ out□T.C. and A. □enton□Scottish agriculture □e□ore the I□ □rovers □an e□□loration□□*The Agricultural History Review*□13 (196□)□82.

[9] □Li□ ing was the single □ ost i□ □ortant ste□ in agricultural i□ □rove□ ent in 18th century Scotland□□ Hay□R.□□Cro□s and livestoc□ in the I□ □rove□ ent □ra□□in □enton□A. □ □. Veitch□(eds.)□*Scottish Life and Society, a Compendium of Scottish Ethnology*. *Volume 2. Farming and the Land* (□din□urgh: □ohn Donald□2011)□248.

[10] The a□□lication o□calcareous □ arl (a □ uddy clay rich in li□ e) could achieve the sa□ e e□□ect □ut re□uired very su□stantially greater □uantities o□□ arl (4□0□600 cartloads □er acre)□co□ □ared to li□ e (10□80 carts □er acre) □ Dodgshon□R.□□Land i□ □rove□ ent in Scottish □ar□ ing: Marl and li□ e in Ro□□urghshire and □erwic□shire in the eighteenth century□□*The Agricultural History Review*□24 (1978)□1□14.

[11] □enton□A.□*Scottish Country Life* (□din□urgh: □ohn Donald□1976)□White□I.□*Agriculture and Society in Seventeenth-Century Scotland* (□din□urgh: □ohn Donald□1979)□Harrison□□.□□Li□ e su□□ly in the Stirling area □ro□ the 14th to the 18th centuries□□*Forth Naturalist and Historian* 16 (1993)□83□9□Hay□ re□ 9□S□ out and □enton□re□ 8□73□□□□or e□a□ □le□a □eu contract o□1630 □etween the □arl o□ Montrose and three □ersons in □aster □algrochan (Stirlingshire) gives the□ □the □rivilege o□winning coal and li□ e through the □ive and a hal□□ er□land o□Carlestoun and □aster and Wester □algrochan as o□old□(□AS GD220/6/330/1 □L□01/49□□0□1630□□. □). The □algrochan re□erred to here is in the central □art o□the □aldernoc□□Ca□ □sie study area.

[12] □elsches□R.□*General View of the Agriculture of the County of Stirling With Observations on the Means of its Improvement* (□din□urgh: □oard o□Agriculture and Internal I□ □rove□ ent□1796).

[13] □ow□ an□I. □History□in Carter□□. (ed.)□*The Forth & Clyde Canal Guidebook* (□ir□intilloch: □orth □ Clyde Canal Society□3rd edition□2001)□44.

[14] □□□lanation o□Mr □arrys □lan o□Survey o□Craig□ addie Muir 177□□□□niversity o□Glasgow Archives □GD 1□2/6 □undle 2

[15] Ross□C.□A Ma□ o□the Shire o□Du□ □arton□(1777)□□ational Archives o□Scotland RH□ □302/20.

[16] Graha□ □□.□*General View of the Agriculture of Stirlingshire* (□din□urgh: □oard o□Agriculture and Internal I□ □rove□ ent□1812).

[17] □ohnson□re□ 6.

[18] e.g.□S□inner□□.C.□*The Lime Industry in the Lothians* (□din□urgh: □niversity o□□din□urgh De□art□ ent o□Adult □ducation and □□tra□Mural Studies□1969)□S□inner□□.C.□□The archaeology o□ the li□ e industry in Scotland□□*Post-Medieval Archaeology*□9 (197□)□22□□30.

[19] Coull□□R.□□Co□ □unications and trade in Scottish □ar□ ing □ro□ the Medieval □eriod to 1900□□in □enton□A. □ □. Veitch (eds.)□*Scottish Life and Society, a Compendium of Scottish Ethnology*. *Volume 2. Farming and the Land* (□din□urgh: □ohn Donald□2011)□8□□□□or Charlestown□see Scottish Li□ e Centre Trust□*Charlestown Limeworks. Research and Conservation* (□din□urgh□2006).

[20] S□inner□re□ 18□□is□et□S.□□The archaeology o□the li□ e industry in Ren□rewshire□□*Renfrewshire Local History Forum Journal*□13 (200□)□□1.

[21] □ohnson□re□ 1□□is□et□re□ 20□Mac□ay□□.□□Li□estone wor□ing. A □orgotten Stirlingshire industry□□ *Forth Naturalist and Historian* 2 (1977)□80□10□□□or e□a□ □le: Cleas□y□I.□□Li□e □ilns and li□ e□urning in Sed□ergh□Garsdale and Dent □art 1□□*The Sedbergh Historian*□3:3 (1994)□2□9□□Li□ e □ilns and li□ e□urning in Sed□ergh□Garsdale and Dent □art 2□□*The Sedbergh Historian*□3:4 (199□)□2□8.

[22] □isho□□□. and G. Tho□ son□□How OS de□icted li□ e□ilns in Scotland□s Central □elt□□*Sheetlines*□98 (2013)□19□31□□isho□□□. and D. Munro□□□urther co□ □ ent on OS □ a□□ing o□li□ e□ilns in Scotland□□ *Sheetlines*□101 (2014)□42□7□□isho□□□. □□Over□coo□ing li□ e □ilns□□□*Sheetlines*□106 (2016)□32□3□ Mitchell and □isho□□re□ 3.

[23] Graha□ □re□ 16.

[24] □ritish Geological Survey□*Glasgow. Scotland Sheet 30E, Solid*. 1:□0□000 (□ottigha□: □ritish Geological Survey□1993)□□ritish Geological Survey□*Airdrie. Scotland Sheet 31W, Solid*. 1:□0□000 (□ottigha□: □ritish Geological Survey□1992)□

[25] S□illen□□. □As□ects o□the alu□ □ining industry a□out Glasgow□□*British Mining*□39 (1989)□□3□60. See also □assett□D.A.□*Geological Excursion Guide to the Glasgow District* (Glasgow: Geological Society o□Glasgow□19□8).

[26] *Ibid*.□Ca□ □□ell□W.A.□□General and □ine inorganic che□icals□□in Russell□C.A. (ed.)□*Chemistry, Society and Environment. A New History of the British Chemical Industry* (Ca□ □ridge: The Royal Society o□Che□ istry□2000)□1□7□96.

[27] □isho□ and Tho□ son□re□ 22□□igure 3.

[28] □isho□ and Tho□ son□re□ 22□□isho□ and Munro□re□ 22.

[29] □isho□ and Tho□ □son, re□. 22.

[30] □elsches, re□. 12□Graha□, re□. 16; □nless otherwise stated, we use the ter□ '□aldernoc□' to cover □aldernoc□ □arish and the i□□ediately ad□acent □arts o□Ca□ □sie □arish on the northeastern edge o□ □aldernoc□ □arish. □Ca□ □sie' then □eans the □ore central □arts o□Ca□ □sie □arish. This a□□roach is sensi□le in that li□e □lns in i□□ediately ad□acent □arts o□□aldernoc□ and Ca□ □sie □arishes (South Craigend in □aldernoc□ □arish and Glenwynd in Ca□ □sie □arish) are wor□ing the sa□e li□estone and coal sea□s. The res□ective □ull na□es are used (e.g., Ca□ □sie □arish) when the individual □arishes are □eing re□erenced.

[31] □nglish Heritage□*Geophysical Survey in Archaeological Field Evaluation (2nd edition)* (Swindon: □nglish Heritage □u□lishing, 2008).

[32] □ach sedi□ent sa□ □le was dissolved using a standard tri□acid (H□, H□O$_3$, HCl) dissolution □rocedure with added 0.2 □l HClO$_4$. All sa□ □les were then diluted so that their □easured concentrations □ell within the 5ppb - 40ppb cali□ration line. 3ppb □is□uth was used as an internal standard and □CR-? geostandard was used as a □uality chec□, with re□eata□ility set at 5%. Analyses were done on an Agilent 7500ce ICP□MS □itted with a sel□as□irating PFA concentric ne□uliser tuned at 0.1 □l/□n. Three □oints □er □ea□and 1□ or 20 □er analysis were used to ac□uire the data. The sa□e standard solution o□□CR□2 was analysed every □ive sa□ □les as an internal chec□, to chec□ □or instru□ental dri□t that was not co□ □ensated □or □y the internal standard.

[33] □ar□er, □.G., L.□. □ades, A.□. Mac□en□ie□A. □iri□a and T.□. □ailey□Watts, 'Sta□le lead isoto□e record o□lead □ollution in Loch Lo□ond sedi□ents since 1630 A.D.', *Environmental Science and Technology*, 30 (1996), 3080□3.

[34] □isho□, P., E. Mu□o□Salinas□A.□. Mac□en□ie, I. □ul□ord and □. Mc□i□□in, 'The character□volu□e and i□□lications o□sedi□ent i□□ounded in □ill da□s in Scotland: The case o□the □aldernoc□ Mill da□ in □ast Dun□artonshire', *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 101 (2010), 97-110.

[35] The wiggle-□atching was underta□en in two se□arate ways. The □irst used a version o□the chi-s□uared (χ^2) test (□ollowing Ra□sey, C.□., van der □licht, □. and Weninger, B. '*Wiggle □atching' radiocar□on dates', Radiocarbon*, 43 (2001), 381□9)[35] to assess the □it □etween the 17 data □oints o□ the South Craigend total lead □ro□ile (the χ^2 test's O□served values) and every □ro□ile o□17 contiguous data □oints (the χ^2 test's □□□ected values) □oving □rogressively down through the dated Loch Lo□ond □ro□ile □□□ected □ro□ile 1 in the Loch Lo□ond data enco□ □assed data □oints 1-17 in those data (calendar years 1990.8 to 1968.7), □□□ected □ro□ile 2 enco□ □assed Loch Lo□ond data □oints 2□18 (calendar years 1990.5 to 1967.0), □□□ected □ro□ile 3 data □oints 3□19 (calendar years 1990.0 to 1965.1), and so on down the Loch Lo□ond □ro□ile. The χ^2 statistic was calculated □or the co□ □arison o□the South Craigend Pb □ro□ile against each o□these 79 17□data-□oint □ro□iles in the Loch Lo□ond se□uence □ac□ to calendar year 1636. The □atch □etween the Loch Lo□ond □□□ected □ro□ile and the South Craigend O□served □ro□ile that gave the lowest χ^2 value was □udged to □e the □est □it and the □asal age o□that □articular Loch Lo□ond 17□data-□oint □ro□ile gave the □asal age o□ the South Craigend in□ill. The second a□□roach to the wiggle-□atching used the '□acon' so□tware to

□atch the South Craigend □□ □ro□ile to the dated Loch Lo□ond □ro□ile (□laauw□M. and □.A. Christen□ □□le□i□le □aleocli□ate age□de□th □odels using an autoregressive ga□ □a □rocess□□*Bayesian Analysis*□6 (2011)□4□7□74). This was underta□en □y Dr Maarten □laauw□the author o□the □acon so□tware□who used the □acon de□ault settings e□ce□t □or a section thic□ness o□10 □ □ □a □rior accu□ulation rate with □ean 3 and sha□e □□and using the dated Loch Lo□ond record as a tailor□ □ade □cali□ration curve□against which the South Craigend □□ □easure□ents were wiggle□□atched (*Pers. comm*. Dr Maarten □laauw□□anuary 6□2017).

[36] □ritish Geological Survey Mine A□andon□ent □lan S□188□1□□17□01 Woodhead 1.

[37] *Pers. comm*. e□ ail □ro□ David Lawrence□□ritish Geological Survey □din□urgh□06 May 2010□who also noted that the □lac□□anded ironstone occurs as the to□□ ost □art o□the coal sea□ □con□r□ing that the coal would al□ ost certainly have □een e□tracted to o□tain the ironstone.

[38] Radcli□e□□ □□On □urning li□ e with □eat□□*Prize Essays and Transactions of the Highland Society of Scotland*□2 (1803)□160□3□□ohnson□re□ 6.

[39] *Glasgow Courier*□23 May 1822.

[40] *Glasgow Herald*□4 March 18□0.

[41] Logan□□.□South Craigend and Cornhill: Reading the ruins□□*Vernacular Building*□38 (2014□1□)□□. □8. The whole o□the □receding □aragra□h draws heavily on this re□erence.

[42] The lac□o□sur□ace □or□hological evidence □or these □iln re□nants □ro□a□ly also □artly re□ects decades□and □erha□s centuries□o□□loughing□over o□that □to□ogra□hy□□as well as the 19th century du□ □ing o□Glasgow city ru□□ish on the agricultural land on Glasgow□s □eri□hery. (McGuire□D.□*Go west for a wife: Family farming in West Central Scotland 1850-1930*□□niversity o□Glasgow □hD thesis (2012)). Many solid ite□s □ro□ household waste can still □e □ic□ed u□ around the □ilns in the □oghall □ield□including □ro□en □orcelain dolls□other □ro□en cera□ ic □gurines□and □rag□ents o□what a□□ears to □e 19th century do□ estic □ottery. The du□ □ing o□ru□□ish has □ro□a□ly served to raise the ground sur□ace around and in the □ilns□and hence to su□due the □iln □or□hology□□ecause □ odern □loughing turns u□ only the □re□reddened and □a□ed □iln □eri□eters and not the □iln □loor (□igure □).

[43] See □igure 3 o□Mac□ay□re□ 21□Harrison□re□ 11□87.

[44] We have not yet seen any □a□□ing that shows Red □iln□□ut the order o□data in the census i□ □lies that it was close to □an□ier.

[45] Si□o□the Hole coal □iners were □ro□ the sa□e □a□ily□na□ely□□ohn Marshall and □ive o□his sons□ the youngest aged only 9 years old.

[46] □isho□ and Tho□ son□re□ 22.

[47] Logan□re□ 41.

[48] *Ibid*.

[49] A Royal Co□ □ission on the Ancient and Historical Monu□ents o□Scotland i□ age o□the Sculliongour (□algrochan) cla□ □ □ilns is given on Scran with the □ollowing ID: 000□000□18□187□C.

[50] The 1630 lease noted in re□ 11 □a□es it clear that □algrochan is a long□standing na□ e in the □aldernoc□li□ e industry. The lease na□ es Carlestoun□which is in the area treated here as

□aldernoc□□□is ad□acent to □aster and Wester □algrochan (though technically these areas are in Ca□ □sie □arish).

□1 Mr Reid Harrison *pers. comm*.□Dece□ □er 2014.

□2 Lanar□ Sheet 6.2 (Maryhill)□surveyed 18□8□□u□lished 186□□Stirling Sheet 30.6 (□al□ir□)□surveyed 1860□□u□lished 1864.

□3 □ow□ an□re□. 13□48.

□4 Harrison□re□. 11□Mc□ay□re□. 21.

□□ Woodhead □state Archives□Mitchell Li□rary Glasgow□T□L□/6/2/1.

□6 □ohnson□re□. 6□127.

□7 Car□ ichael□re□. 4□6□.

□8 OS 2nd edtion 1:2□00 □a□□ing□Du□ □artonshire sheet 23.11□revised 1896□□u□lished 1898

□9 Ward□T.□□□raehead Village□South Lanar□shire: a survey and historical review□□*Biggar Archaeology*□no date□online at htt□://www.□iggararchaeology.org.u□/□d□□re□orts/□raehead.□d□□ accessed □uly 22□2013

60 □is□et□re□. 20.

61 htt□://www.geogra□h.org.u□/article/West□Dun□artonshire□Li□ estone□Industry□□etwor□□accessed □anuary 23□2017. See also Mitchell□□.□□Cornstone □urning □or □ertili□er in eighteenth□century Du□ □artonshire and Stirlingshire□□*Scottish Local History*□8□ (2013)□43□4□.

62 Diro□ □□no initial□□□□lan and descri□tion o□li□e□□ilns□□*Prize Essays and Transactions of the Highland Society of Scotland*□3 (1807)□110□7.

63 Scottish Li□e Centre Trust□re□. 19.

64 □a□ton□R. and □. Shi□way□*Civil Engineering Heritage: Scotland - Lowlands and Borders* (Tho□as Tel□ord Ltd)□349.

6□ Scottish Li□e Centre Trust□re□. 19.

66 Wallace□□.□□Account o□the □ethod o□calcining li□estone in so□e o□the li□estone □uarries in Scotland□□*Transactions of the Highland and Agricultural Society of Scotland*□□ew Series□□ (1837)□ 441□□□.

67 Tac□dated □e□ruary 26 1813. Woodhead Archives□Mitchell Li□rary Glasgow TL□□ 6/2/1.

68 □ohnson□re□. 1.

69 □ohnson□re□. 6.

70 Car□ ichael□re□. 4.

Table 1. □u□ □ers o□□ilns in □aldernoc□ and Ca□ □sie □ro□ OS □a□□ing su□□le□ented □y □ield chec□ing. All □ilns re□orted here are cla□ □ □ilns and no draw □ilns have □een either □a□□ed □y OS or identi□ied in our □ield □a□□ing. Re□er to □igure 2 □or locations.

Locality; guide GR and Fig reference (if relevant)	Area (Parish)	Number of kilns	Other lime-related features from OS mapping, field checking, census data, archives etc
□1. □oghall□ □S□7974□ □igure 3	□aldernoc□ (□aldernoc□)	17	1. □o □ilns or □ines □a□□ed □y OS□ 2. S□ all horse□shoe sha□ed □ilns revealed □y gradio□eter survey (□igure 3A and □)□ 3. Heat□reddened (□a□ed) clay and vitri□ied stone on ground sur□ace□and si□ilar colouration visi□le on colour□enhanced Google □arth i□age (□igure 3C)□ 4. □ilns are ad□acent to a tree□covered de□ression (□igure 3□) in which the □aldernoc□Li□estone is □a□□ed as cro□□ing out. Local □nowledge con□ir□s that the de□ression is the re□ains o□a coal and/or li□estone □uarry/□ine.
□2. □th □ardowie□ □S□81749	□aldernoc□ (□aldernoc□)	□	1. Re□ains o□a grou□ o□□our cla□ □ □ilns (not □a□□ed □y OS) □lus one (now destroyed) □a□□ed □y OS on □id□19th century 1st ed. adjacent to 'Coal Mine'; 2. □o □ilns □a□□ed on OS 2nd ed. (late 19th century) but 'Airshaft' mapped on 2nd ed. is ad□acent to the □our □ilns noted in 1.□ 3. Local in□or□ation con□ir□s that one or □ore o□the grou□ o□□our □ilns was o□erating in the early 1900s□ with the li□e going □y horse and cart to local railway □or trans□ort (□resu□a□ly □or the 10□□ or so into Glasgow□see te□t).
□3. Hole□ □S60□7□2 □igure 4	□aldernoc□ (□aldernoc□)	11	1. All OS mapped kilns labelled as 'Old Limekilns' (□igure 4)□ 2. Multiple mines ('Old Pit'; 'Old Pit Coal & Limestone'; 'Limestone Pit'; 'Coal & Limestone Pit' [the latter two la□els□lacking 'Old', i□ □lying active □ining when OS surveyed the area in 1860□)□ 3. Re□ains o□elevated (constructed) ridge □or tra□way □ro□ □ine entrance to □ilns (□igure 4)□ 4. Downhill terminus of 'South Craigend Lime Road' (□igures 4 and 9).
□4. Linn□ □S□907□6	□aldernoc□ (□aldernoc□)	1	1. Single □iln ad□acent to a (□resu□a□ly li□estone) □uarry or □ine□ 2. □nla□elled on OS 1st ed. 6" mapping, but 'Old Limekiln' on OS 1st ed. 25" and OS 2nd ed. 6" □a□□ing□ 3. A □a□or underground li□estone □ine (the □aldernoc□ Linn Mine) is also ad□acent□ 4. House 'Linn' mapped adjacent to the quarry and kiln on OS 1st ed.; this is presumably the 'Linn Bank' occu□ied □y a li□e □iner and his □a□ily in the 18□1 census□ □. □nroo□ed house □a□□ed on OS 2nd ed.
□□. South Craigend□ □S602760 □igure □	□aldernoc□ (□aldernoc□)	37	1. All kilns labelled as 'Old Limekilns' on OS 1st and 2nd eds□ 2. Subsurface 'plumbing' connecting clamp kilns indicated on gradio□eter survey (□igure □□) 3. Multi□le □ine sha□ts (identi□ied in □ield and not □a□□ed □y OS□central □ine entrance □a□□ed on □ine a□andon□ent □lan □□igure 8□)□ 4. □□hill ter□inus of 'South Craigend Lime Road' (□igure 9).

□6. □lairs□aith Trig□ □S□96767 □igure 6	□aldernoc□ (□aldernoc□)	26 (□ini□u□ □ecause □arts o□ this area are highly distur□ed □y later □orestry activities)	1. OS □a□□ed only three □ilns□all labelled ‘Kilns’□ i□ □lying that they were still □unctioning in the □id□ 19th□as is also i□ □lied □y the □uildings ad□acent to the □ilns □eing □a□□ed as roo□ed□and the □act that the la□els on the □ines do not include the descri□tor ‘Old’; 23 □ilns not □a□□ed □y OS□ 2. Multiple mines, two of which mapped by OS (‘Coal & Limestone Mine’; ‘Coal & Limestone Pit’); other (un□a□□ed) sha□ts very o□vious on the ground□ including two su□stantial water□illed sha□ts□one o□ which is□in □lan view□□40□ long and □1□□ wide□ 3. Re□ains o□constructed ridge □or tra□way (not □a□□ed □y OS) □ro□ □ine entrance towards □ilns□ and a di□□erent tra□way □a□□ed on OS 1st ed. □ut not located on the ground□ 4. Large drains running downhill away □ro□ (□u□ □ing□) sha□ts.
□7. Glenwynd□ □S606761 □igure 7	□aldernoc□ (Ca□ □sie)	24	1. All OS□mapped kilns labelled as ‘Old Limekilns’; 2. Nine mines (all ‘Old Pit Coal & Limestone’) mapped □y OS in area i□ □ediately surrounding these □ilns□ with other un□a□□ed □ines and/or air sha□ts located in □ield□chec□ing and/or □a□□ed □y OS as s□all circular □onds□ 3. Glenwynd □ar□ house is u□hill ter□inus o□ ‘Glenwynd Lime Road’ (□igure 9).
□8. Langshot□ □S61□7□8	□aldernoc□ (Ca□ □sie)	6	1. All OS mapped kilns labelled as ‘Old Limekilns’; 2. On side branch of ‘Langshot Lime Road’ (□igure 9).
□9. Culloch Sla□□ □S622773 □igure 12	Ca□ □sie (Ca□ □sie)	1st ed.: 7 2nd ed.: □	<u>OS 1st edition</u>: 1. Mapped as ‘Limekilns’ on OS 1st ed 6" map and as ‘Old Limekilns’ on OS 1st ed 25" map; 2. □1□0□ long tra□way □a□□ed connecting □ilns to ‘Culloch Slap Old Mine Coal & Limestone’. <u>OS 2nd edition</u>: 3. □ilns re□uilt□ 4. Mapped as ‘Limekilns’ and there□ore assu□ed to □e o□erating□ □.1□0□ long tra□way still □resent and a second tra□way□□00□ long□to a new (second) □ine is □a□□ed.
□10. Ca□s□ie Alu□ Wor□s□ □S632770	Ca□ □sie (Ca□ □sie)	1st ed.: 8 2nd ed.: 8	<u>OS 1st edition</u>: 1. Mapped as ‘Limekilns’ on 1st ed 6" and 25" maps; 2. Two tra□ways connecting □ilns to □ines: one □□00 □ long to ‘Coal & Limestone Mine’□and the other □ 960 m long to ‘Tarfin Mine (Alu□ Coal □ Li□estone)’. <u>OS 2nd edition</u>: 3. □ilns re□uilt□rearranged and enlarged (two □a□□ed as □eing □17 □ long)□ 4. □00□ long tra□way still connecting to □irst □ine noted under 1st edition, now called ‘Boydsburn Mine’.
□11. □aldoran (Derry Coal □ Li□e Wor□s on 1st ed.□ Glorat Li□e Wor□s on 2nd ed)□ □S6□0772 □igure 13	Ca□ □sie (Ca□ □sie)	Derry: 11 Glorat: 13	<u>OS 1st edition: Derry Coal □ Li□e Wor□s</u> 1. □ight 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. □n□a□□ed □it sha□ts or airsha□ts also identi□ied in □ield □a□□ing. <u>OS 2nd edition: Glorat Li□e Wor□s</u>: 3. The eight ‘Old’ kilns and adjacent ‘Old Limestone Pit’ as □a□□ed in 1st ed. (see 1.) are re□eated in 2nd

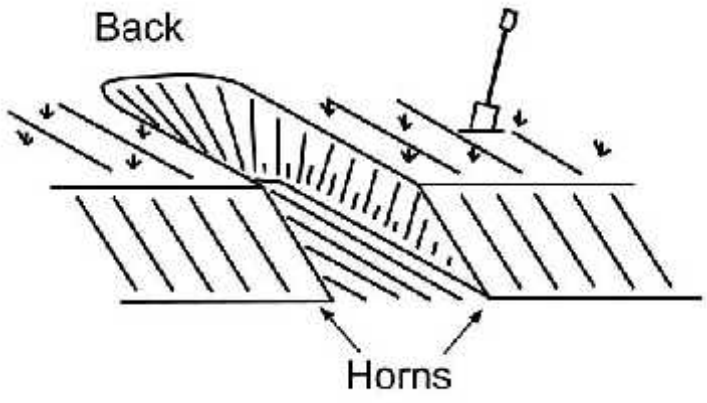
			ed.□ 4. □ive large □ilns have re□laced the three 'limekilns' □ a□□ed in 1st ed.□ □. Tramway and roadway into 'Levels' (adits)□airsha□t□ plus 'Old Limestone Pit'; 6. 600 □ long tra□ way connecting the Glorat Li□e Works to the North British Railway's Blane Valley □ranch line (including a □ridge to cross the Gla□ert Water).
□12. Glorat House Coal □ Li□e Wor□s (1st ed.)□ □S644781	Ca□ □sie (Ca□ □sie)	1st ed.: □ 2nd ed.: 0	OS 1st edition: 1. □ □ilns o□di□erent si□es and slight di□erences in □lan□view □ or□hology (one with rounded end□the re□ainder with s□uared□o□□ends)□ 2. 'Coal & Limestone Mine', with two roofed buildings ad□acent□ 3. 'Old Coal Pits'. OS 2nd edition: 4. 'Old Coal & Limestone Mine', with no buildings; □. 'Old Quarries'.
□13. Scullion□our Li□e □ Coal Wor□s□ □S626790	Ca□ □sie (Ca□ □sie)	1st ed.: □ 2nd ed.: 8	OS 1st edition: 1. 'Mines', 'Old Coal Pits'. OS 2nd edition: 2. □ilns re□uilt□reorganised□and a□□arently increased in si□e and nu□ □er o□□ilns□ 3. 'Levels'; 4. More than 800 □ o□tra□ ways □etween levels and □ilns□ □. Roo□ed □uilding ad□acent to □ilns.

Table 2. □u□ □ers e□ □loyed in the li□e and coal industries in □aldernoc□and Ca□ □sie □arishes according to various 19th century censuses

	Census	□aldernoc□ □arish	Ca□ □sie □arish
Li□e	1841	14	3□
	18□1	6	29
	1861	1	22
	1871	0	□4
Coal	1841	12	70
	18□1	7	118
	1861	14	118
	1871	7	143

□ote: The 1841 and 18□1 census data were o□tained □ro□ www.□reecen.org.u□□and the data □or the 1861 and 1871 censuses were derived □ro□ the □icro□il□ co□ies o□the original census enu□erator □oo□s held □y the □ast Dun□artonshire Leisure and Culture Trust at Willia□ □atric□Li□rary□ □ir□intilloch. The □icro□il□ reader at the Willia□ □atric□Li□rary was □rovided □y the □ews□a□er 2000 □ro□ect□the Heritage Lottery □und□and the Regional □ews□a□er Industry.

Figures:



A.

B.

Figure 1. A. S□etch o□cla□ □ □iln redrawn □y □isho□ □ro□ □is□et□S.□re□ 3□□igure 1. □. Degraded re□ains o□cla□ □ □ilns at □lairs□aith Trig□□aldernoc□ (le□t: □□sha□ed □iln□and right: ad□acent horseshoe□sha□ed □iln□□oth at centre□le□t o□□igure 6 □see □igure 2 □or location and detail□).

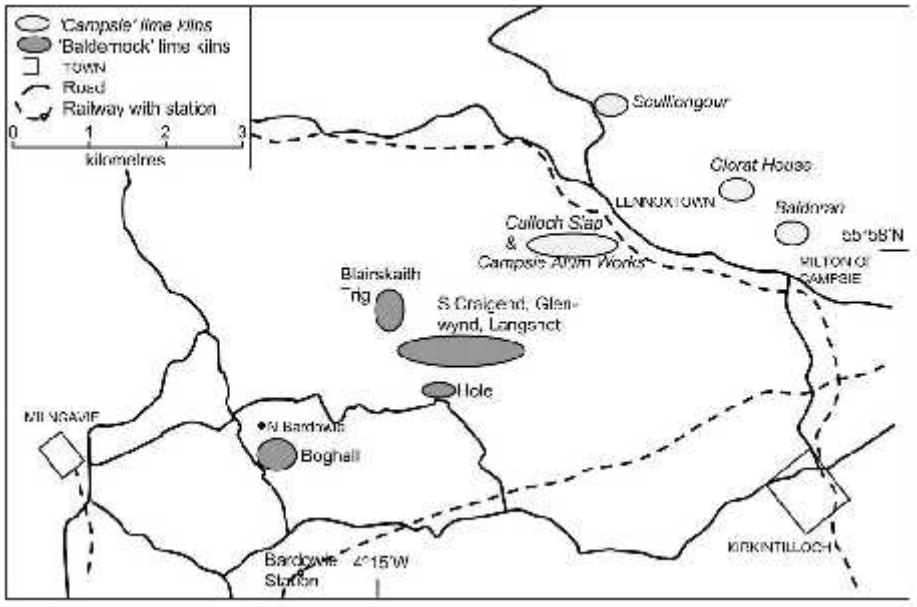
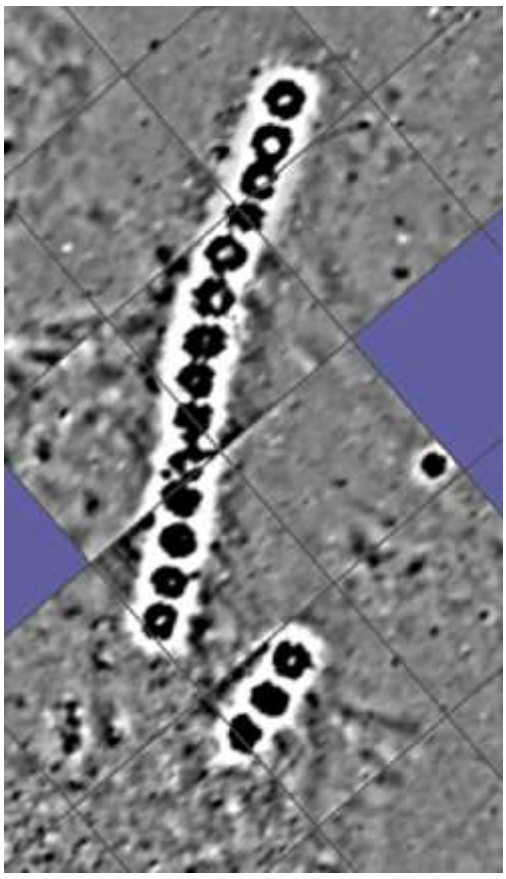


Figure 2. Ma□ o□the □rinci□al li□e □iln sites in □aldernoc□ and Ca□ □sie □arishes. The South Craigend □ilns lie in □aldernoc□ □arish. The ad□acent Glenwynd and Langshot □ilns are in Ca□ □sie

□arish□□ut they are treated here together as □art o□the □aldernoc□li□e □ilns □ecause they are clearly wor□ing the sa□e occurrence o□the □aldernoc□Li□estone and its associated coal.



A

B

C.

Figure 3. □oghall li□e □ilns. A. Gradio□eter survey showing the re□ains o□17 horseshoe□sha□ed cla□ □ □ilns. □. The □oghall □ilns as revealed □y gradio□eter survey in conte□t□highlighting the □ilns□

closeness to the ad□acent □ine in the □aldernoc□Li□estone and associated coal □easures. C. Colour□and contrast□enhanced aerial □hotogra□h highlighting the circular reddened □urnt ground re□nants corres□onding to the □agnetic ano□alies in A and □.

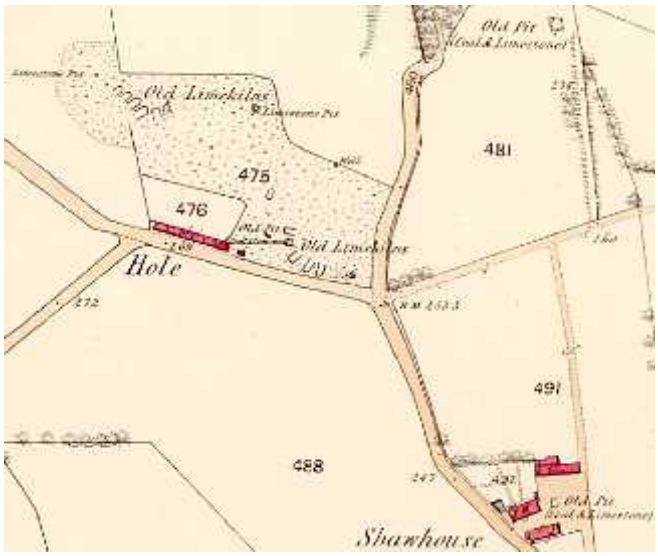
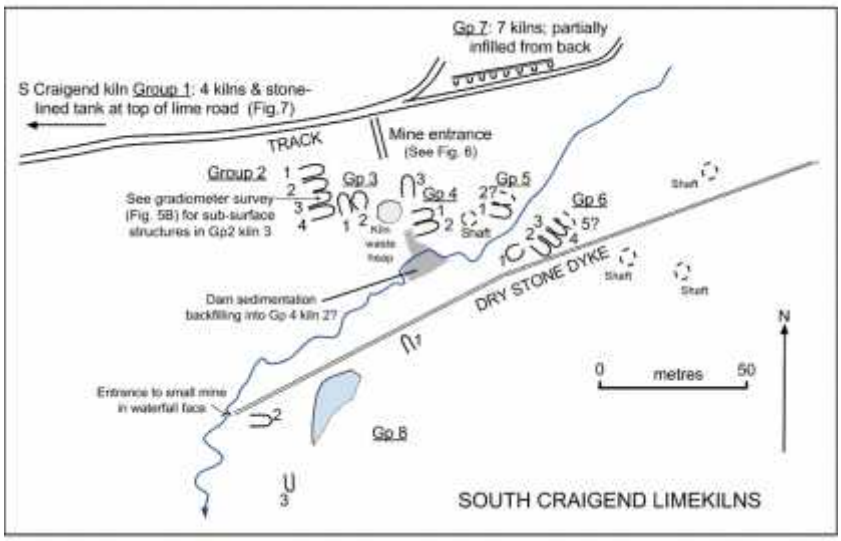
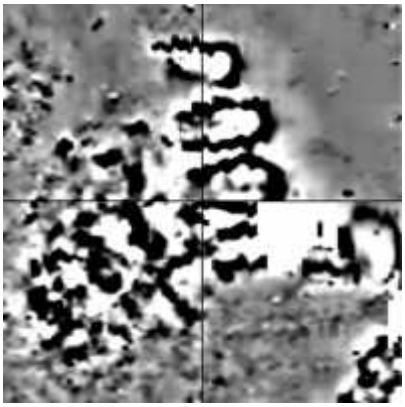


Figure 4. OS 1st edition 2□inch □a□□ing o□li□e industry re□ains at Hole (Stirling Sheet 32.4 (□aldernoc□ □arish)□survey date 1860□□u□lication date 1864). The elevated ridge at u□□er right is inter□reted to have carried a tra□way □ro□ old □it in u□□er right□hand corner. A second un□a□□ed elevated ridge (i.e.□second tra□way) ran □ro□ the southern end o□the □irst tra□way (at s□ot height □260□) WSW along the □a□□ed trac□to the cross□road in the □iddle o□the □igure (□ar□ed □□.M.2□3.3□). That tra□way would have then continued on to the □ilns ad□acent to the □uildings (□iners□cottages) at Hole. The road co□ing in □ro□ the north□west i□ □ediately to the west o□Hole is the downhill ter□inus o□the □South Craigend Li□e Road□(see also □igure 9). (Re□roduced □y □er□ission o□the □ational Li□rary o□Scotland)

A.





B.

Figure 5. A. Re□ ains o□the li□ e industry at South Craigend □ased on □ield □ a□□ing. At least one □urther □iln and ad□acent □ ine sha□t occur □ust to the south o□the area □ a□□ed here. □. South Craigend gradio□ eter survey o□Grou□s 2 and 3 □ilns (□ollowing nu□ □ering in A at le□t))□the □lan□ area □etween Grou□ 2 □iln 4 and Grou□ 3 □iln 1 corres□onds to a tree where it was not □ossi□le to survey. □ote the □ossi□le su□□sur□ace structures (□lu□ □ing□) in the □loor o□□iln 3 in Grou□ 2 (centre o□□igure) and □ossi□le connection □etween that □iln and the ad□acent □iln 2.

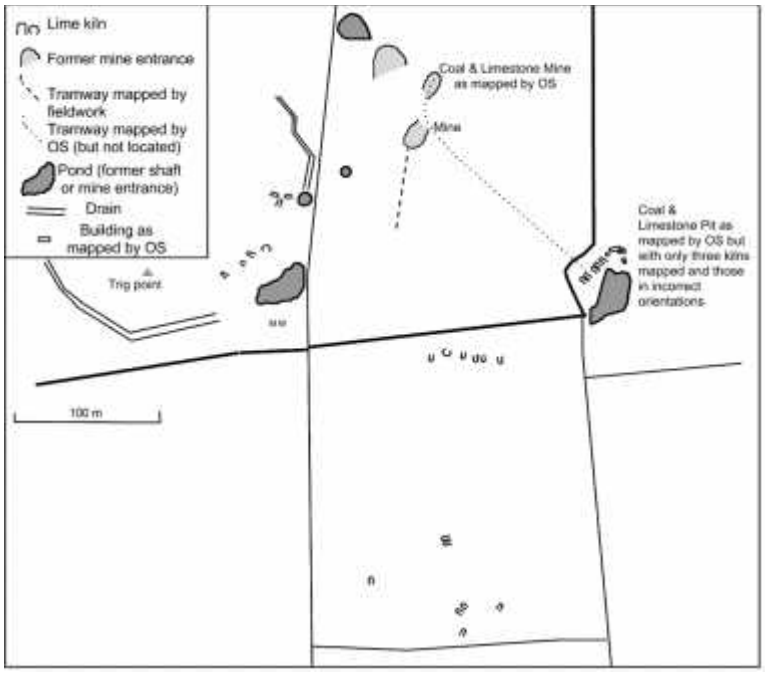


Figure 6. The area o□□lairs□aith Trig station showing □ilns and □ ines. OS □ a□□ing shows only the three □ilns at centre right and no □ ine entrances or drains.

Figure 7. OS 1st edition 2□ inch □ a□□ing o□24 cla□ □ □ilns near Glenwynd (Stirling Sheet 27.16 (Ca□ □sie □arish)□surveyed 1860□□u□lished 186□). Ground survey con□r□s this □ a□□ing as

accurate and as co□ □lete as it is □ossi□le to assess□given the considera□le distur□ance □y current □orestry activities o□the northern hal□o□the area in this □igure. (Re□roduced □y □er□ission o□the □ational Li□rary o□Scotland)

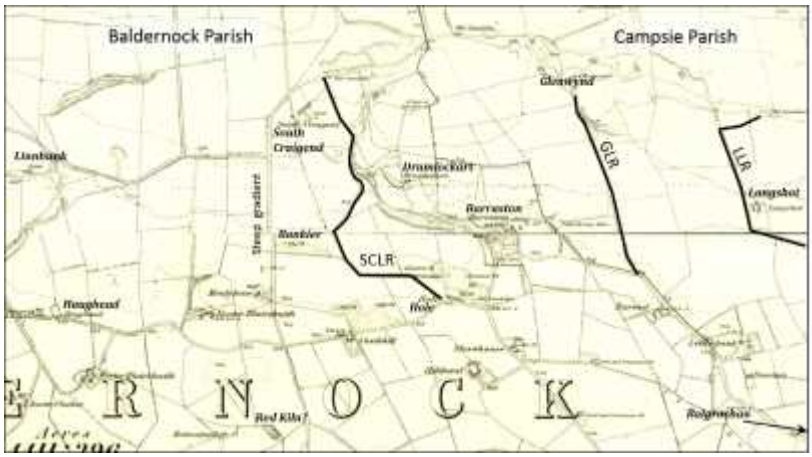


Figure 8. Li□e roads in □aldernoc□□na□ing various localities □entioned in the te□t□□ase □a□is the □id□19th century OS 1st edition 6□□a□(u□□er □ortion: Stirlingshire sheet 27□surveyed 1860□ □u□lished 186□□lower □ortion: Stirlingshire sheet 32□surveyed 1860□□u□lished 1864). SCLR: South Craigend Li□e Road□GLR: Glenwynd Li□e Road□LLR: Langshot Li□e Road. (Re□roduced □y □er□ission o□the □ational Li□rary o□Scotland)

Figure 9. □aldernoc□Li□e Roads in relation to the whar□at Hungryside on the □orth and Clyde Canal (see □igure 9 □or details and na□es o□Li□e Roads).

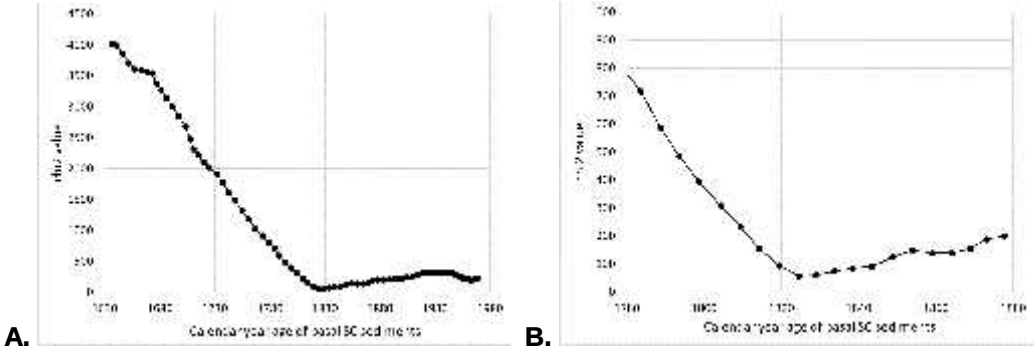


Figure 10. □lots o□χ^2 values □or the lead (□□) se□uences in the South Craigend water tan□(□igure □A) and the dated se□uence in Loch Lo□ ond. (A) χ^2 values □or the goodness o□□it □etween the 17□ □oint South Craigend □ro□ile and all □ossi□le 17□□oint □ro□iles □oving □rogressively down through the dated Loch Lo□ ond □□ se□uence□□o□ed □art enlarged in (□). The □ini□u□ χ^2 gives the □asal age □ 1824.□□say 182□ □ □or the onset o□sedi□entation in the South Craigend water tan□se□uence (and hence the assu□ ed age o□the onset o□decline o□the South Craigend li□ e o□erations).

Figure 11.OS 2nd edition 6" □a□□ing o□Culloch Sla□ li□ e wor□s showing re□uilt □ilns and new tra□ way (Stirlingshire Sheet 27.S□□revised 1896□□u□lished 1899). The elevated ridge that carried this second tra□ way is still clear in the □ield. (Re□roduced □y □er□ ission o□the □ational Li□rary o□ Scotland)

Figure 12. OS 2nd edition 6" □a□□ing o□the □or□ er Derry Li□ e Wor□s at □aldoran redevelo□ed in the secnd hal□o□the 19th century as the Glorat Li□ ewor□s showing tra□ ways connecting □ilns to the □ ine north o□the □ilns and to the □ ainline railway to the south. (Re□roduced □y □er□ ission o□the □ational Li□rary o□Scotland).

Figure 13. Google □arth i□ age o□the draw □iln at the □or□ er Cults Li□ ewor□s□□itlessie□□i□e (eastern Scotland). □ote the □ assive s□uare □ asonry structure surrounding and su□□orting the □iln □ot (the central circular □eature).