The limestones of Scotland v.1 — Chapter 6 Detailed description of resources

Details regarding the limestone resources in the various counties are given below. A certain unevenness in the treatment will be evident. This is partly due to the need for reviewing at length some of the poorer occurrences where these are nearest to, or most accessible from, areas of demand and so might have the advantage over material of higher grade situated some distance away. It is in part to be accounted for, however, by the need for referring to well known deposits which have been extensively worked in the past. In these cases it is desirable to draw attention to the present position and future prospects, more often than not in a statement to the effect that they are never likely to be used again.

A fuller detailed consideration of many of the individual localities will be found in Wartime Pamphlet No. 13, Limestones of Scotland. One of the chief purposes of the present publication is to select what is significant from the accounts in the Wartime Pamphlet and to indicate more clearly the occurrences that are of importance either from the geological or from the economic point of view.

The petrographical notes, apart from field descriptions, are based on Dr. J. Phemister's examinations of specimens selected as typical of the samples analysed at the Macaulay Institute.

The locality names and locations are followed by figures in brackets. These indicate the sheets of the one-inch geological map of Scotland and the quarter-sheets of the six-inch map of the county in question. Thus *Glenbuchat* (75. 50 S.W.; 60 N.W.) means that the limestone occurrences at Glenbuchat are shown on sheet 75 of the one-inch Geological Map and on quarter-sheets 50 S.W. and 60 N.W. of the six-inch Ordnance Map of the county, in this case Aberdeen.

Aberdeen

Aberdeenshire is poor in limestones of present economic value. Many deposits of low grade occur throughout the county and were formerly quarried and burnt for agricultural purposes. With the coming of railways, however, the quarries gradually fell into disuse, and for many years no lime or ground limestone whatsoever has been produced. In recent years, however, some limestone has been quarried, but only for roadstone, at one or two localities.

The limestones of Aberdeenshire (Figure 2) are all metamorphic rocks belonging to the Dalradian Series. Probably the best known and most readily accessible is the Deeside Limestone. This limestone, which is generally regarded as stratigraphically equivalent to the Loch Tay Limestone of Perthshire, etc., forms a large outcrop between Ballater and Aboyne. Unfortunately it is only of poor to moderate quality. The insoluble residue is invariably high, partly owing to the combination of some of the lime and magnesia with silica to form minerals of the calc-silicate group. For this reason it is unlikely that the Deeside Limestone, although worked in the past, will ever again be quarried for agricultural requirements. It is, however, of some value as roadstone, and might also be considered as a source of raw material for the manufacture of rock wool.

In the south-western corner of Aberdeenshire the Blair Atholl Limestones crop out extensively, forming the continuation of important occurrences of the same limestones farther to the south-west, in Perthshire. Small exposures occur in the Dee valley east of Braemar, but the rock is altered by surrounding granite to highly metamorphosed calc-silicate hornfels. The main' outcrops are those south of Braemar. Analyses are not available, but it is clear that the stone is of good quality, although of doubtful economic interest owing to comparative inaccessibility and distance from markets.

Farther north small outcrops of limestone, of fair purity, occur in Upper Donside, for example, at Corgarff and Glenbuchat. Here again distance from markets is a factor unfavourable to exploitation.

In central and north-eastern Aberdeenshire, from the Correen Hills to Fraserburgh, there are several isolated outcrops of limestone, most of which were formerly quarried. As these deposits, however, are usually thin, of small size, and, as shown by several analyses, of low quality they are of very doubtful economic value.

Mention may also be made of limestones which form outcrops of slight extent north-west of Huntly (*see* (Figure 11) and (Figure 12)). These, like the Banffshire limestones of which they are a continuation, are of good quality, and as they are fairly accessible, offer reasonably favourable subjects for exploitation on a moderate scale.

The only other calcareous deposit in Aberdeenshire to which reference need be made is the blown sand which occurs along the coast between Fraserburgh and Peterhead. This is shelly in places and was formerly used for agricultural purposes. It is doubtful, howevef, if it contains material of sufficient purity and in sufficient quantity to be of value under modern conditions.

To sum up it may be said that future development of limestone quarrying, for agricultural purposes, is unlikely on any important scale, owing to the poor quality of the accessible deposits and, with the exception of those north-west of Huntly, to the comparative inaccessibility of the outcrops of better stone.

Deeside Limestone

A number of openings in the Deeside Limestone occur in the Aboyne district. One of these, Deecastle Quarry, is described as typical of a working in very impure limestone, used only for roadstone, and another, Mains of Midstrath Quarry, as an example of a somewhat purer rock which was formerly burnt.

Deecastle Quarry: [NO 44025 96913] alongside the South Deeside road, 5½ m. W. of Aboyne. (66. 92 N.E.)

The quarry is in a banded calc-silicate hornfels with alternating quartzose layers and greenish layers containing wollastonite, pyroxene, oligoclase, epidote, prehnite and sphene. In bulk analysis (SL 77) [NO 4402 9692] it shows CaO 25.08; MgO 2.47 and Insol. Res. 66.85. The general dip is N.W. at 30° but there is an anticline in the centre of the quarry. The thickness exposed is about 30 ft. The face is about 50 ft. high, with only slight drift overburden, but the rock is weathered to a depth of 10 ft. or more. Reserves are probably considerable A short distance to the north-east similar rock is exposed in a disused quarry at Corntulloch.

Mains of Midstrath Quarry [NO 58809 95264]: 4½ m. E.S.E. of Aboyne. (66. 93 N.E.)

This is a disused opening, reached by a rough but short track. It was worked in a massive, coarse, greyish-white limestone (SL 78) [NO 5890 9520], composed of calcite with subordinate scapolite and pyroxene, showing on analysis: CaO 36.04; MgO 1.43; Insol. Res. 37.38. Not all the lime and magnesia, however, occur as carbonates, the figures for which are $CaCO_3$ 52.97; $MgCO_3$ 0.46. The stone, which is at least 30 ft. thick, lies horizontally or dips gently E. at the east end of the quarry. The face is about 30 ft. high, with very slight overburden. Reserves are probably large, and only some undergrowth would require to be removed in order to reveal an excellent face for working. Other quarries in similar rock are located at Gallowhill Wood and Wood Cottage nearby.

Blair Atholl Limestones

The only exposures of the Blair Atholl Limestones which need to be considered are those which occur near to the road that leads south from Braemar to the Devil's Elbow. Half a mile S. of Braemar (65.98 N.W.) several bands of good grey limestone up to 20 ft. thick are seen in the River Clunie. The ground alongside the river, however, is fairly flat and drift-covered so that it is doubtful if a face suitable for quarrying could be readily developed. Still farther, south, limestone occurs alongside the road for one mile N. of Glen Clunie Lodge (106 N.W.) and again for two miles N. of the Devil's Elbow (111 N.W.). There is no record of these limestones having been worked.

Unclassified Limestones of Upper Donside, and of Central and North-Eastern Aberdeenshire

In the Corgarff and Glenbuchat districts of Upper Donside limestones of moderate purity occur, of which the most important is probably that at Glenbuchat. Farther to the north-east there are exposures in the Correen Hills, at Largie, Old Meldrum, Auchnagatt, Fetterangus, Strichen, Fraserburgh and elsewhere, but these are not of sufficient importance to be described in detail.

Glenbuchat. (75. 50 S.W.; 60 N.W.)

There are several disused quarries near a small school, 3 m. N.W. of Glenbuchat [NJ 33723 17797]. The stone varies from a medium-grained grey type to a fine, hard, somewhat less pure type. An-analysis is not available, but taken as a whole the stone is of moderate purity. Probably the best quarry for re-opening is that situated immediately east of the road, 200 yds. S. of the school. The limestone beds are vertical and strike N.20°W. The total width is 60 ft. The height of the face is 30 ft. but could be readily increased to 50 ft. Overburden is absent. The limestone could be worked to the north for 100 yds. where there is another disused quarry showing much the same section as that just described.

Other openings in the same band occur near the road north of the school. Farther east another band is exposed in a large opening termed the Bealach Quarry [NJ 33840 17465]. This working is, however, much less accessible than those at the roadside as it lies 200 ft. up a rough hillside.

Corgarff: disused quarries at Luib [NJ 26783 08776], Dikehead [NJ 27455 08511] and [NJ 29482 08223]. (75. 68 N.E.)

The opening at Tornahaish appears to be the most promising, should exploitation of limestone in the district be considered. The stone is of a grey, medium-grained type, massive in some places, in others rather broken. It is at least 10 ft. thick and has a general dip to the E. at 40°. Overburden is practically absent. The reserves are plentiful, as the limestone could be worked along the strike for at least 100 yds. either north or south.

Limestones of North-Western Aberdeenshire

The limestones west of Huntly belong to the Sandend and Portsoy groups of Banffshire, of which they are continuations. The quarries at Blackhillock (Ardonald) and at Broadland are typical (Figure 12).

Blackhillock Quarry. (86. 16 S.E.)

This is a disused opening near the farm of the same name which is situated three-quarters of a mile S. of Coachford and 4½ m. S.S.E. of Keith. It was worked in a grey limestone (SL 71) [NJ 4591 4482] of the Sandend Group, showing on analysis: $CaCO_3$ 91.62; $MgCO_3$ 3.28; Insol. Res. 4.44. Only about 8 ft. of good limestone with thin micaceous partings are now exposed although at least 20 ft. of limestone must originally have been worked. The dip is E.15°N. at 40° to 60°. The face is 15 ft. high, and overburden is moderate. Reserves could be worked along the strike in either direction.

Broadland Quarry: 3¼ m. W.N.W. of Huntly and 6 m. S.S.E. of Keith. (86. 25 N.E.)

Broadland Quarry was worked in a blue, medium-grained limestone (SL 240) [NJ 4797 4167] with thin impure partings, belonging to the Portsoy Group and showing on analysis: $CaCO_3$ 89.39; $MgCO_3$ 2.22; Insol. Res. 7.12. The limestone is at least 30 ft. thick and dips E. at 80°. Overburden is slight. There are considerable reserves along the strike to the north, where the limestone is exposed in other old workings. In these the dip of the limestone is as law as 55°.

Angus

The county of Angus (Forfarshire) has practically no limestones of present economic value. Geologically it belongs partly to the Grampian Highlands and partly to the Midland Valley, the dividing line between the two regions being marked by the Highland Boundary Fault (Plate 2).

North-west of this fracture Angus is made up chiefly of schists of the Dalradian Series intruded by granite. There are also outcrops of the Loch Tay Limestone in Glen Isla, but they are not of economic importance. Thin limestones of slight extent make comparatively inaccessible outcrops near [NO 49191 79726] in Upper Glen Esk (Figure 2).

South-east of the Highland Boundary Fault the county is composed of rocks of Old Red Sandstone age. In the lower division of this formation there is a well marked bed of cornstone which was formerly worked in a line of quarries near Brechin (57. 26 S.E.; 27 N.W., N.E.). Cornstones which occur in the Upper Old Red Sandstone of the Montrose district

were also wrought at one time, notably at [NO 71370 53327], 2 miles S. of Montrose (57. 35 S.W.). Neither the Lower nor Upper Old Red Sandstone cornstones appear to be of economic importance at present.

Argyll

Limestones are both plentiful and widely distributed in Argyll (Figure 3); and although seldom of the highest degree of purity are frequently of moderate or good quality. At one time they were quarried and burnt in almost every part of the county, but within the last 60 years or so the number of kilns in operation has steadily declined. Realization of the value of ground limestone has led in recent years to a small-scale revival of limestone quarrying. At present (1947) there are four quarries producing ground limestone, and one at which limestone is burnt somewhat intermittently for purely local use.

Geologically Argyllshire is most complex, and the limestones accordingly show a wide variation in physical characteristics, composition and mode of occurrence. A small portion of the county, at Toward Point, belongs to the Midland Valley and is made up of Upper Old Red Sandstone, cut off to the north-west by the Highland Boundary Fault, the line of fracture being marked by a band of carbonated serpentine. The Upper Old Red Sandstone contains bands of cornstone, some of which were formerly worked; but they are probably not of sufficient extent to be of present value. An analysis (SL 283) [NS 134 685] of one of these cornstones from a stream exposure 250 yds. N. of Toward Taynuill, shows: $CaCO_3$ 49.95; $MgCO_3$ 38.90; Insol. Res. 6.30.

The part of Argyllshire between the Highland Boundary Fault and Loch Linnhe consists essentially of metamorphic rocks of the Moine and Dalradian series intruded by granite and related igneous rocks. The Moine Series here is of small extent and contains no limestones. In the Dalradian Series, on the other hand, limestones are abundant and widely distributed. The most important bands may now be described, roughly in order from south to north.

The Loch Tay Limestone forms a long outcrop extending from Campbeltown to Glen Fyne, near which it passes into Perthshire (p. 153). It is associated with mica-schist and intruded throughout by sills of epidiorite. Though low in magnesia, it is of only moderate quality, the chief impurity being silica. Nevertheless, it has been opened up for agricultural purposes in numerous quarries, two of which, at Campbeltown [NR 72186 19721] and [NR 74244 54929], are still in production. As it is fairly massive, the Loch Tay Limestone has also been worked for roadstone.

To the north-west of the Loch Tay Limestone an important division of the Dalradian, the Ardrishaig Group, forms an extensive outcrop which has been traced from Gigha to Dalmally. A smaller outcrop of the same group also occurs in the Craignish peninsula and around Loch Melfort. The Ardrishaig Group as a whole is calcareous and contains the Shira Limestone, which is of small extent and of moderate purity. It has been quarried at a few localities, at one of which it is still intermittently burnt.

Between the two outcrops of the Ardrishaig Group just mentioned, the Loch Awe Group forms all the country in a belt stretching northwards from the Tayvallich peninsula and the lower part of Loch Awe to near the head of the loch (Figure 4). This group contains the important and widely distributed Tayvallich Limestones. These show great variation in composition, although they are seldom of more than moderate quality. They are interbedded with black schists and nearly always associated with epidiorite. One quarry near Kilchrenan [NN 03712 22942] produces ground limestone for agricultural purposes.

North of Loch Etive there are two important limestones, the Ballachulish Limestone and the Appin Limestone (Figure 3). The latter is strongly magnesian and locally approaches the composition of a true dolomite, with a small percentage of silica. The Ballachulish Limestone crops out round the entrance to Glen Coe [NN 09836 59273], but owing to its poor to moderate quality and the lack of suitable outcrops for quarrying it is not, as far as Argyllshire is concerned, of economic importance. Farther to the north-west, in Inverness-shire, an important outcrop is worked north-east of Fort William [NN 18045 77621] (p. 113).

The island of Lismore [NM 84579 41521] in Loch Linnhe is composed almost entirely of metamorphic limestone which is generally of moderate quality, but which, in places, rises to a fairly high degree of purity. This limestone is in general

noteworthy for its low content of magnesia. Its chief impurity is silica. It was formerly quarried in many places, but is not being worked at present.

With the exception of its western part, the island of Islay (Figure 5) also belongs geologically to the Grampian Highlands. It contains the important Islay Limestone, which is of fairly high quality with a low magnesian content. The Islay Limestone was at one time wrought in numerous quarries, one of which was in production up till 1939. Lately a new quarry has been opened up at Ballygrant.

In parts of Argyllshire south-east of Loch Linnhe the schists are overlain by rocks of Old Red Sandstone age. These are mainly of a volcanic nature, and such sediments as occur contain no limestones of importance. Near Campbeltown the Old Red Sandstone is succeeded in turn by Carboniferous strata, which include thin limestones. The outcrops of the latter are small and are not readily accessible.

The part of Argyllshire north-west of Loch Linnhe belongs structurally to the *Northern Highlands* and *North-Western Highlands.* In Mull and Ardnamurchan there are also extensive outcrops of Tertiary lavas, and of Tertiary intrusions of great complexity.

The oldest rocks in this area are Lewisian gneisses found in western Islay, Coll, Tiree and Iona (Figure 3). In the three last-named islands marbles occur, some of which were at one time quarried as ornamental stones. The quantity of this material now available is very limited.

In Islay, Colonsay and Iona, Torridonian sediments occur and include, in Colonsay, bands of limestone of moderate thickness.

Metamorphic rocks of the Moine Series are found in Mull and on the mainland westwards from Loch Linnhe. Bands of marble in Ardgour probably belong to this formation, but are not of economic importance.

Beneath the Tertiary lavas Mesozoic sediments have been preserved at numerous localities in Mull, Morvern and Ardnamurchan. In western Mull and in the nearby island of Inch Kenneth there are Triassic corn-stones. In Mull, Rhaetic limestone occurs, but is too impure to be of value. The only important Mesozoic limestones are those belonging to the Lower Lias, which are of fair purity and have been quarried and burnt at one or two localities. Thin, unimportant outcrops of chalk also occur in Mull and Morvern.

Finally, mention should be made of shell sand, which occurs at many localities on the western seaboard of Argyll, particularly on the islands (see below, p. 58).

To sum up, it may be said that in the mainland of Argyll south-west of Loch Linnhe, in Lismore, and in Islay, there are ample supplies of limestone for agricultural purposes and also for roadstone. In the district north-west of Loch Linnhe, and in the other islands, limes tones are not so plentiful; but agricultural requirements could be met locally in some districts by working the Lower Lias limestones or the shell sands.

Dalradian

Loch Tay Limestone

At present only two quarries are worked in the Loch Tay Limestone, one at Askomill near 'Campbeltown, and the other at Ronachan farther up the Kintyre peninsula. On the east side of Loch Fyne there are disused quarries about a mile south of Kilfinan and at Otter Ferry. At the last-named locality the stone was not only burnt at one time, but has also been used for roadstone. Still farther north there are important outcrops in Glendaruel and in a large disused quarry at Glensluan, one mile south of Strachur.

Askomill Quarry [NR 73381 20787]: ½ m. E.N.E. of Campbelltown. (12. 258 N.W.)

The stone here is a very coarse blackish, crystalline limestone or marble (SL 128) [NR 734 211], with subordinate finer bands. Quartz is the principal impurity, along with pyrite and graphite. Analysis showed: $CaCO_3$ 83.87; $MgCO_3$ 1.30; Insol. Res. 14.83. Many calcite veins are present, some stained with haematite. The limestone dips E.25°N. at 25° to 30° and is 40 to 50 ft. thick. The face of the quarry is about 50 ft. high, excluding overburden, which amounts to 10 to 15 ft. of boulder clay. Near the floor of the quarry there is a sill of epidiorite, 3 to 4 ft. thick. The stone is worked to produce ground limestone.

There is a line of fault, accompanied by much brecciation, along the west wall of the quarry, and the ground between this fracture and an old quarry to the west appears to contain no limestone. To the north, extension is cut off by a main road. There may be reserves to the east, in the direction of dip, although there are signs of faulting. Eventually, a new quarry might have to be opened north of the road.

Ronachan Quarry: 1,300 yds. E. by S. of Ronachan House, West Loch Tarbert. (20. 224 N.W.)

The stone is a grey, medium-grained limestone (SL 147) [NR 7553 5499], with accessory quartz, albite, muscovite, clinozoisite and pyrite, showing on analysis: $CaCO_3$ 75.82; $MgCO_3$ 0.69; Insol. Res. 20.81. The limestone dips W. by N. at 70°. The thickness of the worked band is about 24 ft., and 30 ft. to the east there is another band at least 18 ft. thick. The face is 7 ft. high, and the overburden is 1 to 2 ft. thick. There are considerable reserves along the strike. Ground limestone is produced.

[NR 99983 86969]. (29. 162 S.W.)

The Loch Tay Limestone makes an extensive outcrop on the west side of Glendaruel. It was formerly quarried in the sides of a stream 750 yds. north of Glendaruel House, where a considerable thickness of limestone is exposed, with some mica-schist partings and sills of epidiorite. A bulk sample was collected from a 20-ft. face of limestone on the north side of the stream. On analysis by G. A. Sergeant (Geol. Surv. Lab. No. 1433), the stone, a grey, medium-grained crystalline limestone with thin micaceous partings, showed $CaCO_3$ 67.67; $MgCO_3$ 1.65; SiO_2, Al_2O_3 and Fe_2O_3 27.40. There are large reserves both to north and south. In the former direction, not far from the stream, there are other small, disused workings in the hillside. Overburden probably does not amount to more than a few feet of scree. The limestone is cut by a few thin basalt dykes. Access is rather difficult, as the outcrop lies about 400 ft. up a steep hillside from the road. Near the road there is ample space for plant.

Other small disused workings in the Loch Tay Limestone occur near the head of Glendaruel, in the vicinity of Kilbridemore (Sheet 37).

Glensluan Quarry [NS 09492 99597]: a large disused opening 1 m. S. of Strachur. (Figure 4) (37. 141 S.W.)

The limestone (SL 134) [NS 0926 9944] is a grey, medium-grained, well bedded, almost flaggy type, with quartz, muscovite and accessory pyrite, and shows on analysis: $CaCO_3$ 66.89; $MgCO_3$ 3.26; Insol. Res. 28.18. There are thin mica-schist partings in places, and a few calcite-haematite veins are present. The limestone is at least 30 ft thick and dips N.N.W. at 20°. The overburden is light. The face of the quarry is 30 ft. high and 150 yds. long. As there is a slight shelf above the quarry, the face could be worked back a short distance without the necessity of removing overlying mica-schist, although it should be noted that the limestone itself becomes less pure and more micaceous towards the top. To the south-west there is a basalt dyke with north-westerly strike; but exploitation could be started beyond this intrusion as well as to the north-east of the present quarry.

Shira Limestone

The only occurrence of the Shira Limestone of economic importance is that at Turnalt (36. 130 S.E.), which is quarried and burnt on a small scale for local requirements. The stone is a fine-grained, bluish limestone (SL 124) [NM 8436 0856], with thin phyllitic partings and subordinate quartz, showing on analysis: $CaCO_3$ 86.04; $MgCO_3$ 2.69; Insol. Res. 10.64. There is a general dip in a direction E. 25° S. at 70°, but the strata are repeated by a small anticline and syncline on the east side of the quarry. The limestone is about 15 ft. thick stratigraphically, but owing to repetition by the folds just mentioned shows a width of 30 ft. in the quarry-face. The face of the quarry is 10 to 15 ft. high and there is no

overburden. The reserves are very considerable to the north-north-east.

Tayvallich Limestones

The Tayvallich Limestones were formerly quarried at numerous localities around the south end of Loch Awe and Kilmartin, for example, at Fincharn and Eurach north of Kilmartin, and at Tayness and Baluachraig south-west and south of Kilmartin (Figure 5). The quarries at Fincharn, where the stone was burnt until quite recently, and at Baluachraig will be described, along with a working at Kilchrenan at the north end of Loch Awe where ground limestone is at present produced.

Fincharn Quarry: at the south end of Loch Awe, 1¼ m. S. of Fincharn farm and 2 m. E. of Ford. (37. 139 N.W.)

The stone is a black, fine-grained limestone (SL 126) [NM 8988 0380], with quartz pebbles.' A small quantity of quartz also occurs in the groundmass. The limestone showed on analysis: $CaCO_3$ 90.09; $MgCO_3$ 0.61; Insol. Res. 8.21. There are many calcite veins. The limestone dips steeply to N.W. and is in places vertical with N.E. strike. A thickness of about 45 ft. is worked, and there is at least a further 10 ft. of similar limestone immediately to the north-west. The face is 15 ft. high and the overburden is light. Plentiful reserves occur to the north-east.

Baluachraig Quarry [NR 83351 96860]: on the N.E. side of the main road, 270 yds. S.E. of Baluachraig which lies 1¼ m. S. by W. of Kilmartin. (36. 149 S.E.)

The limestone (SL 125) [NR 8336 9685] is very variable in grain, and in the coarsest beds there are pebbles of quartz and feldspar up to ½ in. in length in a matrix of calcite. The stone showed on analysis: $CaCO_3$ 66.44; $MgCO_3$ 0.55; Insol. Res. 32.05. The limestone dips W. 30°N. at 70°, and is at least 180 ft. thick. The quarry face is 15 ft. high with no overburden. There are considerable reserves up the hillside to the east. The quarry is disused.

Kilchrenan Quarry: on the W. side of the road to Taynuilt, 1 m. N. of Kilchrenan. (45. 112 N.E.)

A black, fine-grained limestone (SL 123) [NN 0384 2447], with scattered quartz grains, is worked; the limestone showed on analysis: $CaCO_3$ 82.39; $MgCO_3$ 0.88; Insol. Res. 13.54. Many veins of calcite occur. The limestone dips W.5°N. at 30° and is 20 ft. thick in the worked face. If it persists down to road-level, as appears likely, the total thickness must be at least 40 ft. The face of the quarry is 15 to 20 ft. high and the overburden is light.

In the direction of dip further limestone beds come on, but these appear to be more shaly and of poorer quality. Exploitation in this direction would also be hindered by a porphyrite dyke about 10 ft. wide. There are crags of limestone along the strike to the south, and the working could be extended in this direction.

Appin Limestone

Interest attaches to the Appin Limestone as a possible source of dolomite, although it has been quarried in the past for agricultural purposes, for example, at Onich (in Inverness-shire) and at Acharra House, Duror. At Ballachulish an impure variety was at one time unsuccessfully tried as an ornamental stone. Much purer material, with magnesium carbonate content of as much as 43.78 per cent. and silica content as low as 3.70 per cent., is exposed in a nearby stream, 660 yds. S. 23°W. of Laroch Bridge. The best quality of dolomite so far known within the Appin Limestone outcrop, however, is that exposed at Dalnatrat, near Duror. A disused quarry is situated beside a rough track 650 yds. E.N.E. of Dalnatrat Bridge (53.43 S.E.), three-quarters of a mile S.S.E. of Duror. The dolomite (SL 87) [NM 9832 5421] is a white saccharoidal type with green streaks of serpentine in places. There are scarce, very thin, siliceous veins. Several analyses have been made, of which one, communicated by the Steetley Lime and Basic Co., Ltd., Shireoaks, shows the following figures: $CaCO_3$ 51.97; $MgCO_3$ 45.67; SiO_2 3.30. Another, communicated by Stewarts & Lloyds, Ltd., Holytown, gives as follows: $CaCO_3$ 54.83; $MgCO_3$ 41.76; SiO_2 1.34. The dolomite dips S.E. at 55° and is at least 40 ft. thick. A face of about 20 ft. is exposed, with overburden varying from 0 to 5 ft. The reserves are probably considerable. At Dalnatrat Bridge there is a tract of flat raised beach which would afford a site for plant, adjacent to the L.M.S. railway line and to the main road.

An analysis (SL 87) [NM 9832 5421] of material from farther north on the same outcrop, south of a road-bend east of Duror station, gave: $CaCO_3$ 47.63; $MgCO_3$ 38.60; Insol. Res. 13.11.

Lismore Limestone

Lismore consists mainly of limestone with partings and subordinate beds of black graphitic schist and igneous intrusions. The limestone varies considerably in composition and, of several samples analysed by the British Oxygen Co., Ltd., the best proved to be that from a 20-ft. band 100 yds. W. of the ruins of Achadun Castle, analysis of which showed: $CaCO_3$ 95.00; $MgCO_3$ 0.13; SiO_2 3.04.

In the past the Lismore Limestone was quarried and burnt at numerous localities. The most important working was a large quarry situated 700 yds. N.E. of Port Salen (Sailean) (44. 72 S.W.). The limestone is of a fine, dark bluish-grey type, showing on analysis by the British Oxygen Co., Ltd.: $CaCO_3$ 90.70; $MgCO_3$ nil; SiO_2 6.68. There is a general dip in a direction E. 30°S. at 70° to 80°, but the rock is contorted in places. The thickness of the limestone is at least 50 ft. in the worked face, which is 80 ft. high and 100 yds. long. Several joints dip W. at 60°, including a large joint forming the back of the quarry. There is no overburden, and the reserves are very great. There is a small quay nearby. The access road to the quarry is rough and steep from the main road in the centre of the island, but is probably possible for lorries.
Limestone has also been worked in the past in a quarry just north of Port Ramsay. On analysis (SL 88) [NM 8844 4558] it showed: $CaCO_3$ 87.17; $MgCO_3$ 0.25; Insol. Res. 11.25.

Islay Limestone

The Islay Limestone has been worked for agricultural purposes at numerous localities, of which Lower Cragabus, Leorin, Persabus, and Bridgend may be mentioned as examples (Figure 5). The quarry at Bridgend was worked till 1939, and a new quarry producing ground limestone has recently been opened at Ballygrant.

Lower Cragabus: 2¼ m. W. of Port Ellen. (19. 231 S.E.)

This disused quarry is on top of a knoll adjacent to a road. The rock (SL 100) [NO 2007 0677] is a fine-grained limestone, showing on analysis: $CaCO_3$ 92.94; $MgCO_3$ 4.87; Insol. Res. 2.83. It dips S.35°E. at 30° to 35°. It is 20 ft. thick in the quarry, but the total thickness is probably considerably more. There is no overburden. The reserves are considerable, as the knoll, which measures 50 by 80 yds. and is 40 ft. high, appears to consist entirely of limestone.

Leorin: 2■ m. N. by W. of Port Ellen. (19. 231 N.E.)

Here there is another disused quarry in the Islay Limestone. The rock (SL 129) [NR 354 485] showed on analysis: $CaCO_3$ 93.14; $MgCO_3$ 2.16; Insol. Res. 4.41. The readily available reserves are not so great as at Lower Cragabus.

Persabus Quarry: ¾ m. W.S.W. of Port Askaig. (27. 198 N.E.)

This quarry has been worked in two benches, the upper of which has a face 15 ft. high and the lower 12 ft. The limestone (SL 132) [NR 420 688], a dark-grey, fine-grained, splintery type with thin oolitic layers, showed on analysis: $CaCO_3$ 91.59; $MgCO_3$ 6.51; Insol. Res. 1.63. It dips N.W. at 30°. There is no overburden, and reserves are considerable. A fairly well-preserved kiln is adjacent to the quarry.

Bridgend Quarry. (27. 208 N.E.)

This recently worked quarry is situated on the north side of the main road, 1,600 yds. N.E. of Bridgend. The rock is a fine-grained, light to dark-grey limestone (SL 131) [NR 347 632] with subordinate bands of graphitic schist up to 6 in. thick. It contains very abundant calcite veins. On bulk analysis it showed: $CaCO_3$ 94.60; $MgCO_3$ 2.42; Insol. Res. 2.96. The limestone is thrown into isoclinal folds, the limbs of which dip S.E. at 30° to 35°. The apparent thickness is at least 85 ft. The face of the quarry is 20 to 30 ft. high, and the overburden is light. There are very considerable reserves to the north-east.

Ballygrant [NR 39560 66077]. (27. 198 S.W.)

There is an exposure of limestone just south of the mill on the south side of the village. The stone appears similar in character and purity to that at Bridgend. It dips N. at about 45°, is from 40 to 50 ft. thick, and has a bed of phyllite in the lower part. There is no overburden, and reserves are abundant.

Jurassic limestones and shell sand

Jurassic

The chief occurrences of Jurassic limestone are in the Lower Lias of Loch Aline and Ardnamurchan (Figure 3). The Loch Aline quarry was producing lime until recently. In Ardnamurchan there are disused quarries at Mingary Castle, Kilchoan and Swordle.

Loch Aline Quarry [NM 6928 4597]: beside the Allt na Samhnachain, on the E. side of Loch Aline. (44. 70 N.E.)

The following section is exposed:

Massive limestone with shale partings and some *Gryphaea* shells	5 ft.
Nodular limestone with many shale partings (forming 40 per cent. of whole) and abundant *Gryphaea*	10 ft.
Massive limestone with shale partings (forming 25 per cent. of whole) and few *Gryphaea*	8 ft. 23 ft.

The upper 15 ft. of limestone (SL 90) [NM 6928 4597] showed on bulk analysis: $CaCO_3$ 87.18; $MgCO_3$ 1.55; Insol. Res. 8.10. For the limestone (SL 89) [NM 6928 4597] in the lower 8 ft. the corresponding figures were $CaCO_3$ 90.05; $MgCO_3$ 1.53; Insol. Res. 6.40. In the stream to the south the lower limestone is 15 ft. thick. The limestone lies practically horizontal. The face of the quarry is 23 ft. high, overburden consisting only of scree.

To the south, extension of the quarry would be cut off by a stream; but to the east the ground is fairly flat for about 50 yds. so that the quarry-face could readily be worked forward in this direction. To the north, the present quarry is limited by a small fault heading N.N.W. at 55° and throwing down in the same direction about 10 ft.; if, therefore, it were desired to extend the quarry to the north a new opening should be made 10 ft. below the level of the present quarry-floor, in order to reach the good lower limestone.

Shell sand

The most important localities for this material are Sanna Bay in Ardnamurchan, Coll, Tiree, Iona, Calgary Bay in north-west Mull (where the carbonate content is recorded as being rather more than 78 per cent.), Ardalanish,Bay in south-west Mull, Colonsay, Oronsay, and Kilnaughton Bay in southern Islay. At the last-named locality, 1¼ miles west of Port Ellen, the sand is dug for agricultural purposes, but is of poor quality with a calcium carbonate content varying from 25 to 50 per cent.

Ayr

The limestone resources of Ayrshire are large, and widely distributed throughout the county (Figure 6) and (Figure 7). At the present day, nevertheless, only five quarries are in operation, whereas, a century ago, there were more than 50, spread over 23 parishes, according to the parochial records (New Statistical Account of Scotland: Ayr–Bute, vol. v., 1845). There were two principal reasons for the former greater activity. In the early decades of the 19th century great changes in farming methods, involving land drainage and liming, were being instituted. A brisk demand for lime thus sprang up, and owing to the difficulties of transport in those days local sources of supply were always developed if at all possible.

A second great need of limestone arose with the development of iron-smelting. Iron works were set up at Glenbuck and Muirkirk about 1787, and from 1843 onwards furnaces were erected at eight other centres in the county—Dalmellington,

New Cumnock, Lugar, Ardeer, Eglinton, Portland (Kilmarnock), Blair (Dalry) and Glengarnock. The industry flourished until the end of the 1914–18 war, but now only the Glengarnock works is in operation. For long these furnaces used local limestones for flux and many quarries were opened, but even before the decline of the smelting industry there was a tendency to abandon the local quarries as soon as the supply of the more readily available stone was exhausted and to use instead limestone brought from a distance. Adequate regular liming of the soil also fell largely into abeyance. As a result the limestone industry lost its vigour and by 1899 only five quarries and one mine were producing. They employ, altogether, less than 100 persons. In 1937 production was taking place only in four quarries. In 1944 five quarries were active.

The geology of Ayrshire is very varied,;nd limestones of workable thickness are found in three of the formations present, the Ordovician, the Old Red Sandstone and the Carboniferous. The Ordovician rocks very largely occupy the upland country south of Girvan. They are partly igneous and partly sedimentary in character. The sediments include conglomerate, sandstone, shale, and a thick limestone known as the Stinchar Limestone. There are many outcrops of this limestone between Colmonell, Barr and Pinmore (Figure 7), and also at Craighead. There are working quarries in it at Tormitchell (Pinmore) and Craighead. Formerly, there were also quarries of considerable size at Colmonell, Aldons and Minuntion.

The Old Red Sandstone formation is represented in many parts of the county. In the south the wide area between Heads of Ayr, Girvan and Straiton is largely occupied by it, as well as a narrow hilly strip extending from south of Straiton eastwards beyond Dalmellington. In the east it is the main formation in the hills between New Cumnock and Muirkirk and appears in the high ground of the Distinkhorn, south of Newmilns, extending westward in a narrow strip almost to Inchgotrick, south of Kilmarnock. In the north there is a coastal strip of these rocks between Ardrossan and Wemyss Bay (10 m. N. of Fairlie, (Figure 6)). Much of the rock in this formation is igneous in character, but, associated with the sediments, particularly in the Upper Old Red. Sandstone, are the nodular limestones known as cornstones. These are often of workable thickness, and as a rule provide a limestone of high quality. At the present time they are not being used. Past workings, however, were extensive—at Balgreggan, Lannielane and elsewhere (Straiton), Craigdullyeart (New Cumnock) and Middlefield (Muirkirk).

Not far short of half the county is occupied by rocks of the Carboniferous system. As well as valuable coal seams this system contains large deposits of limestone. These are present in the two lowest geological sub-divisions, the Calciferous Sandstone Series and the overlying Carboniferous Limestone Series. Regionally, the limestones are most abundantly developed in the north, roughly north of a line joining Ardrossan, Kilwinning, Kilmaurs and Newmilns. A second extensive area has its centre about Muirkirk, while there are also considerable deposits at New Cumnock and Patna. The Carboniferous limestones of Dailly are largely obscured by superficial deposits. These limestones were extensively quarried in the iron-smelting era, but now work is proceeding only at three localities—Lugton, Dockra and Nettlehirst, all in North Ayrshire (Figure 10).

Ordovician

The Stinchar Limestone of South Ayrshire (Figure 7) is at present worked at Tormitchell (Tramitchell), S.E. of Girvan, and at Craighead, N.E. of that town.

The numerous abandoned quarries are mainly situated in the Colmonell–Barr district. The principal openings and outcrops are listed below.

Tormitchell Quarry [NX 23392 94402]: 7½ m. by road S.E. of. Girvan (8. 56 S.W.)

In this quarry the exposed face of limestone is about 100 ft. high; and the width of the outcrop may be as much as 300 ft., due to repeated folding of the limestone bed. The true thickness of the limestone is believed to be about 60 ft. The dip of the beds varies between 30° and vertical. Throughout most of its thickness the limestone is a dark grey, compact rock. Two analyses have been made. One of these (SL 153) [NX 23 94] represents the bulk of the quarried rock. It shows as follows: $CaCO_3$ 87.14; $MgCO_3$ 2.80; Insol. Res. 8.78. A 6-ft. band of paler limestone (SL 154) [NX 23 94] at the south margin of the quarry is of greater purity. Its analysis proved: $CaCO_3$ 95.54; $MgCO_3$ 1.34; Insol. Res. 2.73.

The bulk of the output of the quarry is converted to road chips, ground agricultural limestone, and stone dust. A small quantity is burnt for lime.

Craighead Quarry [NS 23427 01368]: 3½ m. N.E. of Girvan. (14. 50 S.W.)

At this quarry the thickness of the worked limestone is at least 30 ft. Owing to the variable dip of the strata and to disturbance by faulting the available reserves are difficult to estimate. However, these are not likely to be as great as at Tormitchell. The limestone (SL 152) [NS 234 012] is compact, pale greenish in colour, and often concretionary and accompanied by green clay partings and aggregates. The analysis shows the presence of a considerable proportion of impurity: $CaCO_3$ 81.96; $MgCO_3$ 1.76; Insol. Res. 14.33. The output is partly burnt, and partly crushed and ground. The quarry is conveniently situated both to road and rail.

Craigneil, Colmonell. (7. 66 N.W., N.E.)

There are two abandoned quarries, one south of the road beside the ruined castle [NX 14699 85375], the other farther west nearer the farm and north of the road [NX 14505 85397]. Both quarries are now much overgrown. The worked bed is about 30 ft. thick and is nearly vertical. In the main (south) quarry some extension to the west is still possible, though not very easy. An analysis, furnished by Messrs. Colvilles, Ltd., Glengarnock, indicates a limestone of only fair quality, calcium carbonate being 84.76 per cent.

Bougang: 2 m. W. of Colmonell. (7. 66 N.W.)

This abandoned quarry is now waterlogged and nothing of importance is to be seen [NX 11415 85494]. The reserves of stone are probably very small.

A mile nearer to Colmonell, limestone outcrops at the roadside 400 yds. E. of the farm of Knockdolian Barns [NX 12675 85813]. This outcrop also is too small to be worth consideration.

Aldons Quarry [NX 19667 89638]: 1½ m. S. of Pinmore Station. (7. 62 N.W.)

In this abandoned quarry is a face of 30 ft. of massive limestone. The quarry could be extended 150 yds. to the south and south-east so that the reserves of stone are considerable. There is no overburden. Access is good, and the quarry adjoins main road and railway. The quality of the rock is fair, the analysis (SL 266) [NX 197 897] indicating $CaCO_3$ 82.39; $MgCO_3$ 0·82; Insol. Res. 13.80.

Millenderdale [NX 17001 90610]. (7. 61 N.E.)

This quarry, adjacent to the farm-steading, is now waterlogged and further development would not be easy. In a field, 100 yds. N.E. of the farmhouse, is a knoll of limestone, 20 ft. in diameter at base and 20 ft. high. The full extent of this outcrop is not clear. The limestone was also exposed about 1 m. E.N.E. of the farm, at a spot 200 yds. S. of the farm road. Only fragments of limestone are now to be seen here.

Little Letterpin:½ m. N.W. of Pinmore Station. [NX 20129 92661] (7. 62 N.W).

About 5 ft. of limestone are seen under conglomerate in an abandoned quarry 100 yds. W. of the farm. Probably all future quarrying would have to be done under the conglomerate. The site is convenient to the main road.

Pinmacher: 1 m. N.W. of Pinmore Station. (7.55 S.E.; 56 S.W.)

There is an abandoned quarry 300 yds. N.N.E. of the farm [NX 19812 93689]. The rock is now poorly exposed here, and further development would probably not be easy. There is also an exposure, with 3 ft. of nodular limestone, in a small stream ½ m. farther to the north-east.

Dupin–Craigwells. (8. 56 S.W., S.E.)

Considerable bodies of Stinchar Limestone are exposed in disconnected outcrops between Dupin and Craigwells. Numerous small quarries have been opened here in the past, but none is now wrought.

a. Dupin Glen, W. of Dupin Farm. Exposures in the stream at Dupin Linn show about 60 ft. of limestone in a vertical band [NX 23605 craigwelldupin93999]. Westward from the stream there is little surface cover for about 50 yds. On the east bank of the stream there is much heavier cover of drift, but the rock was noted at the surface again 200 yds. farther to the east.

b. East of Dupin Farm [NX 24182 94078]. Exposures in three small streams and in old quarries east of the farm show that the limestone has thinned to about 20 ft. It appears somewhat disturbed and crushed, standing vertical or dipping S. at a high angle under conglomerate. Surface cover here is thin.

c. Craigwells Quarries [NX 25618 95226]. In this outcrop, which extends over half a mile, six old quarries are indicated on the six-inch map. In these the limestone dips to the south at 30°, and the bed has been worked to a depth where the overburden of shale and conglomerate has become too thick for further economic removal. Erosion of the top of the limestone, too, has reduced the thickness of the bed to 10 ft. or less. Not much more rock could readily be removed here.

Daldowie Hill. (8. 56 S.W.; 62 N.W.)

This is a somewhat remote and inaccessible area in which outcrops of Stinchar Limestone were quarried on a small scale when liming of the permanent pastures was practised.

a. North of Daldowie Hill and south of the Water of Assel. [NX 21918 93350] An outcrop of the limestone extends along the hill-slope for about 1,000 yds. The rock was formerly seen in the Auchmaddy Burn, 350 yds. upstream from its junction with the Water of Assel. There were also small quarries and exposures 200 yds. and 500 yds. farther west, on the north side of the belt of trees known as Shalloch Wood.

b. South of Daldowie Hill. [NX 22059 92027] The outcrop extends from near the summit of the hill southwards for 1,000 yds. There is a quarry and an old kiln half a mile N. 20° W. of Minuntion. About 20 ft. of limestone are visible, but the situation is remote.

Pinmore. (8. 62 N.W.)

a. Kilpatrick Quarry, ■ m. *N.E. of Pinmore [NX 21151 91278].* Ten feet of limestone are here seen beside a ruined kiln. An intrusion of igneous rock might tend to interfere with its working. This locality is somewhat inaccessible.

b. Pinmore. A few feet of shattered limestone are exposed in Balcoun Wood at the side of the road to Kilpatrick farm [NX 20878 90499]. This outcrop probably extends south-westward towards Aldons, but rock is not seen again until the railway cutting at Aldons Wood is reached.

c. Pinmore Mains, 400 *yds. S.E. of Pinmore.* A small outcrop of shattered, yellow, impure limestone occurs in the bank of a streamlet, 100 yds. S. of the farm buildings [NX 20948 89976]. Another exposure of the same outcrop occurs in the next stream to the east, 400 yds. N.E. of the farm and 50 yds. N. of the road [NX 20948 89976]. Ten feet of good limestone are visible here, but the overburden is considerable. The dip of the strata is S.E. at 25°.

Minuntion to Auchensoul. (8. 56 S.W., S.E.; 62 N.W.)

The Stinchar Limestone forms a continuous outcrop on the north side of the River Stinchar from just west of Minuntion to Auchensoul, a distance of about three miles. Throughout this length it dips into the hillside in a north-westerly direction at angles up to 60° and higher, but generally round about 40°. The limestone is overlain by a few feet of shale, above which comes a very thick conglomerate (Benan Conglomerate) covering all the high ground above.

There are now no workings located on this outcrop, but numerous old quarries and sections furnish information. The principal exposures are detailed below:

a. Minuntion Quarry (62 N.W.), north bank of river, 500 *yds. W. of the farm. [NX 22069 91142]* The working face is 30 ft. high, and 30 ft. wide. The dip of the strata is N.W. at 45°. Overburden is slight. Working could be extended to the north-east for 400 yds., without difficulty.

*b. Auchlewan (62 N.W.), ½*m. *E.N.E. of Minuntion. [NX 23066 91997]* The limestone crops out on the hillside above the farm ruins over an extensive area free of overburden. It has a dip to N.W. of 40° to 45°.

c. Benan Quarry and stream section, ½m.. N. of Benan Farm. (56 S.W.). At the quarry in the fork of two streams 20 ft. of massive, yellow-weathering limestone are at present visible, dipping N.W. at 37°. The outcrop is free of overburden, and can be followed westward without difficulty for 150 yds. In the Benan (Kirkland) Burn, 700 yds. to the east, 20 ft. of limestone are exposed, with, however, much drift in the vicinity.

d. Kirkdominae Hill [NX 25037 93037] to Auchensoul [NX 25778 93325]. (56 S.E.). The outcrop of the Stinchar Limestone broadens to about 100 yds. on Kirkdominae Hill and continues so to just east of Auchensoul Burn, 300 yds. upstream from the farm [NX 25799 93190]. The limestone is well displayed in shallow quarries. There is little or no overburden. A sample (SL 267) [NX 251 929] from a quarry on Kirkdominae Hill, 800 yds. W. of Auchensoul, showed, on analysis: $CaCO_3$ 75.58; $MgCO_3$ 1.38; Insol. Res. 20.49.

e. Dularg Quarry. (56 S.E.) [NX 25821 92668]. South of Auchensoul the limestone appears again beside the farm of Dularg. In a quarry in the field 150 yds. S.S.W. of the house 4 ft. of massive, partly reddened limestone are to be seen, while in the stream, a few yards to the west, 10 ft. of limestone are exposed. A few feet of overburden are present.

Another outcrop of similar reddened limestone appears at Dularg Hill, 600 yds. E.S.E. of the farm [NX 26438 92460].

Old Red Sandstone

Cornstones are widely distributed in the Upper Old Red Sandstone of Ayrshire (Figure 9). Frequently the beds are thin, less than 3 ft. in thickness, and of the characteristic nodular habit (Plate 5A); but, on the other hand, in some areas much thicker and massively developed deposits occur, which were widely worked in the past. These thicker developments, which are here described, are situated near Straiton, south-east of Maybole, between New Cumnock and Muirkirk, and south-east of Galston:

Balgreggan Lime Works: 2 m. W. of Straiton. (14. 45 S.W., S.E.; 51 N.W., N.E.)

Cornstone was at one time extensively worked in quarries and mines in the vicinity of Balgreggan, Todglen and Three Thorns. In the main Balgreggan quarry only 6 ft. of the mined cornstone are now seen, and this band is overlain by 20 ft. of strata, including a 6-ft. seam of nodular cornstone which was not mined.

The strata dip westward at from 15° to 30°, but this direction is reversed in the Todglen quarry [NS 34337 04586], ¼ m. to the west. Here there is an ingoing eye in a 9-ft. cornstone, overlain by sandstqne with thinner cornstone bands. It is probable that underground workings of unknown extent connect the Balgreggan and Todglen quarries.

At Three Thorns [NS 35891 04493] the worked cornstone was also overlain by a considerable thickness of sandstone with thinner cornstone bands.

Reserves of good stone in this locality are probably considerable, but, for the most part, are now available only by mining.

Auchalton Lime Works [NS 33488 03556]: 3 m. W.S.W. of Straiton. (14. 51 N.W.)

In this abandoned quarry only 3 ft. of the worked cornstone are now seen under a cover consisting of at least 20 ft. of sandstone beds with thin bands of either massive or nodular cornstone. This is overlain by 6 ft. of drift. The dip is N.W. at 10°. The site is adjacent to the main highway, and access is easy. Reserves are probably large but only readily accessible by mining. The analysis, carried out at the Coal Survey Laboratory, Glasgow, and published by permission of the Director of Fuel Research, indicates a limestone of very high quality: $CaCO_3$ 98.11; $MgCO_3$ 0.08; SiO_2 1.30.

Lannielane Lime Works [NS 31220 01754]: 1 m. S.W. of Blair farm, 5 m. W.S.W. of Straiton. (14. 51 S.W.)

At this locality a quarry was first opened up, and then short mines were driven from the quarry face. The thickness of the bed is 12 ft. and it dips N.W. at 40° under an overburden of several feet of rock. Access is by farm road, 1½ m. to the main highway. Reserves are large, but the steep dip makes mining almost imperative. The quarry might be extended to the south-west but the overburden of drift increases in this direction. The analysis (SL 156) [NS 313 017] indicates a limestone of a high degree of purity: $CaCO_3$ 92.05; $MgCO_3$ 2.48 Insol. Res. 5.92.

Another cornstone bed, 4 ft. thick, below the horizon of the worked seam, is exposed in the stream close at hand. Analysis (SL 155) [NS 313 017] has shown this band to be of great purity: $CaCO_3$ 97.98; $MgCO_3$ 1.11; Insol. Res. 1.72.

Craigdullyeart [NS 66447 15321]; 3 m. E.N.E. of New Cumnock. (15. 42 N.E.)

The cornstone here is a band about 15 ft. thick, which dips westward at 10° to 15° under a thick cover of sandstone. There was an initial opencast, from which mines were afterwards driven.

Accessibility is very good. The quarries are adjacent to a main road, and three miles distant from a railway station. There are large reserves of stone, now, however, accessible only by mining. In the analysed sample (SL 94) [NS 663 153] the following percentages were found: $CaCO_3$ 85.43; $MgCO_3$ 1.86; Insol. Res. 12.71.

The outcrop extends over a distance of 1,500 yds. alongside a main road, and opencast working has already been developed over about 1,000 yds. of its length in the part really suitable for quarrying. The mines are on a smaller scale, with workings 12 to 14 ft. high. The worked stone is a compact, cream-coloured rock with occasional arenaceous patches.

The analysed sample relates to the worked face, and probably by judicious selection material of a higher grade could be obtained.

Glenmuirshaw [NS 69382 20181]: 8 m. E. of Cumnock. (15. 37 N.W., S.W.)

The thickness of the cornstone bed here varies between 6 and 20 ft. It is a compact, pale-cream, brown or chocolate-coloured limestone, usually of high purity, but sometimes sandy, particularly towards the top of the bed; or it may be traversed by veins of chert (silica). Also accompanying it may be deposits of green and purple marl. The locality is remote and is reached, finally, by a second-class road.

In this region a thick cornstone bed is widespread at the base of the Upper Old Red Sandstone, which here rests unconformably on sediments and lavas of Lower Old Red age. The Glenmuirshaw occurrence is representative of this outcrop, which has been traced from a point in the Guelt Water, 2 m. S. of Glenmuirshaw, as far as Stony Hill, 2½ m. N.E. of Glenmuirshaw, a distance of over 5 m. At Stony Hill [NS 72363 21520] the thickness of the bed is 25 to 30 ft.; elsewhere it is generally between 12 and 20 ft., and seldom less than 10 ft. It is free of thick overburden over considerable areas, and the dip varies between 10° and 30°. The area of its occurrence, however, is high-lying moorland, 1,000 to 1,800 ft. above O.D., without roads of any kind except the cart-track to Glenmuirshaw. Because of its inaccessibility, therefore, working would be difficult.

The analysis of a sample (SL 257) [NS 700 201] from near Glenmuirshaw, showing $CaCO_3$ 94.64; $MgCO_3$ 0.79; Insol. Res. 4.99, indicates the good quality of the stone.

Middlefield Lime Works [NS 69472 30041]: 2½ m. N.W. of Muirkirk. (23. 25 S.E.)

Disused quarries and kilns mark this site. The worked bed had a thickness of between 20 and 30 ft., and dipped to S.W. at angles between 45° and 30°. The locality has an elevation of 950 ft. above O.D., and is 3 m. distant from a railway station. It is adjacent to a road. There is probably a considerable reserve of rock still available, which could be quarried. The analysed sample (SL 170) [NS 6945 3006] showed as follows: $CaCO_3$ 91.23; $MgCO_3$ 1.32; Insol. Res. 7.98.

Cornstone Workings S.E. of Galston. (22. 24 N.W., S.W.)

Cornstone was formerly quarried at a number of localities in this area of Upper Old Red Sandstone. The more important sites are as follows:

a. Burn Anne at Cessnock Castle. (24 N.W.) [NS 51290 35584] The cornstone was quarried and mined on both banks of the stream. When fully exposed it was reported to be 18 ft. thick, but now only 6 ft. are visible, overlain by 17 ft. of sandstone.

b. Auchencloigh [NS 53760 32109], Carleith [NS 54146 32966] and Auchmannoch [NS 54494 30844], 3½ to 4½ m. S.E. of Galston.(24 S.W.) In this faulted tract of Upper Old Red Sandstone sediments there are a number of long-abandoned quarries in cornstone. Auchencloigh quarry, 670 yds. W.S.W. of Auchencloigh farm, shows 12 ft. of limestone, dipping S. at 10° under boulder clay and 12 ft. of sandstone. Mining as well as quarrying was carried on here. A number of other openings in cornstone have been made throughout this tract, particularly at Crofthead and Coplar, N. and N.E. of Auchmannoch, and at Carleith. (Plate 5A)

Carboniferous

Carboniferous limestones of useful thickness are developed in the two lower sub-divisions of this formation, the basal Calciferous Sandstone Series and the Carboniferous Limestone Series. Occasional limy bands occur in the Millstone Grit 'and Coal Measures. These are of importance to the geologist as horizon indicators, but are not of economic value. The description of one such type in the Barren Red Measures which has been sporadically worked is included in this account.

The principal limestones that have been worked are the Calmy Limestone and Index Limestone of the Upper Limestone Group, the Hurlet Limestone of the Lower Limestone Group, and the Broadstone Limestone of the Calciferous Sandstone Series (Figure 8). In Ayrshire, as elsewhere, these limestones have their local names, often taken merely from that of the quarry where they have been worked (*see* (Table 2), pp. 8 and 9).

Dailly and district (14. 45 S.W.; 50 N.E., S.E., S.W.)

Carboniferous Limestone strata extend from the vicinity of Kilkerran railway station [NS 29686 04347] southwestward to near Killochan House [NS 22728 00365] (Figure 6) and (Figure 7). Limestones are known to occur both in the Lower and Upper Limestone groups, but generally, exposures of these beds are poor and little quarrying has taken place.

A complete section of the Lower Limestone Group is exposed in a quarry and an adjoining stream near Heronspark [NS 29305 04549], north-west of Dalzellowlie. There is an upper calcareous horizon (probably Hosie Limestones) separated by 17 ft. of strata from a lower 7-ft. limestone seen in the stream. The latter is known locally as the Captain's Bridge Limestone, and is believed to represent the Hurlet Limestone. There are a few other exposures of these strata in the neighbourhood: the Black Glen [NS 30188 05268], west of Kilkerran Acid Works, 1,100 yds. N.N.E. of Dalzellowlie; a roadside section at Captain's Bridge [NS 28505 03575], 1,500 yds. S.W. of Dalzellowlie; Quarrelhill Burn, 1,200 yds. W.N.W. of [NS 25981 02462]; and Lauchlan Burn, 440 yds. W.S.W. of Bargany House [NS 23993 00095]. In the Quarrelhill Burn the Hurlet Limestone, a pale, fairly solid limestone about 25 to 30 ft. in thickness, is thicker and apparently purer than elsewhere. The beds are practically vertical.

The Upper Limestone Group constitutes a narrow belt of strata extending from near [NS 28021 03704] south-westward to beyond Cairnhill [NS 22827 00228]. There is also a small area near Kilkerran station. The Index Limestone was at one time worked in a quarry in Burninghill Wood. It may also be seen at a mine-mouth just south of the Bardrennan Burn, in a railway-cutting below a road-bridge north-east of Maxwell Pit, at the Holehouse Mine, and in the adjoining Quarrelhill Burn. The limestone together with the associated limy shale is fairly thick, but the proportion of massive limestone suitable for quarrying is not very high. There are practically no other sections in which the Upper Limestone Group is exposed. The sequence, however, has been proved in mineral bores and pits. 'The best section, in a bore half a mile N. of Cairnhill farm [NS 23442 00939], showed five seams of limestone including the Index Limestone. The most important of these, the third from the base and 210 ft. from the surface at this point, is 33 ft. thick. In another bore, north-west of Killochan Pits [NS 22754 00388], a still higher limestone was proved, making six seams in all in the Upper Limestone Group. The outcrops of these limestones, with the exception of the Index examples just quoted, are concealed by drift,

which is generally thick in the area. Nothing is known about their quality.

Patna, Dalmellington and Martnaham (Figure 6)

The principal outcrop of the Carboniferous Limestone Series in this area is practically confined to the valley of the River Doon between Carnochan, N. of Patna and Dalnean Hill, S.W. of Dalmellington. Limestone also appears in the Dalcairnie Burn, S.E. of Auldcraigoch. The Index Limestone is well developed throughout the district, and may be seen in a number of natural sections: The best of these is in Keirs Glen. The Keirs Limestone was formerly extensively quarried at Keirs Lime Works, now long abandoned. Its position in the sequence is about 120 ft. above the Index Limestone.

Cairnshalloch Lime Works [NS 40844 10040]: 800 yds. S.S.W. of Patna. (14. 46 N.W.)

The thickness of the Patna Limestone here was about 12 ft., but only 3 ft. are now seen. There is an overburden of 12 to 13 ft. of rock at the quarry face. The dip of the strata is about 20°. The outcrop probably extends at least 300 yds. beyond the most southerly of the old quarries, but in this direction there is an increasing cover of drift. The exposed rock is a compact, grey, crinoidal limestone of high purity, yielding on analysis (SL 149) [NS 408 100]: $CaCO_3$ 97.25; $MgCO_3$ 0.99; Insol. Res. 2.37.

Keirs Glen: just below Keirs farm [NS 43038 08015]. (14. 46 N.W.)

The Index Limestone, a hard band 12ft. thick, causes a waterfall. It proved on analysis (SL 150) [NS 431 081] to be a very impure rock: $CaCO_3$ 54.34; $MgCO_3$ 5.02; Insol. Res. 26.20. This Limestone is also exposed in the Glenhead Burn, north-west of [NS 45866 05523]; in the burn 350 yds. S.E. of Auldcraigoch Burn; and in the Dalcairnie Burn, 600 yds. above Dalcairnie Bridge [NS 46975 04634].

Keirs Lime Works [NS 43295 07562]. (14. 46 S.W.)

In the quarry the Keirs Limestone is a compact limestone, 11 ft. thick, in parts thinly fissile, but generally in posts about 1 ft. thick separated by partings of limy shale. The bed dips N.E. at 10° and workings could be extended to the south-east without encountering excessive overburden. The analysis (SL 151) [NS 435 078] indicates a limestone of the argillaceous type, which might be useful in the cement industry: CaCO, 73.73; $MgCO_3$ 2.78; Insol. Res. 20.20.

Martnaham Loch [NS 39483 17269] and Kerse Loch. (14. 33 S.E.; 34 S.W.; 39 N.E.; 40 N.W.)

In this area the outcrop of the Carboniferous Limestone Series is much interrupted by faulting, and, in addition, exposures of the solid strata are infrequent. It is known from borings that the limestone bands are generally thin. Many years ago limestone was wrought in a quarry 500 yds. N. of Kerse Loch [NS 42206 14863], on the north side of the road passing Kerse Park farm, but the seam is no longer visible here. Above its position in the quarry are about 25 ft. of strata, including an impure limestone band.

New Cumnock, Cumnock, Muirkirk, Glenbuck, Sorn and Catrine **(Figure 6) and (Figure 9)**

In this wide tract of eastern Ayrshire the Carboniferous Limestone Series crops out extensively. In the past the thicker limestones were much sought after, partly, doubtless, because it was a very active centre of the iron-smelting industry.

The Hurlet Limestone is known as the Hawthorn Limestone at [NS 70523 26525]. It was extensively worked there and also near Cronberry (Gass Water), as well as in lesser degree elsewhere. The MacDonald (Hosie) Limestone was also worked but not to the same extent. There were quarries in the Index Limestone at High Polquhirter, New Cumnock and at Blairmulloch, Sorn. The Calmy Limestone was principally worked at Benton near New Cumnock.

Westwards of Cumnock the Barren Red Coal Measures, at the top of the Carboniferous sequence, extend in a wide outcrop. Thin, pale or colour-banded limestones, often with the fossil *Spirorbis,* occur sporadically in these beds. One of these bands was at one time worked near Ochiltree. They are very pure, but too thin, as a rule to command attention. An analysis of one example from near Catrine has been made (p. 73).

High Polquheys and Muirfoot Burn: 2 m. N. of New Cumnock. (15. 42 N.W.)

A limestone, possibly the Hawthorn Limestone, was formerly worked in a quarry 200 yds. W. of High Polquheys farmhouse [NS 62133 16394]. It has a thickness of 25 to 30 ft. and dips E. at 45°. The overburden is thin to the south but thicker to the north. The present opencast could probably be extended in both directions for a considerable distance. The elevation is 900 ft. above 0.D., but the site is convenient to the farm road. The limestone is a compact, flaggy rock with occasional partings of shale. Some yellowish-weathering bands in the face are probably dolomitic.

In the Muirfoot Burn [NS 62397 16042], to the south of High Polquheys, several outcrops of limestone are recorded, but in no case does the bed exceed 3 ft. in thickness.

Mansfield Hall and Linn Burn: N. of River Nith, 1½ in. E. of New Cumnock. (15. 42 N.W., N.E.)

A number of limestones of the Upper Limestone Group crop out in this neighbourhood.

a. Hall Quarry, 400 *yds. N. of Mansfield Hall. [NS 64004 14970]* (42 N.W.) The limestone, not now visible, was worked under a cover of about 30 ft. of rock. There was a kiln in the vicinity.

b. Mansfield Linn, 500 *yds. E. of Hall Quarry. [NS 64384 14903]* (42 N.E.) The limestone here is 12 to 15 ft. thick and dips N.W. at 5°. There is a cover of sandstone, thin in the vicinity of the stream, but increasing to the north-west. There are probably considerable reserves, but the quality of the rock is not very high. It is a flaggy, sandy limestone with some bands of purer stone.

c. Linn Burn, Mansfield House [NS 64337 14374]. (42 N.E.) The Index Limestone crops out on the bank of the stream opposite Mansfield House, and also 400 yds. farther downstream. The thickness is 10 to 14 ft., of which about half is calcareous shale or soft rubbly limestone. The dip is moderate. There is a cover of 6 ft. of sandstone and shale at the outcrop, and this will increase away from the stream.

High Polquhirter [NS 63409 12387]: S. of R. Nith, 1 m. S.E. of New Cumnock. (15. 42 S.W., S.E.)

There are abandoned quarries in the Index Limestone close to the farm of High Polquhirter, and also half a mile to the west, east of Laigh Park [NS 62013 12213]. At High Polquhirter about 6 ft. of rock were quarried. Exposures are now very obscure, the rock dipping N. under a cover of drift probably several feet thick. In the adjacent stream only the top 2 ft. of the bed are exposed. An analysis (SL 95) [NS 633 125] proved this part of the bed to be a dolomite: $CaCO_3$ 51.83; $MgCO_3$ 29.42; Insol. Res. 6.98. There is probably some iron carbonate as well.

The long opencast east of Laigh Park [NS 62356 12332] was probably in the same limestone, but now only 2 ft. of limestone are visible under 6 ft. of other rock. The dip of the strata here is N. at 15°, and the outcrop should extend eastwards towards High Polquhirter.

Benston Lime Works [NS 58012 15852]: 3 m. N.W. of New Cumnock. (14. 41 N.E.)

The Calmy Limestone was at one time worked here in considerable quarries. Eventually, as the cover got too thick for economic removal, mining was resorted to. The underground workings are probably not very extensive. The thickness of the limestone is about 18 ft. The dip of the beds is very slight, but there is now an overburden of 20 to 30 ft. of drift at the quarry face. The quarry adjoins a main road and access is easy. There are probably large reserves of stone available by mining.

The Benston limestone is a compact, bluish-grey rock, rather siliceous in character, which was highly esteemed as a source of lime. Its analysis (SL 92) [NS 5820 1600] shows as follows: $CaCO_3$ 73.00; $MgCO_3$ 1.84; SiO_2 21.61.

Glenmuir: 4 m. E. of Cumnock [NS 62970 20780]. (15. 36 N.W.)

The Hawthorn Limestone was worked extensively in this district. In the Glenmuir Lime Works quarry, half a mile E. of High Glenmuir, the thickness of the limestone was 13 ft. The dip is to the W. at 5°. At the present quarry, now

abandoned, there is a cover of several feet of drift on top of 7 ft. of sandstone. The stone could probably be followed northward for 500 yds., but westward only mining is possible. An analysed sample (SL 93) [NS 630 211] from the quarry shows: $CaCO_3$ 85.72; $MgCO_3$ 2.17; Al_2O_3 2.44; Insol. Res. 9.23. These figures indicate a slightly argillaceous limestone, but, as a rule, the Hawthorn is of a higher quality.

North of Glenmuir Quarry an older opencast in the limestone extended ¾ mile towards High Gaswater Row [NS 62948 21866]. The limestone dips westward here also, at a moderate angle, but the cover is much thicker, comprising peat, up to 8 ft.; boulder clay, 10 ft.; sandstone, etc., 12–18 ft. It is thus evident that here, only mining is now practicable.

At Springhill [NS 64116 20117], ¾ m. S.E. of Glenmuir Lime Works, there was formerly a small quarry in a detached outcrop of the Hawthorn Limestone. Only a few feet of the limestone are now visible here. Further quarrying operations would have to contend with a thick covering of peat as well as of boulder clay.

Dalblair: 5 m. E. of Cumnock [NS 63797 19414]. (15.36 N.E., S.W., S.E.)

There are several outcrops of the Hawthorn and MacDonald limestones in this vicinity, for example, in the Glenmuir Water, Guelt Water and small tributary streams. The district is somewhat remote. For this reason, and also because of heavy cover, none of the outcrops is particularly attractive from a working point of view.

Commencing about 150 yds. west of Dalblair Bridge a much-faulted section of the Hawthorn Limestone is traceable in the Glenmuir Water downstream over a distance of 500 yds. towards Dornal. The rock was formerly quarried on a small scale at the western end of this exposure, and there is evidence of a kiln some distance farther upstream. The seam has a thickness of 15 ft., with the stone in compact bands 2 ft. thick, separated by shale partings. The cover of rock is heavy, 20 to 25 ft. This outcrop would now be difficult to work even on a moderate scale because of the thick cover and proximity of the river.

The Hawthorn Limestone also crops out in the Dornal Burn at a small waterfall 700 yds. N. of Dalblair [NS 64498 19829], and again 200 yds. farther upstream [NS 64519 20065]. At the waterfall about 10 ft. of limestone are visible dipping N.E. at 5°. At the higher exposures not much is now seen. The situation is relatively inaccessible, and there is probably a thick cover of drift. The MacDonald Limestone crops out in this burn 100 yds. below the waterfall. Its thickness is about 10 ft., and it dips N.E. at a gentle angle. The cover of drift is probably thick.

East of Dalblair the Hawthorn and MacDonald limestones crop out at several points in the Glenmuir Water and tributary streams. The MacDonald Limestone appears on the steep slope behind the Dalblair buildings and extends as far as The Bank. It is also present on the opposite side of the river from Dalblair in the side of the bluff above the road leading up to Kyle farm [NS 64786 19184], and at Whiteholm, half a mile to S.E. on the Guelt Water [NS 65531 18632]. Its thickness is about 15 ft., of which only 10 ft. are solid limestone. The dip is moderate, but everywhere there is a thick cover of rock and drift.

Penbreck [NS 72534 19749]: 5 m. S.S.E. of Muirkirk and 7 m. N.W. of Sanquhar. (15. 37 N.W., S.W.)

There is here a small outlier of Carboniferous Limestone strata in which the Hawthorn and MacDonald limestones are exposed as well as three thinner limestones of the Upper Limestone Group. As coal is readily available a lime works was at one time in operation, but little of the kiln now remains.

The exposures in the Penbreck Burn in the vicinity of the kiln north-east of the shepherd's house include: Hawthorn Limestone, 3 ft. visible; MacDonald Limestone, 11 ft. thick, 30 ft. above the Hawthorn; three higher limestones, each not exceeding 3 ft. in thickness, separated by a fault from the MacDonald Limestone. The thin limestones reappear with a steep dip farther downstream, 600 yds. west of the house. The locality is very remote and is best approached from Sanquhar. There is only a track for part of the way.

Garpel Water: S.W. of Muirkirk. (15. 30 S.E.)

In the Garpel Water seven limestones appear in the first half mile of its course above the railway bridge [NS 68750 25784], 1½ m. S.W. of Muirkirk. That farthest upstream, 1,000 yds. above the bridge [NS 69214 25205], is the Hawthorn Limestone. Only 3 ft. of its thickness are visible. The dip is N.W. at 15°. There is evidence of a quarry on its outcrop about 100 yds. away from the right bank of the stream, but no rock is now to be seen.

Two hundred yards downstream, above the confluence with the Slack Burn, the MacDonald Limestone crops out. It is composed of about 5 ft. of solid limestone in three posts, associated with about 13 ft. of calcareous shale. It does not appear to have been quarried in the vicinity.

The Index Limestone is poorly exposed in the stream 500 yds. above the railway bridge. Its thickness is probably between 6 and 10 ft.

Three hundred yards from the railway bridge, beside an old stone bridge locally known as Tibbie Pagan's Bridge [NS 68924 25762], 7 ft. of a compact argillaceous limestone are exposed; while 100 yds. lower down a calcareous horizon with two solid posts of limestone appears.

Under the railway bridge [NS 68682 25865] is the outcrop of the thickest of the limestones, the Blue Tour (Calmy) Limestone. The section shows: platy limestone (top), 3½ ft.; shale, 3 ft.; limestone, 4½ ft.; shale, 8 ft.; limestone, 15 ft. The outcrop of the limestone here coincides with the line of the railway, and thus quarrying on a large scale is impossible. The limestone appears again, however, ¾ m. to the S.W. at the head of the Wellwood Burn, and also in a small tributary to the west, about 200 yds. S.E. of Knowehead [NS 68268 24445]. Quarrying may be possible here, but the thickness of the superficial deposits is not known. The analysis (SL 113) [NS 686 258] from the outcrop at the railway bridge shows as follows: $CaCO_3$ 88.22; $MgCO_3$ 2.66; Insol. Res. 8.29.

Hawthorn and MacDonald limestones east of Muirkirk. (15.31 N.W.)

The Hawthorn Limestone and, to a lesser degree, the MacDonald Limestone were extensively quarried east of Muirkirk when the Muirkirk Iron Works were in operation. The principal quarries were situated on the Linky Burn and Auldhouse Burn about 1 m. S.E. of the town [NS 70855 26121], on the Crossflat Burn [NS 70783 27414] just south of the railway, and, farther east, in quarries near Airdsgreen close to the railway [NS 73051 28272]. These quarries are now waterlogged or obscured, and further working would be difficult because of a thick overburden of boulder clay.

The Hawthorn has a thickness of 10 to 12 ft., and is known to be of good quality. Only the top 6 ft. of the bed were visible in the Crossflat Quarry when the analysed sample (SL 114) [NS 720 276] was collected. This yielded the following figures: $CaCO_3$ 92.62; $MgCO_3$ 1.19; Insol. Res. 4.96.

The overlying MacDonald beds, as at Garpel Water, comprise relatively thin posts of solid limestone associated with much calcareous shale.

Glenbuck [NS 74872 29494]: 3 m. E.N.E. of Muirkirk. (23. 26 S.E., S.W.)

It was in this remote corner of Ayrshire that the first of the iron-smelting furnaces was erected (1787). Doubtless local limestone was used as a flux, as there is an old quarry in the Hawthorn Limestone ½ m. E. of the village.

Several limestones crop out in the district, but none is at present utilized. The Hawthorn Limestone probably showed a thickness of 7 to 8 ft. of good stone under a capping of inferior quality. As well as in the quarry already mentioned, this limestone crops out on the hillslope north and west of the village, on the edge of the mineral field. Everywhere the dip of the strata is high (40° and upward), and consequently narrow opencasts or mining would have to be resorted to in its exploitation.

The MacDonald Limestone, a few feet above the Hawthorn Limestone, pursues the same course. In this bed a great deal of inferior limy shale is present and probably not more than 6 ft. of good limestone could be extracted.

A higher limestone, the Blue Tour (Calmy) Limestone, is also present but is not well exposed. Its outcrop is known from bores and extends from just west of Spireslack [NS 74700 29788]northward for about ½ m. on the north-west side of the mineral railway. Its recorded thickness is about 18 ft. Its quality may be expected to be similar to that of the rock analysed from the Garpel Water (p. 71).

Sorn: 4 m. N. of Cumnock. (14. 29 S.E., N.E.)

Several outcrops of limestone appear in the River Ayr between Sorn [NS 55582 26491] and Upper Heilar [NS 59898 26020]. None is now of much importance, although workings, mostly on a small scale, have at one time or another been carried on at a number of localities.

The Index Limestone was worked at Blairmulloch Lime Works [NS 56104 28199], 1 m. N. of Sorn. The thickness of the limestone here is 8 ft., and it dips S.W. at 15°. In the present quarry there is now an overburden of drift, sandstone and shale. The thickness of the overburden would be a handicap to further quarrying.

Catrine [NS 52964 25848]: 4 m. N.W. of Cumnock. (14. 29 S.W.)

Thin beds of white, flesh-coloured or striped limestones occur rather sporadically at various horizons in the Barren Red Coal Measures of Ayrshire. They are probably mainly of chemical origin, for they are generally unfossiliferous, but occasionally they contain the fossil *Spirorbis* in abundance, and so are often referred to as Spirorbis limestones. A bed of this nature was at one time worked as a source of lime near Ochiltree, but its outcrop is now obscured. A similar bed, rich in *Spirorbis,* is well exposed in a bluff in the right bank of the River Ayr, 700 yds. W. of Catrine. This bed is only about 1 ft. thick, and so is too thin for working, but it has been analysed as a good example of this type of limestone. It is notable for its high quality. The analysis (SL 96) [NS 521 262] shows as follows: $CaCO_3$ 96.75; $MgCO_3$ 0.90; Insol. Res. 2.69.

North Ayrshire; Beith, Dalry and Kilwinning

The principal Carboniferous limestones of economic importance in North Ayrshire are the Broadstone, Dockra (or Hurlet), Index and Upper Linn (p. 75). Their distribution, excepting that of the Index, which is of less importance than the other three, is shown in (Figure 10). From the figure the wide extent of the outcrop will be evident. As in this region there were at one time five centres of iron-smelting, the quarrying and mining of limestone was vigorously pursued. At the present day the output of limestone is absorbed mainly by agricultural needs. None is used for fluxing.

The Broadstone Limestone (so called from a quarry on Broadstone farm [NS 36113 53112]) is generally a dark-coloured limestone, about 20 to 25 ft. thick, and is often in fairly massive posts with partings of limy shale. The principal quarries were in the neighbourhood of Beith and Dalry. It is at present being worked only at Nettlehirst [NS 36667 50498] and Auchenmade [NS 34993 48210].

The Dockra Limestone (so called from a quarry at Dockra farm [NS 36345 52499]) occurs from 6 to 20 ft. higher in the geological succession than the Broadstone Limestone. Consequently the outcrops of the two limestones are nearly always closely adjacent, and sometimes both limestones, as well as an intermediate thinner band, the Wee Limestone, may be visible in the same quarry. The Dockra Limestone and the associated limy shale may be as much as 60 ft, thick, but hard, compact, workable rock varies between 12 and 40 ft. in thickness. In contrast with the Broadstone the colour of the Dockra Limestone is generally white or pale cream. The limestone at the present day is being worked at Dockra [NS 36345 52499] and Hessilhead [NS 39224 52199]? (Lugton Lime Works).

The Index Limestone was at one time quite extensively worked in a line of quarries and mines at Goldcraig [NS 31877 44872], N.E. of Kilwinning. Its thickness, however, does not exceed 6 ft., and on this account it is doubtful if it will ever be much worked in future.

The Upper Linn Limestone is best developed in the neighbourhood of Dalry, and can be seen in the Caaf Water near Lynn Spout [NS 28281 48511]. It is not at present being worked.

Langside [NS 36904 53690] and Lyonshields [NS 37359 53876]: 1½ m. E. of Beith. (22. 8 N.E.)

The Broadstone Limestone was both mined and quarried here. The mines were not of great extent, and only started when the overburden became too thick for economic removal.

At Langside [NS 36904 53690] 13 ft. of limestone are visible under 8 ft. of shale and sandstone, upon which is some boulder clay. The upper part of the limestone is somewhat shaly. The workings are in the bottom 10 ft. and from this a sample for analysis (SL 108) [NS 3690 5365] was taken. This indicates the following composition: $CaCO_3$ 91.96; $MgCO_3$ 1.55; Insol. Res. 4.67.

The rock is of a similar character at Lyonshields, ¼ m. farther east [NS 37359 53876]. About ¼ m. S. of Lyonshields, almost opposite Trearne House, the upper part of the limestone is visible in a low rocky scarp on the east side of the road.

Broadstone Quarry [NS 36265 53101]: 1 m. S.E. of Beith. (22. 8 S.W.)

Broadstone Quarry is now abandoned. The rock had a thickness of about 25 ft., but the face is now poorly exposed. The dip of the strata is at angles up to 5°. Overburden of drift is slight but rock cover is now coming on. The accessibility is good and reserves are extensive. Probably further development would have to be by mining.

Nettlehirst Quarry [NS 36860 50455]: 2¼ m. S.S.E. of Beith. (22. 8 S.W.)

The worked portion of the Broadstone Limestone here is 12 ft. thick. The overburden is slight and considerable reserves are still available for quarrying. The analysis (SL 122) [NS 3645 5057] from this locality shows the following figures: $CaCO_3$ 90.62; $MgCO_3$ 1.43; Insol. Res. 6.00.

The Dockra Limestone, 21 ft. thick, is exposed in a disused opening 300 yds. S.W. of the present quarry in the Broadstone Limestone.

Quarries S. and S.W. of Beith. (22. 8 SM.)

The Broadstone Limestone was formerly quarried at Roughwood [NS 34555 52261], 1 m. S. of Beith, and at Crawfield, 1½ m. S.W. of that town. Both sites are easily accessible and there are reserves of limestone still available by mining.

Hessilhead Quarry (Lugton Lime Works): 2 m. E. of Beith. (22. 8 N.E.) (Plate 3)

This is a working quarry in the Dockra Limestone. The quarry face is about 20 ft. high. The beds dip at a low angle. There are ample reserves. The limestone is pale grey in colour, has occasional bands of darker stone, and is of excellent quality. It is used for agricultural purposes in the raw ground state and for stone-dusting in mines, as well as for poultry grit and road chips. Its analysis (SL 109) [NS 3770 5325] shows as follows: $CaCO_3$ 91.86; $MgCO_3$ 1.55; Insol. Res. 6.09.

Lugton [NS 41275 52946]: Dockra Limestone at various localities. (22. 8 N.E., S.E.)

The outcrop of the Dockra Limestone covers nearly a square mile of ground west and north of Lugton. Considerable parts of the area are free of thick overburden and the limestone was formerly quarried at Lugton station, North Biggart [NS 40478 53666] and Middleton [NS 39551 52368].

At Lugton most of the readily accessible stone has been wrought out. At the quarry at North Biggart, ¾ m. N.W. of Lugton station, 20 ft. of dark limestone, with shaly partings throughout, are visible. A third of a mile farther south (W. of South Biggart) the same type of stone appears as crags in the fields. At Middleton, 1½ m. W. of Lugton station, quarrying was also formerly pursued on a considerable scale. As at North Biggart, posts of solid limestone alternate with shale partings and hence good rock cannot be won so economically as at other localities.

A boring at the Old Mill [NS 39051 52344], 400 yds. W. of Middleton; proved the following succession: surface, 3 ft. 4 in.; limestone with partings (Dockra Limestone), 44 ft. 8 in.; shale, 4 ft. 3 in.; coal, 10 in.; fireclay and ribs, 10 ft. 3 in.; fireclay, 1 ft.; limestone (Broadstone Limestone), 19 ft.; fakes, 3 ft. 10 in.; coal, 2 ft. 5 in. (1 ft. clean).

Dockra Quarry [NS 36329 52502]: 1½ m. S.E. of Beith. (22. 8 S.W.)

This quarry, long abandoned, has now been reopened. The output is used entirely as ground limestone for agricultural purposes. The full thickness of the workable face is about 40 ft. Reserves are extensive.

Auchenskeith Quarry [NS 31382 46908]: 2¼ m. S.E. of Dalry. (22. 11 S.E.)

Both Broadstone and Dockra limestones were formerly worked here, the Broadstone being 15 ft. thick and the Dockra 18 ft. They are separated by 7 to 9 ft. of strata, consisting of fireclay and marl, with a thin coal close below the Dockra, and were worked together in one face. The dip is S.E. at 5°. Overburden is heavy.

The upper 12 ft. of the Dockra Limestone in this quarry consist of thin limestone bands alternating with limy shale; only the basal 6 ft. form a solid post.

Auchenmade Quarry [NS 33810 48556]: 3 m. E. by S. of Dalry. (22. 12 N.W.)

The Broadstone Limestone and a thin bed above it, the Wee Post (Baldernock) Limestone, are now being worked. The stone is burnt for lime. The section in the quarry shows: overburden, 8 ft.; Wee Post Limestone (worked). 2 ft.; shale, 1 ft.; coal, 14 in.; limy shale, 3½ ft.; Broadstone Limestone (worked face), 12 ft.; limy shale, up to 2 ft.; thin coal.

The analysis of the Broadstone Limestone (SL 136) [NS 3380 4855] shows: $CaCO_3$ 89.37; $MgCO_3$ 0.94; Insol. Res. 6.92. That of the Wee Post (SL 135) [NS 3380 4855] shows: $CaCO_3$ 90.86; $MgCO_3$ 2.05; Insol. Res. 4.81.

The Dockra Limestone also crops out close at hand and was formerly quarried. It is a white limestone with shale partings, about 12 ft. thick, overlain and underlain by limy shale.

Dalry: outcrop of the Upper Linn Limestone. (22. 11 N.E.)

The Upper Linn Limestone is well exposed in the Caaf Water at Lynn Spout [NS 28282 48529] and in the adjacent Lynn Quarry [NS 28415 48604]. The thickness in the stream is about 30 ft. In the quarry about 15 ft. are exposed under an overburden of 10 ft. of boulder clay.

The limestone is also exposed in the Caaf Water close to Drumastle Mill [NS 27852 48035], ½ m. S.W. of Lynn Spout; in the vicinity of Broadlie House, N.W. of Dalry; and at Loans Quarry on the Bombo Burn, about 1 m. E.S.E. of Dalry station. At Loans Quarry, now disused, 16 ft. of limestone are visible, under 6 ft. of boulder clay. Borings, it may be noted, indicate a thickness of as much as 45 ft. for the Upper Linn Limestone, but this figure includes some beds more precisely described as limy shales. The more solid posts do not exceed 25 to 30 ft.

The Upper Linn Limestone is a grey, compact rock of uniform grain. A sample for analysis (SL 111) [NS 2842 4855] collected at Lynn Quarry showed as follows: $CaCO_3$ 89.48; $MgCO_3$ 1.26; Insol. Res. 8.75.

Kilwinning: Index Limestone workings. (22. 12 S.W.)

The Index (Highfield) Limestone was at one time extensively worked at Goldcraig, 1½ m. N.E. of Kilwinning. The seam here has a thickness of 6 ft., and dips to the S.E. at 8° or less under an overburden of sandstone. It is conveniently situated beside the highway. There are still ample reserves for mining.

The limestone is a brownish-grey, compact rock with some limonitic cement. On analysis (SL 196) [NS 3190 4477] it showed the following figures: $CaCO_3$ 84.77; $MgCO_3$ 4.20; Insol. Res. 6.55.

The opencast workings extend for nearly 1½ m. between Goldcraig [NS 31905 44864] and Clonbeith [NS 33875 45537]. Opposite Clonbeith the underground workings cover about 50 acres, and a smaller area of about 2 acres was mined at Goldcraig. It was both quarried and mined a little S.W. of Goldcraig, N.E. of Redstone [NS 31319 44376].

There was also a quarry of some size at Lylestone [NS 33006 45549], 3 m. N.E. of Kilwinning. The section here shows 5 ft. of massive limestone under 4½ ft. of concretionary limestone, above which is an overburden of 12 ft. of shale and clayband ironstone balls. The outcrop extends for about 1½ m. westwards through High Gooseloan [NS 32460 46263] to beyond Mosside, and several quarries have been at one time or another opened up along its course. The area is drift-covered and further operations would be restricted to mining. A massive sandstone lying a few feet below the Highfield Limestone was also worked at Lylestone Quarry.

Banff

Banffshire is one of the Scottish counties most richly endowed with limestones. Their exploitation for agricultural purposes, particularly around Keith and Dufftown, has continued on a considerable scale for at least a century and a half. In the past forty years, however, the number of working quarries has gradually fallen, and at present there are only three or four producing lime or ground limestone for agricultural purposes. Though this number is exceeded in Argyllshire, so far as size and output are concerned the Banffshire quarries are the more important.

In addition to the quarries producing lime or ground limestone, a number of openings are worked by local authorities for roadstone. In the past a considerable amount of limestone was also used for building purposes, for which it is well suited, as is shown by the fresh condition of the walls of many of the houses built of it. This trade has now completely died out.

All the Banffshire limestones are metamorphic rocks belonging to the Dalradian Series, which makes up the greater part of the county. The majority belong to a subdivision termed the Sandend Group, which commonly contains several bands of limestone separated by black schist. The Group is first seen to the north on the shores of the Moray Firth at Sandend Bay, 2 miles west of Portsoy (Figure 11). It runs inland for 3 miles in a south-south-westerly direction past Fordyce, and its outcrop is then interrupted for 2½ miles by overlying Old Red Sandstone. It reappears south of Kirkton of Deskford, where it was worked recently at Craibstone, and thence continues south-westwards to Keith and Duff town. South-west of Dufftown the main outcrop extends for a considerable distance up Glen Rinnes beyond Rinaitin. Extensive exposures of limestone around Tornintoul and southwards to the borders of the county at Loch Builg, beyond Inchrory, probably also belong to the Sandend Group (Figure 2) and (Figure 11).

Several of the limestones of the Sandend Group are of high quality, with calcium carbonate percentages of between 90 and 96. The proportion of magnesium carbonate does not generally exceed 3 per cent. but the stone would appear to be somewhat magnesian in character in the neighbourhood of Dufftown and Glen Rinnes, as two analyses from this district show magnesium carbonate percentages of 8.03 and 12.56 respectively. The chief impurity is silica, which in some examples becomes fairly plentiful, so that the percentage of carbonate falls as low as 80. In Banffshire such rocks are worked only for roadstone.

To the east of the Sandend Group another subdivision of the Dalradian Series, the Portsoy Group, contains impersistent bands of limestone, of moderate to good quality, one of which is wrought in an important quarry at Limehillock, Grange. Still farther east the Boyne Limestone, which is of fairly good quality, is worked at Boyne Bay, east of Portsoy. It is the thickest in the whole county, but cannot be traced far inland.

From the above outline it will be evident that limestones are very abundant in Banffshire. It should be pointed out, however, that in the north there is almost everywhere a heavy overburden of boulder clay. For this reason it is very difficult to indicate new outcrops that might be quarried. Future development therefore is more likely to take the form of extension of existing quarries or, in one or two cases, the reopening of disused workings. In the south of the county there are huge reserves of limestone, with only light cover, around Tomintoul and farther south; but for the present at any rate they must be regarded as too far from markets-to be of importance.

Sandend Group

In the extreme northern part of their outcrop, limestones belonging to the Sandend Group were at one time worked at Sandend Bay and at Fordyce. These openings are now much obscured by slipped overburden, the great thickness of which renders their future exploitation unlikely.

At Craibstone (96. 8 N.E.) [NJ 49696 59416], one and a half miles south of Kirkton of Deskford, there is a quarry that was worked until quite recently. The stone (SL 74) [NJ 4965 5915] is of excellent quality, on analysis showing: $CaCO_3$ 95.62; $MgCO_3$ 1.22; Insol. Res. 3.48; but the overburden thickens on all sides and reserves which could be economically quarried are small.

Goukstone Quarry [NJ 49095 56164]: a short distance E. of the Keith–Cullen Road, 5 m. N.E. of Keith. (86. 14 N.E.)

The limestone, which is worked for roadstone, is a grey, banded, medium-grained, slightly flaggy type with a few black schist partings. An analysis is not available, but the stone appears to be of fairly good quality. Joints in the limestone are thickly coated with calcite. The general dip is to S.E. at 15°, but there is a flattish anticline at the north end of the quarry, with a slight pitch to N.E. The thickness of the limestone is at least 25 ft. The face of the quarry is 20 ft. high, and overburden does not amount to more than 4 ft. The reserves are large.

Hillockhead Quarry [NJ 39157 49962]: on the S. side of the main road 2½ m. W. by S. of Keith. (85. 13 S.E.)

The limestone (SL 72) [NJ 3915 4989], which is worked for roadstone, contains a fair amount of quartz and subordinate muscovite, and showed on analysis: $CaCO_3$ 79.60; $MgCO_3$ 1.34; Insol. Res. 19.45. In general it dips N.W. at 30°, but at the west end of the quarry there is a shallow syncline in the core of which black schist and impure limestone come on above the better stone. The thickness of the latter is 50 ft. The face of the quarry is 30 ft. high, and the overburden is slight. In all probability the reserves are large.

Glenisla Quarry [NJ 42602 50256]: on the E. side of the railway just S. of Keith. (85. 14 S.W.)

The limestone (SL 238) [NJ 426 503], is a grey, banded type, generally of medium grain but with some fine-grained bands, and with accessory quartz. It is worked for roadstone. An analysis showed: $CaCO_3$ 79.39; $MgCO_3$ 0.65; Insol. Res. 17.89. It dips S.E. at 25° and is 60 ft. thick. The face of the quarry is 35 to 40 ft. high. Overburden is heavy to the south, but fairly light to the north. The limestone has weathered deeply along joints, which in places have become enlarged to form underground solution cavities. Reserves are large along the strike to the north-east.

Disused openings where limestone was formerly quarried for agricultural purposes occur at Douglasbrae [NJ 41213 48976] and Maisley [NJ 41015 49398](Figure 12), 1½ and 1¾ m. S.W. of Keith respectively. Both may be regarded as worked out. Other quarries where agricultural lime was also produced, but which are now disused, are situated at Braehead, 1 m. S.S.W. of Keith and at Blackhillock, 1½ m. S. by E. of Keith. At both places reserves of limestone still exist, but owing to the heavy overburden it is doubtful if they could be economically quarried. An analysis of stone from Blackhillock (SL 68) [NJ 439 482] showed: $CaCO_3$ 91.82; $MgCO_3$ 1.91; Insol. Res. 6.62.

Drummuir Quarry [NJ 38844 46184]: just S. of the farm of Upper Towie, 1¼ m. N.N.E. of Drummuir Station. (85. 19 S.E.) (Plate 7A)

Both lime and ground limestone are produced. The limestone is a grey, medium-grained type with accessory quartz, and showing on analysis (SL 73) [NJ 3895 4625]: $CaCO_3$ 94.03; $MgCO_3$ 2.23; Insol. Res. 4.04. The limestone dips N.W. at 30° to 50°, and is at least 55 ft. thick; black schist comes on in the direction of dip. The face of the quarry consists of 50 ft. of solid rock overlain by 12 ft. of brecciated limestone mixed with some overburden. On the south-east side of the workings there is a fault, heading N.W. and probably throwing down in the same direction, along which the rock is much crushed with many calcite veins. The brecciation extends for several yards out from the fault. The overburden varies from 1 ft. to at least 6 ft.

Limestone is also seen farther south, notably in an old quarry. Good, solid limestone, almost vertical, is also exposed opposite the present quarry on the south side of a stream. Here the overburden may be too heavy for economic working.

Mention may be made of a small opening for roadstone at Lochpark, between Drummuir and Dufftown.

Parkmore Quarry [NJ 33019 40836]: ¾ m. N.E. of Dufftown. (85. 25 N.W.) (Plate 4A)

This quarry is close to the main road and on a siding of the L.N.E.R. Ground limestone is produced in a large modern plant, and some stone is still burnt. The limestone is a grey, medium to coarse type with some accessory quartz, and shows on analysis (SL 70) [NJ 3325 4078]: $CaCO_3$ 93.75; $MgCO_3$ 2.69; Insol. Res. 3.66. There are many calcite veins and some schist partings. The limestone dips N. 35° W. at 40° to 50°, and is 105 ft. thick. The main face is 50 ft. high, and a lower bench is also being worked. The overburden is light. The reserves are very large, and the quarry could be extended along the strike to the north-east and at the same time the lower bench could be further developed.

Richmond Quarry [NJ 33096 39646], Dufftown. (85. 25 S.W.)

This quarry was formerly worked for agricultural lime, but is now only used as a source of roadstone. The limestone varies from a medium-grained, softer type to a fine-grained harder type. On analysis (SL 239) [NJ 3315 3965] it showed: $CaCO_3$ 82.75; $MgCO_3$ 8.33; Insol. Res. 7.98. The dip in general is S. 15° W. at 20° to 30°, but varies both in direction and amount, thus making the true thickness of the limestone difficult to estimate. The face of the quarry is 20 to 40 ft. high and nearly 100 yds. long. The overburden is 4 to 8 ft. thick. Reserves are large.

At Tininver [NJ 32861 39939], close to Richmond, there is a disused quarry, where agricultural lime of high quality was at one time produced. It is now much obscured, and also probably lies in a too highly built-up area to be re-opened.

In Glen Rinnes, 6 m. S.W. of Dufftown, there is quarry for roadstone at Rinaitin [NJ 26265 32795]. The limestone (SL 75) [NJ 263 328] is noteworthy, for the Sandend Group, in showing 12.56 per cent. of magnesium carbonate. The calcium carbonate percentage amounts to 74.62, and the insoluble residue to 12.72.

Craig Chailceach (Craighaulkie) Quarry [NJ 15598 19383]: alongside the main road, 1 m. W.N.W. of Tomintoul (Figure 11). (75.40 S.W.)

This limestone is worked for roadstone. It is a grey, medium to coarse-grained, somewhat flaggy type, with accessory quartz, and shows on analysis (SL 76) [NJ 153 193]: $CaCO_3$ 87·34; $MgCO_3$ 1.13; Insol. Res. 10.88. It dips S.E. at 30°, and is 150 ft. thick. The face of the quarry is 40 to 50 ft. high, and there is an overburden of from 3 to 6 ft. of boulder clay. Reserves are large.

Portsoy Group

Formerly, quarries in limestone of the Portsoy Group were worked at Woodside, Fortry Wood, Craiglethie and Muiryfold, but as the boulder clay overburden in this district is heavy it is doubtful if they would be worth re-opening.

Limehillock Quarry [NJ 51365 51674]: near a road l¼ m. N.E. of Grange station. (86. 15 S.W.) (Plate 4B)

Ground limestone is produced, and some of the stone is burnt. The limestone is *a* light grey, medium-grained type with dark layers and micaceous partings, but uniform on the whole. It bears some accessory quartz and muscovite, and showed on analysis (SL 67) [NJ 5150 5181]: $CaCO_3$ 90.49; $MgCO_3$ 1.5; Insol. Res. 8.02, There are many calcite veins. The limestone dips E. by S. at 40° and is at least 125 ft. thick. The quarry is about 250 yds. long with a face 40 ft. high. Overburden is light. Reserves are probably considerable to the north.

Boyne Limestone

The Boyne Limestone forms a wide outcrop on the shore at Boyne Bay, 1½ m. E. of Portsoy (Figure 11). It is worked in the Boyne Bay quarry between the shore and the road, but cannot be traced more than 1 m. inland and has not been found elsewhere.

Boyne Bay Quarry [NJ 61446 65936]. (96. 4 N.W.)

Limestone was worked here for many years till 1914, and burnt in adjacent kilns. Recently (1945) the quarry has been re-opened, and ground limestone is now being produced in a modern, electrically driven plant. The limestone is a light grey, coarse-grained rock with dark micaceous bands. It showed on analysis (SL 69) [NJ 6140 6610]: $CaCO_3$ 89.25;

$MgCO_3$ 2.81; Insol. Res. 9.30. The bedding is so distorted that no general direction or amount of dip can be given. The true thickness of the limestone cannot therefore be estimated, but the width of outcrop of good quality stone on the shore amounts to some 200 yds. The strike is N. 35° E. To the west there is another outcrop about 100 yds. wide of limestone with numerous mica-schist bands. The quarry now shows a face of limestone about 70 ft. high, with an overburden of 10 to 15 ft. of boulder clay. The main reserves lie to the south-west, between the existing workings and a loop of the stream which flows into Boyne Bay. To the north-east the overburden from the old workings, which has been dumped over the west bank of the stream, would make exploitation expensive; moreover, rockhead falls in this direction towards the shore. The available reserves to the south-west are, however, very considerable, and should suffice for, a long period at the present rate of working, although their exploitation will entail the removal of considerable overburden.

Berwick

Limestone deposits of workable thickness are not known in Berwickshire. A century ago lime for agricultural purposes was carted from Dunbar and Northumberland. Lake marl deposits, too, were worked on a small scale near Harden and Edrom during this period. (New Statistical Account of Scotland: Berwickshire, vol. ii, 1845, pp. 29, 267).

The upland regions of the Lammermuirs between St. Abbs Head and Lauder, and also an area between Eyemouth and Foulden, are occupied mainly by strata of Ordovician age, consisting of shales and hardened grits, but without limestones. Southward of the Lammermuirs, and generally at a lower altitude, the Old Red Sandstone formation crops out in an extensive area north of Chirnside, and also in the stretch of country between Duns and Greenlaw on the east and Lauder and Earlston on the west. The type of rock here is predominantly sandstone. Occasional marly beds occur, but there are no thick limestones of the cornstone type, such as characterize this formation in some other parts of Scotland.

Following upon the Old Red Sandstone we find strata of Lower Carboniferous age in the Merse of Berwickshire, south and east of Chirnside, Duns and Greenlaw. These strata comprise sandstones, shales and thin ribs of dolomitic limestone (cementstones). The cementstones have not been used as a source of lime. The exposures of them, are poor except in the Whiteadder and Blackadder river sections. Somewhat higher beds of Carboniferous age appear on the coast line between Burnmouth and Lamberton.. These contain one limestone seam, visible in the cliffs, but it does not exceed 4 ft. in thickness.

Bute

The county of Bute contains very little limestone. The island of Bute itself has only one occurrence of any interest, namely, a dolomitic cornstone in the Upper Old Red Sandstone at Kilchattan (Figure 3). The Cumbraes contain nothing of value. In Arran, there are some outcrops of Carboniferous limestone on the north-east coast. Of these only the Hurlet, locally called the Corrie Limestone, is of importance. There have been fairly extensive workings in this seam, chiefly by mining, but reserves are still available at Corrie.

Kilchattan, Bute [NS 106 542]: quarries near Kelspoke Castle (ruin), S.E. of Kilchattan. (21. 215 S.E.)

Cornstone at the top of the Upper Old Red Sandstone was once worked here (Gunn, 1903, pp. 33, 148, 149). The seam was about 15 ft. thick, dipping W. at 25° to 30°. Overburden consisted of 5 ft. of drift. Reserves are considerable; the main (south-east) quarry could be extended about 100 yds. to N.W. without difficulty. New openings might be made to the south-east along the strike of the worked outcrop. Geological considerations indicate that a second outcrop of the same cornstone should be present 300 yds. west of the quarries, a short distance below the lava escarpment. This should persist to the north-west as far as Creag a' Chlaidheimh, south of Gatehouse, but its exact position under the cover of drift would have to be located by trenching.

Microscopic examination shows the rock to be mainly an aggregate of small dolomite crystals, with a few calcite grains, rather more abundant quartz grains, and some feldspar. The chemical analysis (SL 228) [NS 106 542] is in keeping with these determinations: $CaCO_3$ 47.29; $MgCO_3$ 30.85; Insol. Res. 20.83. The rather large insoluble residue is mainly silica.

There is an excess of 5.85 per cent. of CaO over the amount required to satisfy the dolomite ratio.

Laggan, Arran [NR 97924 50782]: shore section 1½ m. E.S.E. of Cock of Arran. (21. 226 S.W.)

Corrie (Hurlet) Limestone. The section exposed 240 yds. north-west of Laggan shows: calcareous shales and shaly limestone, 10 to 12 ft.; sandstone, 60 ft.; calcareous shales and limestone, 10 to 12 ft.; sandstone, 30 ft.; Corrie Limestone, 35 ft. The dip is N. at 40° to 50°. The limestone can be followed inland in a westerly direction for some 500 yds., to some old grassed-over quarries. The remains of a kiln on the shore show that it was at one time calcined. The nearest road is the Loch Ranza–Sannox road, from which the quarries are separated by a ridge of hilly ground rising to over 1,000 ft. above sea-level. There is a rough track crossing the ridge from Loch Ranza to the coast at Cock and Laggan.

Corrie Harbour, Arran [NS 02475 43513]. (21. 238 S.E.)

Corrie (Hurlet) Limestone. The quarry and mine workings are now abandoned. The full thickness of the limestone is said to be 20 ft., but only 12 to 15 ft. of good limestone can now be seen. It lies under a cover of sandstone and shale reaching 30 ft. The individual limestone beds are separated by partings of reddish fossiliferous shales; and the roof of the old mines is formed of a hard band crowded with *Productus giganteus.* The dip is S.E. at 25°, Reserves are large, but mining would be necessary. Analysis (SL 82) [NS 024 434] showed percentages as follows: $CaCO_3$ 88.21; $MgCO_3$ 1.30; Insol. Res. 10.29. The present line of quarries follows the outcrop up the steep hillside above Corrie Harbour for a distance of about 400 yds. before it is cut off by a fault. The underground workings are in the stretch of face nearest the harbour. There is an old kiln close to the main road.

Other occurrences of the. Corrie Limestone are to be found between Corrie and Brodick; and some of these, for example, that at An Sgriob, 1½ m. S. by W. of Corrie Harbour and ½ m. N. of Maol Donn (244 N.E.; 238 S.E.) are considerable deposits. They would require to be mined.

Caithness

There are several different kinds of calcareous beds in Caithness (Figure 13), but only one of these, namely, the shell sand of the John o' Groat's area, is of substantial economic interest. Of the other sorts, there are two different types of limestone in the Middle Old Red Sandstone, freshwater lake marl is found in several areas, and one or two springs deposit calcareous tufa.

The calcareous beds associated with the flagstones of the Middle Old Red Sandstone have been examined in several places, and analyses were Made in two cases. That at Robbery Head, 2 m. S.W. of Lybster (110. 39 N.E.), showed 52.41 per cent. $CaCO_3$ and 12.15 per cent. $MgCO_3$ (SL 167) [ND 222 333]. The other, from a stream section and quarry ½ m. E.S.E. of Halkirk Station (116. 17 N.E.), showed 28.93 per cent. $CaCO_3$ and 12.15 per cent. $MgCO_3$ (SL 163) [ND 13917 58274]. A 4-ft. limestone similar in character to that at Robbery Head was formerly quarried at Port of Brims, about 5 m. W. of Thurso. These limy beds are not now likely to be of any economic value.

Another type of calcareous deposit is found in the Reay and Achvarasdal district, where the basal beds of the Middle Old Red Sandstone contain a local development of tufaceous limestone in several places. This has been worked in the past, but such deposits are too inconstant in thickness and too discontinuous in lateral extension to be of any great interest, though they have provided, and might still provide, a limited local supply.

The freshwater marl found in Loch Stemster, Loch Brickigoe, Loch Watenan, Westfield, Loch Calder, Marl Moss, Loch Durran, Loch Watten and Westerdale has been of some local importance in the past. Samples from a few of these deposits were examined, and the following percentages, calculated on the dried material, will indicate their character:

Loch Brickigoe, W. of Loch of Yarrows	75.0 per cent. $CaCO_3$
Westfield, 4 m. S.W. of Thurso	89.94 per cent. $CaCO_3$

Loch Watten, 5 m. E.S.E. of Halkirk	59.41 per cent. $CaCO_3$ 0.61 per cent. $MgCO_3$
Westerdale, 5 in. S. of Halkirk	86 per cent. $CaCO_3$

There is no doubt that calcareous material is still being deposited in some of the lochs. The Westfield occurrence has been investigated in detail and the results are summarised below. From them it may be concluded that no elaborate investigation of the other lochs, with a view to industrial use of marl, would be worth making, having regard to the small quantity likely to be available; but the examination of the contents of the lochs with a view to local exploitation might be profitable.

There are springs at Mey and Freswick depositing calcareous tufa, but they are only of the most limited local interest.

John o' Groat's Shell Sand. (116. 3 S.W.) Reference: Crampton, 1914, p. 141.

Shell sand forms a great accumulation between John o' Groat's and Bay of Sannick. Behind the Ness of Duncansby it spreads inland for' about a quarter of a mile. There must be at a conservative estimate 1½ million tons. The commonest type of sand consists almost entirely of comminuted shell-fragments, largely between one-sixteenth and ■ in. in diameter. Analysis *(a)* is of material of this sort from just above high-water mark ¼ m. E. of John o' Groat's Hotel. At other localities, especially at Ness of Duncansby, there are large banks of only slightly broken shells. Analysis *(b)* shows the composition of this material. Inland the shell sand is stained a brownish colour, but is remarkably free from mineral contamination. Analysis *(c)* is of this material collected 2 ft. beneath the surface, 200 yds. inland from Ness of Duncansby.

The analyses referred to above gave the following percentages:

(a) (SL 164) [ND 385 735]	$CaCO_3$	93.11	$MgCO_3$	1.80	Insol. Res.	2.53
(b) (SL 165) [ND 38939 73810]	$CaCO_3$	95.45	$MgCO_3$	0.86	Insol. Res.	1.03
(c) (SL 166) [ND 38979 73622]	$CaCO_3$	91.07	$MgCO_3$	2.51	Insol. Res.	4.04

The sand was formerly dug by local farmers and burnt in small peat-fired kilns. It is now being dug extensively for agricultural use in the raw state and also for poultry grit.

Achvarasdal: disused quarry 1,450 yds. S. by W. of Achvarasdal [NC 98929 60817]?, which is 21 m. S.E. of Reay. (115. 10 S.W.) Reference: Crampton 1914, p. 170.

A tufaceous limestone near the base of the Middle Old Red Sandstone was formerly quarried and burnt south of Achvarasdal. It is probably only local in extent. About 10 ft. of limestone is seen in the west side of the quarry, and the total thickness of the bed is probably about 15 ft. The dip is N.N.E. at 6° to 7°. The limestone is overlain by 1 ft. of coarse breccia composed of fragments of granite, but there appears to be another bed of limestone above. The cover is light and there may be reserves for about 50 yds. to the northwest. The stone is fine-grained, light grey to buff in colour, and is well bedded. Analysis (SL 282) [NC 993 613] showed 81.8 per cent. of calcium carbonate. The impurities, chiefly quartz, white mica and potash feldspar, form 154 per cent. of the whole.

In the same district, at a point just west of the road and 1 m. S. of Shebster, there is an old lime kiln and a poor exposure of impure limestone. Again at Red Point, 2¼ m. W. by N. of Reay, the base of the Middle Old Red Sandstone is formed of a granitic breccia, with a strongly calcareous cement, which in places merges into a tufaceous limestone. The latter, from 4 to 12 ft. thick, is probably only local in development.

Westfield: 4 m. S.W. of Thurso [ND 07711 63150]. (115. 11 N.W.) Reference: Crampton 1914, p. 170.

Lake marl is found in a drained loch about ¼ sq. m. in area. This occurrence, which may be taken as typical of the lake marl deposits in Caithness, was investigated in detail by the Macaulay Institute in 1944. It was found to contain marl throughout its area, varying from less than 1 ft. in places found the edges to a maximum of 12½ ft. near the centre. The marl is overlain by mud varying in thickness from 6 in. to 9 ft. There is also mud below the marl. It was calculated that there was a recoverable quantity of 553,000 tons of mail slurry, leaving out of account areas with less than 3 ft. of marl. The report (*by* Dr. R. Glentworth and Dr. R. C. Mackenzie) states that from analyses of 32 representative samples of marl, the following average figures were obtained:

Specific gravity: 1.30.

Moisture content: 60.4 per cent.

$CaCO_3$ content of oven-dry marl: 89.94 per cent.

Loss on ignition of oven-dry marl (CO_2+organic matter): 44.02 per cent.

Clackmannan

The county of Clackmannan has no limestone of economic value. A vein of calcite in Old Red Sandstone volcanic rocks on the escarpment of the Ochil Hills, half a mile N.E. of Menstrie (Figure 37) [NS 85261 97708], was worked at one time (39. 133 N.W.). It varies from 9 to 14 ft. in width, and the mineral content is almost entirely reddish-stained calcite. The vein can be traced on the hill-slope for about 200 yds., the old quarry face being about 30 ft. high. Two analyses (by Messrs. Colvilles, Ltd.) showed as follows: $CaCO_3$ 96.34 and 98.20; $MgCO_3$ 0.76 and 1.26; Iron (expressed as FeO), trace and 0.36. The iron content is too high to allow of the use of this material for chemical purposes, and its inaccessibility rules it out as a source of agricultural lime.

Dumbarton

There is almost no limestone in the county of Dumbarton. Formerly the Castlecary Limestone was extensively mined at Castlecary ((Figure 37), p. 176) near the extreme eastern end of the detached portion of the county (31. *In* Stirling, New Meridian 29 S.W.: New Series 29 N.E.,S.E.). The bed was about 6 ft. thick on the average; but the accessible area is now quite worked out. The stone was of good but not exceptional quality, showing on analysis 87.36 per cent. $CaCO_3$ and 3.35 per cent. $MgCO_3$ (Hinxman, 1917, p. 25). The Hurlet Limestone was worked along with the underlying alum shale and coal at Baljaffray [NS 53058 73577], 1■ m. N.W. of Bearsden, (30. 23 S.E.) where the section showed: limestone, 3 ft.; alum shale 6 in.; coal, 4 ft. In this area there are still some reserves which might prove to be worth mining along with the associated coal.

The only occurrences that may have interest in the future are the dolomitized serpentine on the Loch Lomond islands and the cementstones of Murroch Glen [NS 41128 77932] near Dumbarton. Even these, however, would only be of interest if the production of rock wool or dolomitic cement were contemplated. Notes on the deposits in these areas are appended.

Inchmurrin [NS 37898 87059] and Creinch [NS 39336 88798], Loch Lomond. (38. New Meridian 14 N.W.; New Series 14 N.W., S.W.)

The brecciated and carbonated serpentine described as occurring in the Highland Boundary Fault zone at Balmaha (*see* Stirling, and (Figure 32)) forms the north-western half of Creinch and runs the whole length of Inchmurrin as a belt 400 to 500 ft. in width. It could be readily quarried on these islands and taken by boat to railhead at Balloch Pier. The same rock is also exposed on the hillside south-west of Arden, on the west side of Loch Lomond, 2½ miles north-west of Balloch, where it forms a broad band, inclined steeply to N.W. and traceable for over 1½ miles.

Murroch Glen [NS 41128 77932]: 2 m. N.N.E. of Dumbarton (Figure 32). (30. New Meridian 18 S.E.; New Series 18 S.W.)

Cementstone in the Ballagan Beds. A natural section in the stream bank shows ribs of cementstone 3 to 6 ins. thick separated by somewhat thicker beds of marl; in all about 20 ft. The dip is S. at a low angle. There are 5 to 10 ft. of boulder clay cover. Access is good as far as Murroch, and the road could be extended to the glen.

A bulk sample of the material (SL 91) [NS 4083 7782], representing six separate cementstone beds, gave percentages as follows: $CaCO_3$ 46.62; $MgCO_3$ 33.69; Insol. Res. 14.39, including 9.44 per cent. SiO_2. This indicates a slightly siliceous dolomite with scarcely any free calcite. Under the microscope it is seen to be a very fine-grained dolomite of grain size about 0.02 mm., containing scattered grains of quartz up to 0.1 mm. across. The alumina percentage is 2.90 which is higher than is normal in a Carboniferous limestone. It is in keeping, however, with the argillaceous character of the cementstones. The marl associated with these beds gave the following figures on analysis (SL 148) [NS 4071 7780]: SiO_2 48.01; Al_2O_3 15.72; Fe_2O_2 6.92; MgO 7.07; CaO 2.90; Na_2O 0.38; K_2O 4.61; H_2O — 5.48; TiO_2 0.84; P_2O_5 0.28; MnO 0.04; CO_2 1.58; FeS 0.13; Volatile Matter 5.64; Total 99.60. Loss on Ignition 12.57; Insol. Res. 75.33; CaO (soluble in acetic acid) 2.38; MgO (soluble in acetic acid) 0.20. Spec. Gray., 2.56. Petrographically, it is a calcareous shale showing abundant angular grains of quartz up to 0.5 mm. across in a brown extremely fine-grained matrix consisting probably of a mixture of calcite and micaceous matter. A similar section, but free from overburden, is exposed in Auchenreoch Glen to the north,

Dumfries

The limestone resources of Dumfriesshire (Figure 14) are associated entirely with strata of Carboniferous age. Three tracts of Carboniferous rocks are present in the county. In the extreme north-west is the Sanquhar and Kirkconnel Coalfield. Only poor seams of limestone occur here, too thin to be of use. Another area of Carboniferous strata occupies the middle reaches of the River Nith in the neighbourhood of Thornhill. Here limestone seams of much greater thickness occur, and there were formerly extensive quarries and mines at Closeburn and Barjarg. In the south-east a strip of Carboniferous rocks several miles wide extends across the county north of the red sandstones of Annan, inland, from Ruthwell and Cummertrees on the coast, by Ecclefechan, Kirtlebridge and Waterbeck to the River Esk south of Langholm, and thence by Harelawhill into the Liddesdale region of Roxburghshire. In this extensive tract there is at present only one working quarry, at Harelawhill; but formerly, there were large workings at Kelhead, Kirtlebridge, Blackwoodridge and Caldronlee. Much limestone of excellent quality still remains at these localities, but generally, under a heavy and increasing overburden. This latter factor was probably important in leading to the abandonment of the quirries.

Thornhill

Limestone is found at the southern end of the Thornhill basin of Carboniferous rocks, at Barjarg, Closeburn, Heathery Dam (2 m. E.N.E. of Closeburn) and Knockbrack (3 m. N.E. of Closeburn). At the two last-named localities the outcrops are not important.

Closeburn Lime Works [NX 91109 91501]: 1 m. S.E. of Closeburn. (9. 31 S.E.)

Lower Carboniferous limestones were wrought at two distinct workings, namely, Croalchapel Quarry and mines, and Park Quarry. There are two seams at each locality, neither now accessible for examination. The section at the Croalchapel working read: strata (mainly sandstone), 40 ft.; top limestone, 19 ft.; red sandstone and clays, 18 ft.; bottom limestone, 17½ ft. The bottom limestone was the more extensively worked. An old analysis showed calcium carbonate 85.18 per cent. and magnesium carbonate 3.79 per cent. (Anderson, T., 1853, p. 280). The top limestone had impure beds at top and base, but 14 ft. of it were good though dolomitic. It was not extensively worked. Reserves of both top and bottom beds are probably considerable, but access to them through the old workings may be difficult. In the bottom limestone the workings are said to extend 200 yds. to the dip.

The Park Quarry [NX 90786 91200] is now waterlogged and difficult to examine satisfactorily. Two limestones were formerly exposed. The kilns are in disrepair. The outcrop is known to extend northward under a cover of gravel and boulder clay.

The Closeburn Lime Works date from about the year 1795, and a detailed account of them is furnished in the Transactions of the Highland and Agricultural Society (Menteath, 1845, p. 296).

Barjarg [NX 88123 90247]: 1½ m. S.W. of Closeburn. (9.31 S.E.)

There are, here, abandoned quarries and mines of considerable extent in a Lower Carboniferous seam of which 10 ft. are now seen, and which dips N.E. at 25° under a cover of 30 to 50 ft. of sandstone. Half a mile to the north-west was Porterstown quarry and mine. The extent of the mines is not accurately known at either locality, but at Barjarg the workings can be penetrated for some distance. The outcrop connecting the two old workings probably runs just east of Nether Keir, through agricultural land. Future surface workings would have to follow this line; or they might be extended towards and beyond Porterstown farm. Superficial deposits cover all this area, and the precise position of the outcrop would have to be located by boring. The situation is convenient to the highway.

The rock is stained a deep red colour; but the following analysis (SL 142) [NX 880 904] shows it to be a dolomite of considerable purity: $CaCO_3$ 53.57; $MgCO_3$ 43.12; Insol. Res. 2.65.

Annan: Kelhead to Waterbeck

Kelhead Lime Works [NY 14625 69181]: 3¾m. W.N.W of Annan. (10. 57 S.W.; 62 N.W.)

This working in a Lower Carboniferous limestone is now abandoned and completely waterlogged. The main worked seam has a thickness of 25 ft. and dips gently E. at a low angle under a moderate overburden. Only the top of the seam is now visible above water. When in operation the section was: (at top) bands of reddish nodular limestone, 4 ft.; reddish shale, 12 ft.; massive limestone, 25 ft. The quality of the limestone was said to be excellent.

Re-opening the quarry would be a difficult and expensive operation because of the great amount of water in it. The outcrop of the limestone should continue just west of Kelhead farm and then should strike N.E. towards Winterseugh: A nodular limestone, believed to be the top seam of Kelhead, crops out in the brook 250 yds. W.N.W. of Winterseugh.

Kirtlebridge Limestone Workings. (10. 58 N.W.)

Three Lower Carboniferous limestones crop out in the vicinity of Kirtlebridge railway station, 5 m. N.N.E. of Annan. In the past all of these have been extensively worked, as a rule in long narrow opencasts, for the beds are steeply tilted.

1. The lowest of the three limestones was worked in a quarry at Donkins Cottages [NY 22657 73161], south-west of the railway line, and, farther to the north-east, at Cauldwellknowe and Donkins [NY 22657 73161]. The beds are still partly exposed at Cauldwellknowe. The thickness of the seam was probably 15 ft., but only 10 ft. of stone are now seen, dipping N.E. at 30° under an overburden of drift and shale. The analysis of the visible limestone indicates a stone of moderate quality (SL 144) [NY 22 73]: $CaCO_3$ 83.77; $MgCO_3$ 3.45; Insol. Res. 8.54.
2. The middle limestone was extensively worked to the west of Donkins Cottages [NY 22578 73152] in a quarry between the railway and Bonshaw Burn. This is now waterlogged. South of the flat land bordering the stream the opencast recommences at Bonshaw-Burnhead and continues for 600 yds. This part supplied the stone for the Burnhead Lime Works. The limestone, which is now only imperfectly seen under water, was lumpy and nodular. The strata dip N.W. at 30° to 38° under an overburden on the quarry-face of 12 to 15 ft. of sandstone and shale. Further working would be difficult except by mining.
3. The uppermost of the limestones was worked in a large quarry just west of the railway station [NY 22516 73456]. The quarry is now completely waterlogged. The limestone was about 33 ft. thick, under a cover of reddish shale. As elsewhere, the strata are inclined rather steeply to N.W.
4. Two of the three limestones were also quarried at the Brownmuir kilns and Quarry Park [NY 21732 72802], ¾ m. S.W. of the station. The Quarry Park excavation was extensive, but is now completely waterlogged. The overburden of drift is very thick here, ranging from 12 to 25 ft. North of the road, at Brownmuir, the quarries were on a smaller scale and little of the limestone is now to be seen. North-eastward from here the outcrop of the limestone has not been opened up, and this area, therefore, offers the best prospects for future quarries. The thickness of the overburden is not

known. The strata will probably be steeply inclined, as elsewhere in the locality.

5. What are probably the same limestones were also laid bare in the railway cutting just north of the road-crossing [NY 22552 73804]?. The dip of the strata here also tends to be high, 33°. The outcrops of the limestones doubtless continue through the cultivated ground to the north-east and south-west, concealed by a thick cover of gravel and boulder clay.

Blackwoodridge Quarries [NY 24365 76187], [NY 24366 75899]: 1 m. S. of Waterbeck, 8 m. N.N.E. of Annan. (10. 52 S.W.)

Four outcrops of Lower Carboniferous limestones were quarried here, namely, (a) a limestone just south of Blackwoodridge Farm, and *(b)* a group of three limestones at Blackwoodridge (ruin, ¼ m. S. of farm).

a. Quarry at Blackwoodridge Farm. The limestone visible in this abandoned quarry has a thickness of 20 ft. The seam dips S. at 15° under an overburden of 12 ft. of surface drift and soft shaly beds. The site is adjacent to a main road. Reserves of stone are large. The present quarry might be extended westward, but further development would be mostly by mining. The analysis (SL 264) [NY 24 75] shows that the quality is excellent: $CaCO_3$ 94.61; $MgCO_3$ 1.28; Insol. Res. 3.17. The limestone is disposed in massive beds with few shaly partings, and should yield a high proportion of excellent stone.

b. Quarries at Blackwoodridge ruins. There are abandoned quarries in three closely adjacent limestones dipping S.W. at 15° to 20°. The lowest limestone is not now well exposed, the quarry being waterlogged. Of the middle limestone, 6 to 8 ft. of pale rock are seen. The analysis (SL 265) [NY 24 75] indicates a rock of excellent quality: $CaCO_3$ 95.74; $MgCO_3$ 0.69; Insol. Res. 0.74. Of the uppermost limestone, 12 ft. of rock are seen in places, this quarry also being waterlogged. The quarries lie adjacent to the main road and reserves should still be large. Although there is a good deal of water in the present quarries it should be possible to extend them or start new excavations both to the east and west.

Caldronlee Quarry [NY 26720 76677]: 1½ m. E.S.E. of Waterbeck. (10.52 S.E.)

Work at this quarry was given up only a few years ago, and the kiln is still in a fair state of preservation. The thickness of the seam at the face is about 30 ft., and it is topped by an overburden of 12 ft. and upwards of sandstone and drift. The quality of the stone (SL 143) [NY 26 76] is excellent: $CaCO_3$ 95.52; $MgCO_3$ 1.25; Insol. Res. 2.82. The limestone at Caldronlee lies in a narrow boat-shaped flexure trending N.E.–S.W., about 600 yds. in length, and with a greatest width of about 100 yds. The limestone on the north-west side of this structure has been quarried out along its length to a depth of about 30 ft. The outcrop on the south-east side has not yet been quarried except on a very small scale, and the limestone at depth, below a cover of 12 to 30 ft. of thin-bedded sandstones and shales, is also intact. There is thus a considerable tonnage of rock still available. On the sides of the flexure the dip of the limestone may reach 45°, flattening out towards the base. The limestone is in well-jointed courses, 6 to 24 in. in thickness, separated by partings of crumbly shale.

Liddesdale

In the Dumfriesshire portion of Liddesdale, thick limestones appear at Harelawhill and in the Liddel Water in the vicinity of Penton Bridge. One quarry is at present being worked at Harelawhill. A number of beds of limestone also crop out in Archer Beck, 2 m. N.E. of Canonbie, and in Whitlawside Burn, Cauldside, 4 m. N.E. of Canonbie. These beds, however, are all thin and do not compare favourably with the limestone of Harelawhill. They are not likely to prove suitable for working at the present day.

Harelawhill Lime Works [NY 42789 78896]: 3 m. N.E. of Canonbie. (11. 54 N.W.)

Two thick limestones of Lower Carboniferous age are exposed in different quarries at Harelawhill. Only the lower of these, in the quarry nearest to Harelawhill farm, is now worked.

The Lower Harelawhill Limestone is a well-bedded, grey limestone 15 to 20 ft. thick, disposed in regular courses 4 to 12 in. thick. The quality is excellent (SL 204) [NY 427 789]: $CaCO_3$ 94.67; $MgCO_3$ 1.91; Insol. Res. 1.27. The full section at one time seen in this quarry was: drift, 4 ft.; grey limestone, 20 to 22 ft.; black fossiliferous shale, 1½ ft.; limestone, 3½ ft.; black shale, 6 in.; coal, 1 ft. There is now considerably more overburden on the quarry.

The Upper Harelawhill Limestone was worked in a quarry 300 yds. W. of the farm [NY 42632 78851]. Its thickness was at least 17 ft., but only 10 ft. are now to be seen, dipping at angles between 15° and 27° under a cover of 12 ft. of shale. Analysis proved the quality of this rock (SL 205) [NY 427 789] to be only moderate: $CaCO_3$ 78.48; $MgCO_3$ 2.99; Insol. Res. 1725.

Limestone outcrops in Liddel Water at Penton Bridge and' vicinity, 2½ m. E.N.E. of Canonbie. (11. 54 S.W.)

South-east of Harelawhill a series of limestones crops out in the Liddel Water at four principal points:

1. at Penton Linns, downstream from Penton Bridge,
2. 400 yds. E. of Penton Bridge and the same distance south of Shielingmoss,
3. 400 yds. N.E. of Shielingmoss, and
4. 1,000 yds. N.E. of Shielingmoss. At the last-named locality a quarry was being worked recently.

a. Penton Linns [NY 43154 77401]. The most complete section of these limestones is exposed here, and on that account, although no quarrying has taken place, it is given in detail. Commencing about 100 yds. below the bridge an ascending series of strata is exposed downstream as far as the Blae Pot Pool. The details, as measured by R. L. Jack during the original survey, are as follows: limestone (forming arch in stream), 14 ft.; strata with thin coal near top, 48 ft.; limestone, 10 ft. with 9 in. coal below; strata, 68 ft.; limestone, 13 ft. (immediately upstream from Loup Sike); strata with two thin coals, 25 ft. limestone with shaly partings, 14½ ft. with 8 in. coal below (downstream from Loup Sike); strata, 39 ft.; limestone, 4 ft. 4 in.; strata with three thin coals, 35 ft.; limestone, 13½ ft.; strata, 14 ft.; coal, 10 in.; shale, 1 ft. 3 in.; limestone, 3 ft. 9 in.; shale, 2 ft. 8 in.; limestone, 21½ ft.; shale, 30, ft.; limestone, 5 ft.; shale, 30 ft.; dislocation in strata; limestone, 18½ ft.; limy shale, 10 ft.; strata, 7½ ft.; limestone, 5 ft.; strata, 36 ft.; limestone, with thin coal at base, 10½ ft. (at top of Blae Pot); strata, 1 ft. 8 in.; limestone, 1 ft. 3 in.; strata (shales and sandstone), 105 ft. The strata dip at angles up to 70°.

b. 400 yds. E. of Penton Bridge [NY 43652 77416]. A limestone, 15 ft. thick, with an 11-in. coal below it, is exposed here, dipping S.E. at 30°.

c. 400 yds. N.E. of Shielingmoss [NY 43825 78002]. At the bend of the river, 200 yds. E. of Janet's Sike, a mass of limestone of unknown thickness crops out in the bed of the stream. Above it, separated by 9 ft. of sandstone, is a 1-ft. limestone band. About midway between the bend and Janet's Sike are two other rather obscure outcrops of limestone.

d. 1,000 yds. N.E. of Shielingmoss. [NY 44146 78184] A series of limestones, similar to that at Penton Linns, crops out in the river at this locality. A quarry, known as the Dormont Quarry, has been opened in one of the limestones on the Scots bank of the river above the Cat Linns. The quarried stone is conveyed by ropeway to kilns on the English bank. The thickness of the limestone exposed is 15 ft. The bed probably extends northwards along the bank towards Holmfoot [NY 44333 78644], appearing again in the stream with a southerly dip just south of the cottage. It is a massive, thick-bedded limestone of excellent quality (SL 206) [NY 442 784] showing as follows on analysis: $CaCO_3$ 93.61; $MgCO_3$ 3.58; Insol. Res. 2.39.

East Lothian

The limestone deposits of East Lothian are fairly extensive (Figure 15), and a century ago limestone-quarrying and limestone-burning were flourishing industries at numerous localities on the outcrops of the seams. For a time, too, limestone from Skateraw, near Dunbar, was shipped to the Devon Iron Works, Alloa, as a flux, and there was a return trade in coal.

Geologically, the limestone in East Lothian is of Carboniferous age. There are two main areas of outcrop. The first is a strip of limestone-bearing strata extending from the coast between Aberlady and Longniddry south to East Saltoun and then westward towards Pathhead in Midlothian. The second is in the vicinity of Dunbar, in the east of the county. There are smaller outcrops near North Berwick, East Linton, Lennoxlove (Haddington) and Kidlaw, at all of which considerable quarrying has been done. The development of the seams is on the whole similar throughout the county. The Dunbar section (Figure 16) has been chosen to illustrate the succession.

At present (1945) the only active working is at Oxwell Mains, near Dunbar. Preparations are being made to restart a quarry at Blance Bridge, near East Saltoun.

Aberlady to East Saltoun

The group of limestones that crops out on the shore of the Forth between Aberlady and Longniddry can be traced inland in a band of varying width to the western march of the county near Pathhead. Throughout the greater part of this area the rock is covered by drift, and sections showing a sequence are scarce. Quarries have been opened up at numerous points, however, those at Harelaw (Longniddry) and East Saltoun being of considerable extent though now no longer working.

Aberlady: shore outcrop at Kilspindie [NT 45241 80352]. (33. 4 N.E.)

There are four limestones exposed in this section; the Long Craig Middle (8 ft.), the Long Craig Upper (12 to 18 ft.), the Skateraw Lower (4 ft.), and the Skateraw Middle (12 ft.). The Long Craig Upper, with three broad outcrops at Aberlady Point, Garlic Rock and Craigielaw Point, is the most suitably disposed for working. The seam dips in a southerly direction at angles up to 5°, and is overlain by shaly limestone and sandstones. The limestone is distinctly dolomitic in character, weathers with a yellow crust and has a nodular carious top. It contains many fossil fragments. An analysis of the Long Craig Upper Limestone (SL 64) [NT 4497 8029] gave as follows: $CaCO_3$ 60.37; $MgCO_3$ 25.60; $FeCO_3$ 10.55; Insol. Res. 1.55. The high percentage (8.19) of iron oxides in the analysis is notable.

Harelaw Lime Works [NY 42686 78878]: beside Longniddry railway station. (33. 4 S.E.)

In the long-abandoned quarries it was probably the Long Craig Upper Limestone that was worked. At the most only 10 ft. of limestone are now visible. The bed dips to the S.W. at 5° under an overburden of drift and rock up to 20 ft. thick. The situation is convenient both for road and railway. The quarry could possibly be extended southwards, but mining offers the best method of further development. The good limestone is not now well exposed, and the analysis is of the best 4 ft. obtainable. The analytical data (SL 65) [NT 4490 7625] are as follows: $CaCO_3$ 90.30; $MgCO_3$ 3.19; Insol. Res. 5.47.

Landridge Lime Kilns [NT 45727 75401]: 1½ m. N. of Gladsmuir. (33. 9 N.E.)

The abandoned quarry, probably in the Long Craig Upper Limestone, is situated ½ m. S. of Harelaw Quarry on the same line of outcrop. Eight feet of limestone are seen, dipping W.S.W. at 5° under an overburden of drift and sandstone. The quarry might be extended southward for a few hundred yards towards Elvington, but there are signs of old workings here. A broad dolerite dyke 100 yds. N. of the quarry limits easy extension in this direction. Mining is possible.

Jerusalem Lime Works [NT 46864 70469]: 2 m. S. of Gladsmuir. (33. 9 S.E.)

There is an abandoned quarry south of Jerusalem farm in a limestone of the Lower Limestone Group. The section now visible comprises: massive limestone, 12 ft.; limy shale, 5 ft.; hard limestone, 2 ft., upon limy shale. The dip is westerly at a very low angle. The analysis of the massive band (SL 60) [NT 4719 6716] indicates an inferior quality of limestone, with only 61.69 per cent. of carbonates and 32.93 per cent. of insoluble residue.

East Saltoun district

The outcrop of the limestone group that has been followed from the north widens very considerably in this locality, and, in the past, an active limestone industry flourished here, with several large quarries round about the village. At present

preparations are being made to recommence quarrying at Blance Bridge.

Blance Bridge [NT 48552 68109]: on the Gifford Road, ¾ m. E. of East Saltoun. (33. 15 N.W.)

The limestone quarried was probably the Long Craig Upper. About 14 ft. of rock were visible in 1944. The overburden is slight to moderate, and there is a large reserve of stone of good quality. The analysis (SL 63) [NT 4857 6797] indicates as follows: $CaCO_3$ 93.75; $MgCO_3$ 1.41; Insol. Res. 4.40.

Saltoun Lime Works [NT 47145 69214]: beside Middle Mains farm, ¾ m. N.W. of the village. (33. 14 N.E.)

A long opencast uncovered both the Long Craig and the Skateraw limestones. The Long Craig limestones were exposed in the part of the quarry north of the road, but this is now obscured. They are cut off by a fault just south of the road, and the higher Skateraw limestones appear in the south end of the quarry. Here 10 ft. of massive limestone, of which 6 ft. are visible, were wrought under 14 ft. of limestone and limy shale in bands. Above the rock is an overburden of 6 to 12 ft. of boulder clay. The wrought limestone was of excellent quality, the analysis (SL 62) [NT 4702 6766] indicating as follows $CaCO_3$ 94.59; $MgCO_3$ 1.91; Insol. Res. 3.21.

Spilmersford [NT 45709 69101]: on the Tyne, 1½ m. W.N.W. of East Saltoun. (33. 14 N.E.)

The quarries are now waterlogged. The good rock consists of 8 ft. of massive limestone overlain by 20 ft. of poor limestone and calcareous shale, on which in places rest as much as 15 ft. of gravel. Further work here is hardly possible except by mining.

East Saltoun to Pathhead (Midlothian). (33. 14 S.E.)

At East Saltoun [NT 47648 67783] the course of the outcrop of the Lower Limestone Group turns south-westward, crosses the Tyne Water at Saltoun Hall and Spilmersford, and continues towards Pathhead [NT 39613 64188] by Glenkinchie, Lampland and Dodridge Law. This tract of country is for the most part deeply drift-covered, but quarries were formerly operated in the vicinity of the places named. The sections are now poorly displayed.

At Glenkinchie Distillery, limestone (probably Skateraw Middle) was worked at two quarries, one situated about 100 yds. east of the distillery buildings [NT 44494 66903], the other about the same distance to the west [NT 44130 66869]. At Lampland Quarry [NT 43942 65698] the Skateraw Middle Limestone was exposed at the base of the section; but is now almost completely hidden. Above it were dark shales, under calcareous shales and a thin ferruginous limestone. At Peaston Quarry [NT 42833 64397], ¾ m. S.W. of Lampland, the face showed dark bluish limestone with shaly partings (base not seen), 12 ft.; under calcareous shale, 1 ft.; topped by grey ferruginous limestone, 4 ft. In the quarry ¼ m. N. of Dodridge Law [NT 42043 64278], 1½ m. E. of Pathhead, 12 ft. of limestone similar to that at Peaston were formerly seen.

The reserves of limestone in the Saltoun–Pathhead area are very large. While the existing quarries might be extended or new ones started, the difficulties entailed through thickness of drift and frequent presence of a bed of inferior rock above the good limestone might best be overcome by mining. The quality of the stone may be expected to be similar to that obtained at East Saltoun to the east, and at Crichton and Middleton in Midlothian to the west.

North Berwick to Kidlaw

In this district are smaller disconnected bodies of limestone in which considerable quarries were at one time developed and which are not yet exhausted.

The outcrops at North Berwick, East Linton and Whittinghame are associated with volcanic rocks, and probably represent the same limestone seam. This seam is on a much lower horizon than the limestones of Lennoxlove and Kidlaw, which are of the same age as those of Dunbar and Aberlady.

Rhodes Quarry [NT 57031 85059]: 1 m. E. of North Berwick. (41. 2 S.E.)

The limestone here is in the Calciferous Sandstone Series of the Carboniferous formation. Its full thickness is about 30 ft., of which 15 ft. are now exposed in the quarry face, dipping northward at a low angle. The quarry is adjacent to the main road, and although it is now partly filled with refuse it could still be extended southward. There is ample stone still available. The limestone is a grey massive rock devoid of partings which ought to be easily quarried with a minimum of waste material. Analysis (SL 199) [NT 569 849] shows it to be of high quality: $CaCO_3$ 87.55; $MgCO_3$ 8.00; Insol. Res. 0.58.

In specimens from one part of the quarry, Dr. Phemister noted celestite (strontium sulphate) in considerable quantity, and on analysis 2.68 per cent. of this mineral was found to be present. A further series of analyses, however, from other parts of the quarry face showed only the normal trace of strontium, and it seems likely that a local concentration of celestite had occurred in the area of the quarry where the first set of samples had been collected. (*See* also Day, 1930, p. 216.)

In a recent bore, 20 yds. or so to the west of the quarry, 27 ft. of hard limestone were cut and a further 5 ft. of rock at the top were reported as soft, grey, decomposed limestone. Lithologically, the hard rock comprised four rather distinct posts of limestone. These, analysed separately, gave the following $CaCO_3$ values: top hard post (5 ft.) 89.3; second post (6 ft.) 99.2; third post (4 ft.) 91.9; bottom post (12 ft.) 81.8 and 5 per cent. $MgCO_3$.

East Linton and Whittinghame. (33. 6 S.W.; 11 N.W.)

In the neighbourhood of East Linton and Whittinghame two outcrops of limestone, in each case associated with volcanic rocks as at North Berwick, have been mapped. One band has been traced from near the farm of Sunnyside northward, past East Linton, to Tyninghame. The other outcrop lies mostly to the west of Whittinghame.

In the East Linton outcrop a considerable quarry was developed about a mile east of the village [NT 59925 76946], near the junction of the Dunbar road and that leading south to Whittinghame. The thickness of the bed is 12 ft., and it dips westward at a low angle. This quarry could be extended to the north or south, or the stone mined to the dip. It is a pale purplish limestone in massive beds of very homogeneous texture, with occasional bands of chalcedony. On analysis it showed as follows (SL 178) [NT 6019 7669]: $CaCO_3$ 92.68; $MgCO_3$ 2.16; Insol. Res. 5.53.

One mile to the south, the limestone was also quarried and burnt on Sunnyside farm [NT 59448 75609]. It is now poorly exposed here under a thick cover of volcanic rocks.

The Whittinghame outcrop is not well exposed. Only a few small quarries were developed in it, viz., 600 yds. S.W. of Whittinghame Mains [NT 59891 72892], 300 yds. E. of Standingstone [NT 57963 73641], and 900 yds. S.W. of Luggate farm [NT 58961 74188].

Ten feet of limestone are visible on the left bank of the Whittinghame Water, ¼ m. W.N.W. of Ruchlaw Mains[NT 61205 74651]. Here it is a fine-grained rock, colour-banded brown to deep red, and in places crowded with stringers and vesicles of chalcedony. Analysis (SL 179) [NT 6127 7451] indicates it to be a dolomite with only a slight excess of calcite and hardly more than a trace of iron. The figures are these: $CaCO_3$ 49.61; $MgCO_3$ 38.85; Insol. Res. 10.48.

It is probably the Long Craig Lower Limestone that forms this outlier of about 40 acres in extent. There were a number of small quarries in it, mainly for road metal. The thickness of the bed is about 18 ft., but now only about 6 ft. of rather weathered rock are visible. The freshest available material (SL 197) [NT 5142 7222] analysed as follows: $CaCO_3$ 85.16; $MgCO_3$ 2.48; Insol. Res. 9.69.

Kidlaw [NT 50957 64499]: 3 m. S.E. of East Saltoun. (33. 15 S.W.)

At this locality a considerable mass of glacially transported limestone was at one time quarried extensively and burnt for lime. Though the mass is not quite exhausted it is not believed that further useful development could be carried out here.

Dunbar district

The Carboniferous Limestone area extends along the coast from near Broxmouth to Long Craig, 1 m. E. of Skateraw, and inland to near Little Pinkerton and Thornton. Excellent sections of the limestones are to be seen on the coast, but inland exposures are rare, except for the quarries at Oxwell Mains and a section at the east end of the railway cutting at Broxmouth.

Nine distinct limestone bands are known, but only three of these are of considerable thickness. They are the Long Craig Upper Limestone (18 ft.), the Skateraw Middle Limestone (18 ft.) and the Chapel Point Limestone (10 ft.). The Chapel Point seam, however, cannot be quarried, as the outcrop occurs close to the shore-line and the bed dips seaward. The present workings are in the Long Craig Upper Limestone at Oxwell Mains.

Oxwell Mains Lime Works [NT 70596 76238]: 2½ m. S.E. of Dunbar. (33. 7 S.W.)

This is the property of the Coltness Iron Company, Limited, and the output of the mine is at present utilized for cement-making at the company's works at Newmains, Lanarkshire. Lime-burning was at one time carried on at the site, but is temporarily discontinued.

The active mine is in the Long Craig Upper Limestone. The thickness of the seam here is 18 ft., of which the basal 12 ft. are extracted. The dip of the bed is low and accessibility is good. The quality of the limestone is excellent, the analytical data (SL 83) [NT 707 759] being: $CaCO_3$ 96.43; $MgCO_3$ 1.70; Insol. Res. 2.01. The Long Craig Upper Limestone was also at one time quarried on the shore at Catcraig, 1 m. to the north. It is sometimes referred to as the Cat-craig seam. At the present mine its position is 32 ft. below the Skateraw Middle Limestone. The extensive quarries and an upper mine at Oxwell Mains were in the latter limestone, but no work in this seam is being carried on at present. The Skateraw Middle Limestone was also quarried on the shore at Skateraw.

Skateraw Quarry [NT 73738 75401]: shore ¼ m. N.E. of Skateraw. (33. 12 N.E.)

The thickness of the Skateraw Middle Limestone in this abandoned quarry is about 22 ft. The strata here dip northwards at between 7° and 10°. There are abundant reserves, but the overburden is heavy.

The limestone is a grey, fossiliferous stone of excellent quality, in thick posts, with partings of limy shale. It was at one time also worked near Catcraig [NT 71798 77206] and at Oxwell Mains. The shaly partings made it more expensive to work than the Long Craig Upper seam. An analysis of material from the quarry (SL 84) [NT 7466 7540] indicates as follows: $CaCO_3$ 94.12; $MgCO_3$ 2.33; Insol. Res. 2.65.

Fife

Fife possessed considerable reserves of easily accessible limestone in the past (Figure 17), but they have been drawn upon extensively both by quarrying and mining, chiefly for agricultural and building purposes. In consequence there are now comparatively few places where the limestone is both thick enough and accessible enough to be of value at the present day. All the workable limestone in the county is in the Carboniferous, and nearly all in the Lower Limestone Group of that formation. The sequence of limestones in the Lower Limestone Group is shown in (Figure 18) (p. 101).

In East Fife thin limestones in the *Calciferous Sandstone Series* have been worked in a number of places, for example, in the ground between Anstruther and Crail. They are not now of economic significance.

The best limestone in the county is the Burdiehouse, in the *Oil Shale Group* of the Calciferous Sandstone Series. Unfortunately, the only place where it is present and accessible is in the Aberdour–Burntisland area. Here it is 15 to 23 ft. thick and yields, over most of this thickness, a stone containing more than 95 per cent. $CaCO_3$ and less than 2 per cent. $MgCO_3$.

The principal seam in the *Lower Limestone Group* is the Charlestown Main Limestone. Normally it is about 6 to 10 ft. in thickness; but exceptionally, as at Chapel, it thickens to as much as 30 ft. In several places it swells out to 60 ft. or so, owing to the occurrence in it of 'reef-knolls'. These knolls were shell and coral reefs formed during deposition of the limestone on the sea-floor, and they now occur as dome-shaped lenticular masses in the calcareous strata. They vary in

diameter from a few feet to several hundreds of yards, and are commonly of greater purity than the surrounding regularly-bedded limestone. The greater part of the extensive workings at Charlestown itself was in one very large 'reef-knoll,' and at Roscobie another of considerable size is being worked. As in the case of the Blackhall Limestone, with which it is correlated, the Charlestown Main is usually overlain by a considerable thickness of shale, the transitional beds being somewhat argillaceous, flaggy limestone bands, sometimes dolomitic. The quality of the Charlestown Main is in general good, showing a percentage of $CaCO_3$ varying from 80 to 96.5, with $MgCO_3$ not exceeding 4 to 5 per cent.

Distribution of Reserves

There is no limestone of any value north of a line through St. Andrews westwards to Cupar and thence south-westwards by Ladybank to Falkland. There is also nothing of importance west of Cleish and Carnock. Again, the thin calcareous beds in the ground east of a line from St. Andrews to St. Monans are of no economic significance. In the remainder of the county there are considerable amounts of limestone still available, chiefly in the Chaflestown Main Limestone. In the Lomond Hills district it should still be possible to win some stone by quarrying, especially if the upper, usually dolomitic, part of the bed could be put to use. Elsewhere, however, mining would be necessary.

Reserves will be considered in more detail under the various districts which have been adopted for descriptive purposes.

Oil Shale Group

The *Burdiehouse Limestone* is a high-grade stone used principally for fluxing. It comes to the surface in the core of the Burntisland anticline along a line of outcrop extending from Dalachy, a mile east of Aberdour, to Burntisland Golf Course, about 1 m. north-east of the town. Even in this short distance it is broken into by the volcanic rocks of the Binn, and at its eastern end reserves are doubtful on account of contemporaneous volcanic rocks replacing part of the sequence. The chief workable area is in the neighbourhood of Nine Lums, a mile west of Burntisland. Here it has been quarried extensively along a length of outcrop of about ½ m., and also mined over a considerable area.

The Oil Shale Group sequence also crops out in the Rosyth area, and the Burdiehouse Limestone was formerly exposed on the shore in the western limb of an anticline at a point ½ m. west of Rosyth Castle. When the excavations for Rosyth Dockyard were being made the section showed about 40 ft. of limestone. This should be compared with the Blackness Bore section on the West Lothian side of the Firth (p. 196), where the Burdiehouse Limestone was found to be 44½ ft. thick.

Newbigging Mine [NT 20991 86293]: Nine Lums, 1 m. W. of Burntisland. (40. 40 N.W.)

The outcrop extends for a distance of about ¾ m. in an E.–W. direction from Grange to Dalachy, and is indicated by a line of old quarries, all of which were stated over 40 years ago to have been long abandoned (Geikie, 1900, p. 46). From outcrop the limestone dips N. at 5° to 15° and underlies the ground in that direction for about ½ m., being stepped up northwards in that distance several times by small faults. A short distance north of the Burntisland–Cowdenbeath road, however, it is thrown out by an E.–W. fault. Within the area described above, the surface survey indicates that the limestone is penetrated by agglomerate in volcanic vents, and this will reduce the total amount of stone available.

The limestone varies in thickness from about 15 to 23 ft., the thickness worked being approximately 15 ft. where seen in 1943. The lowest post, called the Bottoming, is variable in thickness and sticks to the ganister pavement: it is not usually extracted. Exploitation was entirely by mining, the workings being approached from Nine Lums by a level cross-cut mine which intersects the limestone about 200 yds. N. of the old quarries. Thence the seam is followed to the dip. The mouth of the mine is on the Aberdour-Burntisland road and near the main L. & N.E. railway-line.

Analyses of the limestone indicate a range of composition in the various posts from 90.09 per cent. $CaCO_3$ and 4.66 per cent. $MgCO_3$ to 96.20 per cent. $CaCO_3$ and 1.62 per cent. $MgCO_3$. The weighted average over the whole face in the measured section given below is 94.3 per cent. $CaCO_3$ and 2.48 per cent. $MgCO_3$. Iron (as Fe_2O_3) is between 0.77 and 0.89 per cent. except in the Top Bed where it rises to 2.24 per cent. The following figures, kindly provided by Carron Company, show the composition of the (burnt) lime from the various posts. The samples from which these figures were

obtained were taken within a week or two of the samples taken by the Geological Survey.

Limestone (Geol. Surv.) Burnt Lime (Carron Co.)

	CaO	MgO	Fe_2O_3	Insol. Res.	CaO	MgO
Top Bed (SL 219) [NT 2155 8637]	50.45	2.22	2.24	1.70	88	3.8
Middle Bed (SL 218) [NT 2155 8637]	53.87	0.77	0.87	1.11	94	1.3
Bottom Bed (SL 217) [NT 2155 8637]	53.47	0.79	0.77	1.74	94	1.4
Flooring (SL 216) [NT 2155 8637]	54.04	0.63	0.89	1.27	94	1.0

The limestone is mined by Carron Company for use in iron smelting. The worked beds are light-grey to creamy-grey in colour, somewhat mottled in places. They are fine-grained, compact, and show sub-conchoidal fracture. They contain abundant ostracod shells. Irregular partings and bedding planes lined with carbonaceous material are common. The Bottoming post is of a fairly light-cream colour and closely resembles lithographic stone in colour, fracture and texture. The polished surface took lithographic ink satisfactorily.

In the vicinity of faults, and along zones of crush and disturbance, there is a good deal of veining, individual veins sometimes extending to several feet in width. The vein-filling is mainly dark-brown crystalline ferro-dolomite, but coarsely crystalline white calcite veining is also common. An analysis of the ferro-dolomite (SL 172) [NT 2155 8637] showed the following percentage composition: $CaCO_3$ 53.15; $MgCO_3$ 25.97; $FeCO_3$ 19.19; Insol. Res. 0.46.

Under the microscope the limestone is seen to consist of a matrix of finely divided calcium carbonate, turbid and brown by transmitted light. In this are set numerous ostracod shells and some fragments of thick lamellibranch or gastropod shells. The dolomitic vein material is composed of anhedral grains of ferro-dolomite with uniform grain-size of 0.1 to 0.2 mm.

The section from which the samples mentioned above were taken gave the following measurements. These may be looked upon as typical of the development of the limestone in the area between the old quarries and the Burntisland–Cowdenbeath road.

	Ft.
Roof: fakes and shale with limy ribs	—
Limestone, Top Bed	4½
Limestone, Middle Bed	4
Limestone, Bottom Bed	5
Limestone, Flooring	1 ft. to 1½
Limestone, Bottoming, not worked	2 ft. to 4
Ganister pavement	over 6

Dodhead [NT 24666 86819]: several old quarries on the golf course: 1 m. N.E. of Burntisland station. (40. 40 N.E.)

Burdiehouse Limestone. Dip, varying from N. at 10° to E. at 12°. The quarries are now largely filled in. A nearby bore recorded the limestone as 22½ ft. thick. Reserves are doubtful on account of contemporaneous volcanic rocks replacing part of the sequence.

Rosyth [NT 10879 82083]: c. ½ m. W. of Rosyth. Castle: excavations in shaft and culverts south of pumping station, during dockyard construction. (32. 43 N.W.)

The following record is taken from a graphic section by R. G. Carruthers (*see* Haldane and Allan, 1931, p. 17).

		Ft.
Camps Shale, burnt		1½
Kingle sandstone		1 in. to 1
Sandstone, soft, grey, ashy, with irregular base		1 ft. to 4
Burdiehouse Limestone	Limestone, pale bluish-grey, chert abundant Burdiehouse at base	about 21
Burdiehouse Limestone	Limestone Limestone, blackish, with fish scales, etc.	about 5
Burdiehouse Limestone	Limestone, pale bluish-grey	about 14
Kingle sandstone and fakes		—

Lower Limestone Group

As a result of the folded and faulted character of the Carboniferous rocks in Fife the rocks of the Lower Limestone Group are brought to the surface in a number of different areas. The three limestones of economic interest in this part of the sequence, namely, the Charlestown Station or Hurlet, the Charlestown Green, and the Charlestown Main or Blackhall (*see* (Table 2) and (Figure 18)) are present throughout the whole district, but nearly everywhere it is only the last-mentioned that is of importance. The separate areas of outcrop are dealt with in order from south-west to north-east.

Charlestown to Dunfermline

A curved outcrop, concave southwards, extends north-east from the Firth of Forth at Charlestown and then east by Dunfermline to Duloch, thence turning south to Inverkeithing. At Charlestown the limestones are well exposed and the Main, which is exceptionally thick, has been worked for nearly 200 years. Elsewhere in this area, however, there is a considerable drift cover, and the small thickness of the limestones in general makes it unlikely that any further work will be done on them.

Charlestown [NT 06515 83550]: 3 m. S.W. of Dunfermline. (32. 38 S.E.)

Charlestown Main Limestone. The limestone crops out round the nose of a northward pitching anticline, the old quarries extending along the outcrop for nearly a mile. The north-eastern or Glen Quarry [NT 06842 83940] has long been disused and is full of water, but the West Quarry has only recently been abandoned.

The thickness of the bed of limestone is very variable owing to the development in places of lenticular reef-knoll structure, a thickness of up to 60 ft. being found in the central portion of one of these dome-like masses which occupied the greater part of the worked-out portion of the West Quarry [NT 06420 84027]. When followed to the west by mining, however, the thickness fell to 6 ft. In both quarries the cover eventually became too thick for opencast working and recourse was had to mining. The workings are all within a few hundred yards of main road, railway and harbour.

A sample of the worked portion of the limestone from the face of the West Quarry (SL 225) [NT 0633 8385] showed $CaCO_3$ 84.71; $MgCO_3$ 2.83; Insol. Res. 11.39. The higher beds at the north end of the face (SL 224) [NT 0656 8423] proved to be dolomite, as the following analytical figures show: $CaCO_3$ 54.03; $MgCO_3$ 41.10; Insol. Res. 2.19. This end of the face is near an E.–W. fault which cuts off the limestone to the north of the old workings; and the dolomitization appears to be, in part at least, subsequent and connected with the proximity of the broken ground.

The worked portion (SL 225) [NT 0633 8385] is a dull, compact, brownish-grey limestone with calcite-filled joints, and is composed of a matrix of brown clayey calcite mud filled with a calcite sand, flattened fragments of thin shells, and fragments of crinoids and of shelly crinoidal limestone. The dolomitic beds (SL 224) [NT 0656 8423] are composed of an

aggregate of buff microcrystalline grains of dolomite with many cavities. There are a few small, irregular grains of chert and secondary quartz and of composite granular quartz probably of detrital origin.

The following section measured near the north end of the West Quarry is typical:

	Ft.
Drift, boulder clay	6 to 10
Shale, flaggy and sandy in top half, passing down into dark shale with some ironstone balls	25 to 30
Limestone, 7 ft. thick at N. end, thickening southwards to about 10 ft. in the middle of the quarry face, and then thinning again southwards; abrupt transition into shale at top. It is an evenly developed post resting with clean junction on top of a rather wavy surface of the underlying beds. This limestone was left as a roof in working; it appears to be slightly magnesian	7 to 10
Limestone, main worked bed, crinoidal and shelly, chiefly crinoid stems seen. Some chert nodules, but good quality limestone on the whole. Reef-knoll lenticular character in parts, but this is not pronounced in the face of the quarry where exposed c.	20 to 25
Underlying beds not seen.	

Carnock to Roscobie

The Charlestown Main Limestone crops out in many places within the triangle of country enclosed by lines joining Carnock, Loch Glow and Loch Fitty. Roscobie is the only active mine at present, but there are old quarries in several other places in the area, as at Dolly, Scotscroft, Linn, Cowden, Lathalmond, Clashiebarns and Gask. The district might be worth re-examination with a view to mining. Unfortunately the exposures in most of the localities mentioned are very poor, and some cleaning up of the old quarry faces would be required before sufficient evidence could be obtained. Drift cover is very variable, and there is a considerable amount of irregularly intrusive dolerite in the area.

Roscobie [NT 09186 92960]: on the Saline–Kelty road 3 m. due N. of Dunfermline. (40. 33 N.E.; 34 N.W.)

Charlestown Main Limestone. The seam varies from 12 to 60 ft. in thickness. It has been extensively quarried and mined. The quarrying was mainly carried out in a reef-knoll dome of limestone similar to that at Charlestown (p. 101). With increase of cover mining was resorted to, and the principal workings are now in thick limestone to the north-east of the opencast area. The thickness of limestone at the south end of the workings, however, is only about 12 ft. There appear to be reserves east of the present workings, south of the Cowdenbeath reservoir.

An average sample of the limestone from the normally developed beds south of the knoll limestone in the mine (SL 9) [NT 0926 9286] gave as follows on analysis: $CaCO_3$ 89.30; $MgCO_3$ 5.31; Insol. Res. 3.42.

The principal access is by road, but there is a mineral railway about ½ m. away to the south-east.

Petrographically the limestone (SL 9) [NT 0926 9286] consists of a turbid, locally black-powdered, matrix apparently composed of shell debris and calcareous mud, with fragments of granular carbonate representing for the most part crinoid ossicles. A little dolomite is present. In a mine at the north-west end of the quarry a dolerite sill was found immediately below the limestone. The limestone a few feet above the contact (SL 226) [NT 091 932] was found to be recrystallized and altered to some extent. A pale brownish to greenish mineral is present and seems to be an antigoritic chlorite. Similar dolerite appears in the present workings south-east of the main reef-knoll area, where it forms a sill several feet thick in the bottom blue post of the limestone.

Where the limestone is of normal thickness, *i.e.,* 12 to 20 ft., and knoll lenses are absent the overlying shale is about 30 ft. thick, but over the knolls it thins by overlap to about 10 ft so that succeeding beds were deposited on a more or less even surface.

Mr. J. Wright (Wright, 1920, pp. 370–375) gives a detailed description of the principal reef-knoll area at the north end of the quarry. Below the overlying shale, which is so characteristic of the roof of the Charlestown Main Limestone nearly everywhere, the section was as follows:

	Ft.
Shale, black, with ironstone balls	
Limestone, white, forming a knoll or 'hump'	up to 20
Limestone, grey, weathering yellow in places, with abundant crinoids, brachiopods, etc.	c. 20
Limestone, blue, full of patches of chert, very irregular upper surface	3
Shale, with *Lithostrotion junceum*	2½
Limestone, blue, with *Productus giganteus*	6

Mr. Wright counted the remains of seven reef-knolls in the old quarry face.

The underground workings, to the dip of the main reef-knoll area, are mainly in the 15 to 20 ft. of grey limestone below the reef-knoll horizon, but they rise well into the knoll lenses in places, especially at the north end. At the northwest end of the quarry there are some 20 ft. of limestone above the knoll horizon, but the knoll limestone rises through and cuts out this limestone until in places it is immediately overlain by the thick black shale with ironstone balls. There is in places a certain bellying downwards of the lenses into the underlying limestone as if their increasing weight during deposition had caused a yielding of the still not completely consolidated calcareous beds beneath them. In the mine workings south-east of the main reef-knoll area the bottom blue post is 4 to 6½ ft. thick and is underlain by shale. This portion of the limestone was formerly much sought after for blast-furnace work. The overlying shale is not usually thicker than about 6 in. in this area, and it passes at the north end of the workings into impure crinoidal limestone.

Luscar: old mine 350 yds. N.N.W. of Luscar House, Carnock. (40. 33 S.E.)

Some 4 ft. of altered limestone, probably the Mid-Kinniny, are to be seen . overlying a dolerite sill. On analysis (SL 281) [NT 0503 8982] it was found to contain as follows: CaO 42.7; CO, 39.1; Insol. Res. 4.3.

Inverkeithing to Loch Gelly and Kirkcaldy

From about 2 m. N.E. of Inverkeithing the outcrop of the Charlestown Main Limestone can be traced at intervals north-eastwards to Loch Gelly, and thence to Chapel. Beyond this it turns southwards by Raith to the Firth of Forth between Kirkcaldy and Kinghorn. There are no quarries working on this outcrop at present, but one or two localities might repay investigation. The most promising is Chapel, where a good thickness of limestone is exposed. At other possible places, as at Shaw's Mill and Glenniston, the limestone is not now fully exposed. From the calcining point of view the Chapel area is not favourable, as the limestone lies immediately above a thick quartz-dolerite sill and contains in places appreciable quantities of boron compounds, apparently derived from volatile emanations associated with the intruded material. This causes fusing in the kiln at comparatively low temperature; but it would not interfere with grinding, and a ground limestone containing such quantities of boron as would be present might indeed possess an advantage over other agricultural lime dressings in that it might counteract boron deficiency and its effects on crops. Along the rest of the outcrop the quartz-dolerite is for the most part too far away from the limestone to interfere with its normal characteristics. Throughout this area there is probably a minimum workable thickness of 10 ft. or so of Charlestown Main Limestone.

The Charlestown Station Limestone has also been worked in this area, for example, at Parkend, Bucklyvie, Walton and Little Raith. Exposures of this limestone, however, are poor and uninformative, except on the coast at Kinghorn where the First and Second Abden limestones occur, being respectively the equivalents of the Charlestown Station and Charlestown Green limestones. These cannot be considered to be of economic interest, but their stratigraphical

importance is such as to make them worth description.

Chapel [NT 25320 93886]: about 2 m. N.W. of Kirkcaldy. (40. 35 N.E.)

Chapel quarries lie just north of Chapel village. Road access is good, but there are no railway facilities near at hand. The average thickness of the limestone is 30 ft., and the general dip is N. at 10°. The seam has been worked, opencast for the most part, on a length of face of about 300 yds.; but some recent development in the lowest 10 to 12 ft. was by mining, the overburden being too heavy to permit of further quarrying. Immediately below the seam there is a thick sill of quartz-dolerite, and a thin dolerite dyke cuts vertically through the limestone in the western part of the quarry.

The stone is of moderately good quality and has been extensively worked. A recent attempt at development, however, proved unsatisfactory owing to the tendency of the limestone to fuse in the kilns.

Petrological examination disclosed the presence of the mineral datolite (calcium borosilicate) in some quantity, irregularly distributed through the limestone, and associated with other alteration products of a thermal metamorphic nature (Phemister and MacGregor, 1942). The presence of boron in considerable quantities was confirmed by the chemical analyses, and may be the cause of the difficulty in the kilns. The positions of the samples analysed are as follows. in the 32-ft. face of the quarry:

Original sample		2.00 per cent. B_2O_3
(SL 210) [NT 252 939]	22 to 32 ft. from base	0.008 per cent. B_2O_3
(SL 211) [NT 252 939]	12 to 22 ft.	0.6 per cent. B_2O_3
(SL 212) [NT 252 939]	9 to 12 ft.	0.025 per cent. B_2O_3
(SL 213) [NT 252 939]	6 to 9 ft.	0.003 per cent. B_2O_3
(SL 214) [NT 252 939]	3 to 6 ft.	0.3 per cent. B_2O_3
(SL 215) [NT 252 939]	base to 3 ft.	0.0015 per cent. B_2O_3

Owing to the effect of the dolerite sill it is not possible to give representative figures for the composition of the limestone as a whole. Generally speaking, however, the lower two-thirds of its thickness gave average figures of 42.35 per cent. CaO and 5.92 per cent. MgO ((SL 211) [NT 252 939], (SL 212) [NT 252 939], (SL 213) [NT 252 939], (SL 214) [NT 252 939], (SL 215) [NT 252 939]. The top 10 ft. (SL 210) [NT 252 939] gave $CaCO_3$ 65.58; $MgCO_3$ 25.30; Insol. Res. 9.97. Silica is high throughout and is the principal impurity.

The following is a general description of the section seen in the quarry:

	Ft.
Shale, under drift	–
Limestone, rather thinly bedded, but with little shale; fairly definite top against shale; contains a fair amount of rather friable crinoidal limestone	10
Limestone, grey to white, in posts, but practically no shale partings	10
Limestone,' several posts of solid stone with intervening softer bands; a number of greenish-yellow blotched, rather nodular beds, chiefly in the lowest 9 ft., but not obviously concentrated in any one closely defined zone. Lowest 3 ft. rather nodular limestone in shale matrix	12

Along its length the quarry face shows gentle undulations over lenticular swellings, like incipient reef-knolls, apparently developed in the middle part of the section.

Bogie Mains Quarry [NT 26255 93450]: just north of Bogie Mains farm, 1. m. N.W. of Kirkcaldy station. (40. 35 N.E.)

The quarry is easily accessible by road. The workings, which are in the Charlestown Main Limestone, are abandoned and full of water, but a portion of the section can still be seen. The general dip is E.N.E. at 10° to 12°. In the centre of the old quarry, just north of the east-and-west track, the dip of the beds west of the flooded area is south-westerly in direction and this suggests that there may have been some reef-knoll development.

The section of the higher beds of the limestone seen between the two flooded areas is as follows

	Ft.
Shale, black, with limy bands	over 6
Black, platy, silicified shale, probably partly pyroclastic from appearance in thin section (SL 277) [NT 2645 9340]	1½
Limestone, crinoidal, mottled blue and green in colour	2
Limestone bands, shaly and nodular	2
Limestone, solid to flaggy, rather more blue in colour than that above	over 2½

The three bands of limestone are all rather coarse in grain and the whole section appears to be altered by proximity to intrusive whinstone.

In thin section a sample typical of the limestone in the section detailed above (SL 278) [NT 2645 9340] was seen to consist of large and small crinoid ossicles cemented by a matrix partly composed of brown, very finely divided calcite and partly of clear granular calcite. In the brown portion of the matrix small and extensive areas of silicification are numerous.

The silicified shale at the top of the section (SL 277) [NT 2645 9340] contained only 1.75 per cent. of CaO soluble in HCl. The main portion of the limestone (SL 278) [NT 2645 9340] showed $CaCO_3$ 60.5; $MgCO_3$ 19.03; Insol. Res. 6.88.

Glenniston [NT 21911 92408]: about ½ m. S.W. of Shaw's Mill and 1½ m. N. of Auchtertool. (40. 35 N.W., S.W.)

Charlestown Main Limestone. An extensive old quarry, now flooded. The top 10 ft. of the limestone are exposed at the east corner of the quarry. As is common in the case of this seam, the top beds are dolomitic.

Petrographically the rock (SL 279) [NT 2180 9250] is a compact, fawn-coloured, micro-crystalline dolomite with scattered flesh-coloured crinoid ossicles. In thin section the rock is composed of interlocking grains of dolomite, 01 to 0.2 mm. across, among which there are single-crystal dolomite replacements of crinoid ossicles and coarsely crystalline aggregates after shell-casts.

Kinghorn [NT 27220 86912]. (40. 40 N.E.)

On the shore below the railway, ½ m. north-east of Kinghorn railway station, the lower or first of the two Abden Limestones is exposed, and the beds between it and the Charlestown Main Limestone crop out in succession in the half-mile of coast section between this and Seafield Tower.

The following section is based upon Mr. J. Knox's account (Knox, 1934, pp. 25–28) amplified by further recent examination of the limestones:

	Ft.
Sandstone	—
Shale with lenticular beds of limestone	45
Seafield Tower or Charlestown Main Limestone, the lowest 3½ ft. dolomitic	10½
Shale	9
Fireclay	1
Sandstone, mainly; sandy fakes at the base	75
Second Abden or Charlestown Green Limestone:	

Argillaceous limestone	3
Limestone in thin beds, medium to fine in grain, nodular; much irregularly developed secondary dolomitization; mixed coral, crinoid and shelly fauna	10
Shale, shelly, with *Myalina* at base	8
Fireclay, ashy at base	2½
Two lava flows, with red bole and ash intervening	70½
Shale, calcareous	1½
First Abden or Charlestown Station Limestone:	
Limestone, fine grained, dense, rather porcellanous	2
Shale parting	—
Limestone, grey, medium to coarse in grain, with thin calcareous shale partings and a few giganteid *Productus* shells	3
Shale, calcareous; coral layer at base	1
Limestone, grey to faintly reddish, compact, with cracks and joints containing calcite and barytes	1½
Shale, calcareous, shelly	0½
Tuff, limy	

An analysis of the lowest 3½ ft. of the Seafield Tower Limestone from the shore south of the tower (SL 280) [NT 2794 8853] gave the following results: $CaCO_3$ (soluble in HCl) 49.95; $MgCO_3$ (soluble in HCl) 37.85; Insol. Res. 2.50.

Lomond Hills district

The high ground between Falkland and Leslie shows a number of more or less discontinuous outcrops of limestone, in many places in close association with dolerite sills. There are many old limestone quarries, most of them in the Charlestown Main. The old Longcraigs and Wilkie's quarries on West Lomond Hill are of no economic significance. The most promising locality is at East Lomond, where the old quarries show enough limestone to make further examination justifiable with a view to mining. At Easter Glasslie and Hanging Myre, in the same area, another limestone, probably the Charlestown Station, is exposed to a thickness of 10 ft., and might be worth investigation. Another possible locality lies farther east, at Forthar near Freuchie.

East Lomond Quarry [NO 23832 06023]: at the base of East Lomond Hill on its S.W. side and ¼ m. S.W. of Falkland. (40. 19 N.E.)

The altitude is about 1,100 ft. above O.D. Road access is passable. The quarry is in the Charlestown Main Limestone and the workings extend for nearly ½ m. along the outcrop. The dip is S.E. at an average of 5°. About 8 ft. of limestone is seen under shale, but the total thickness of the seam is not known. There is a cover of 20 to 30 ft7 of baked shale, the thickness increasing southwards. The limestone is mainly bluish-grey in colour, of cystalline texture and containing occasional crinoids and shells. The top beds seem slightly dolomitic in character, but the main portion of the section (SL 98) [NO 2383 0584] shows a good analysis, as follows: $CaCO_3$ 96.54; $MgCO_3$ 2.43; Insol. Res. 1.87.

Easter Glasslie farm steading [NO 23724 05250]: about ¼ m. S. of the East Lomond Quarry. (40. 19 N.W.)

About 8 ft. of limestone, probably the Charlestown Main, are exposed under 5 to 6 ft. of drift clay, the cover increasing rapidly northwards. The beds are nearly horizontal. The locality, though nearly 1,000 ft. above O.D., is easily accessible by road. On analysis the rock (SL 97) [NO 2371 0524] is found to be highly dolomitic, showing the following figures: $CaCO_3$ 51.48; $MgCO_3$ 37.08; Insol. Res. 3.57.

The same bed, much altered, has been worked at Hanging Myre, ¾ m. farther E. (40. 19 N.E.)

Balgeddie [NO 25496 02525]: ½ m. N.N.W. of Leslie Bridge. (40. 19 S.E.)

This was the site of the Rothes Lime Works. Here the Charlestown Main Limestone was mined between 1870 and 1902. The thickness as worked was about 10 ft., under 24 ft. of shale, but the quality deteriorated eastwards. At present there is very little to be seen at the surface. The following section is given for the east workings: ironstone bands in shale roof, 18 in.; limestone, 34 in.; dirt, 2 in.; limestone, 87 in.

In the surface exposures there is obvious alteration in the limestone due to proximity of intrusive rock.

Forthar [NO 30253 06351]: 1 m. E.S.E. of Freuchie and the same distance S.S.W. of Kettlebridge. (40. 20 N.W.)

Charlestown Main Limestone. The section was as follows: sandstone, 3 ft.; shale, 8 ft.; limestone, with parting, 10 ft.; sandstone, fakes and shale, 3 ft.; limestone, red, 2 ft.; sandstone and shale, with coaly top, 1 ft.; limestone, 18 ft.; shale with sandstone, 5 ft.

This limestone was formerly quarried and mined on a large scale, but was abandoned about 70 years ago. Reserves are probably considerable in depth to the S.E., but faulting might make further working troublesome. Road and rail access are convenient.

Cults, Ceres and Largo Ward

Old workings, both quarries and mines, occur in a number of places in East Fife and indicate a considerable amount of former exploitation. The limestone in nearly every case is one that was taken as the base of the Carboniferous Limestone Series in the original survey of the district. The resurvey of the Carboniferous areas of Fife has now been completed and it has been found that this limestone corresponds to the Charlestown Main Limestone of West Fife. The distribution of the limestone is affected both by faulting and by igneous intrusions. Generally speaking it lies in a syncline with N.–S. axis, the western outcrop running northwards from near Largo through Ceres to Ladeddie and the eastern one from St. Monans and Elie through Largo Ward to Winthank and Lumbo. The Cults occurrence is in a different structural block farther west.

A further outcrop of the Lower Limestone Group is found on the coast at St. Monans. The limestones there are of no economic significance, but the section is important stratigraphically as showing the development of the limestones near the base of the Carboniferous Limestone Series in this area.

There are thin calcareous beds in the Randerstone area just north-west of Fife Ness and in the ground between Crail and Anstruther. These lie in the Calciferous Sandstone Series, and in composition and physical character they resemble strongly the cementstones of the lower Carboniferous sequence elsewhere in the Midland Valley and in the Border counties. None of them is more than a few feet thick so that there is no likelihood that they will ever be of economic use. The following are typical analyses. The figures for $FeCO_3$ are partly derived from direct estimations of FeO, and partly calculated from residual CO_2.

Randerstone, coast section 7 m. E.S.E. of St. Andrews: four typical beds:

a. Bed 4 ft. thick (SL 29) [NO 6099 1147]	$CaCO_3$	48.15	$MgCO_3$	28.44	$FeCO_3$	12.9	Insol. Res.	6.37
b. Bed 2 ft. 3 in. thick (SL 28) [NO 6113 1133]	$CaCO_3$	52.08	$MgCO_3$	32.64	$FeCO_3$	11.6	Insol. Res.	1.48
c. Two 1-ft. beds (SL 30) [NO 6125 1131]	$CaCO_3$	43.89	$MgCO_3$	25.16	$FeCO_3$	17.2	Insol. Res.	9.38

d. Bed 1 ft. 3 in. to 2 ft. thick (SL 31) [NO 6133 1128] $CaCO_3$ 53.19 $MgCO_3$ 37.33 $FeCO_3$ 6.4 Insol. Res. 1.29

Lathockar, 2 m. N.E. of Radernie; 2-ft. bed in Cameron Burn (SL 40) [NO 4914 1140]: $CaCO_3$ 52.18; $MgCO_3$ 36.40; Insol. Res. 5.37.

Carnbee Den, 3 m. N.W. of Anstruther (SL 33) [NO 5312 0668]: $CaCO_3$ 34.97; $MgCO_3$ 20.34; $FeCO_3$ 12.7; Insol. Res. 21.14.

The thickness of the Charlestown Main Limestone is 12 to 13 ft. where worked at Cults on the north-west, and 11 ft. at Lumbo and Winthank on the north-east, but it is probably not more than 10 ft. on the average in the area_ east and south of Ceres. In the St. Andrew's Well Quarry, however, at the north-western end of the Ladeddie'outcrop, up to 20 ft. of limestone are exposed. The old mines and quarries do not as a whole form a favourable subject for investigation at the present time, though large reserves of limestone of between 8 and 10 ft. in thickness are undoubtedly present at moderate depths. The stone at the surface has in nearly every case been thoroughly exploited. Old workings in this area are found at the following localities:

Lumbo, 1½ m. S.W. of St. Andrews.

Ladeddie, 4½ m. W.S.W. of St. Andrews.

Cassindonald and Winthank, 3 to 3½ m. S.W. of St. Andrews.

Craighall, ¾ m. S.E. of Ceres.

Greigston and Wilkieston, 1¼ m. S.E. of Ladeddie.

Radernie and Lathones, 4½ to 5 in. E.S.E. of Ceres.

Teassies, 3 m. N. of Lundin Links station.

Balcarres, Gibliston and Baldutho, on an outcrop 2 m. long running north-eastwards from Colinsburgh.

Cults: quarries and mines 4 m. S.S.W. of Cupar. (40. 13 S.E.)

The Charlestown Main Limestone crops out, on a hill-slope facing north, from Cults [NO 34705 08614] westwards to Coaltown of Burnturk [NO 32907 07437], a distance of about 2 m. The dip is S. at 5°. The limestone has been quarried along practically the whole outcrop, and mining was resorted to when the overburden became too thick for opencast work. The workings at Cults have now extended nearly ½ m. south from the outcrop, but reserves are still available. On the east the limestone is eventually cut off by a dolerite sill, and westwards also it is seen in close contact with dolerite at Bowden Hill. There is still a large area unexplored to the south of the old and present mine-workings beyond an E.—W. fault. In this direction too, however, the Clatto Hill dolerite sill may be an interfering factor.

There is a mineral railway serving the works, and road access is good.

The limestone in the present Cults working is 12 to 13 ft. in overall thickness. It is overlain by a thick bed of shale and rests on a black fireclay 4 ft. thick. The top 3-ft. bed of the limestone is left to support the roof in the main levels, but elsewhere the whole thickness of limestone is worked. About 80 per cent. of the limestone is extracted, leaving pillars 10 to 12 ft. square.

The quality of the limestone is shown by the following analysis (SL 49) [NO 344 080]: $CaCO_3$ 96.20; $MgCO_3$ 1.28; Insol. Res. 1.14.

The following figures give the $CaCO_3$ content of the different bands of limestone in the face as worked:

Top stone	3 ft. thick	97.9 per cent. $CaCO_3$
Second post	1½ ft. thick	98.4 per cent. $CaCO_3$
Third post	2 ft. thick	98.6 per cent. $CaCO_3$
Fourth post	1½ ft. thick	94.6 per cent. $CaCO_3$
Fifth post	1½ ft. thick	53.8 per cent. $CaCO_3$

Anal., A. Hodge & Co., 26/2/40.

The lowest post is composed of dolomite. It varies from 9 in. in thickness on the west side of the workings to 2 ft. on the east side.

The limestone is grey in colour, and in thin section is found to consist chiefly of debris of shells, crinoids, polyzoa and foraminifera.

A bed of limestone, 5 ft. 9 in. thick and lying about 17 fms. above the Charlestown Main in the sequence, has recently been exposed by surface excavations in the ground a short distance south of the mine-mouth. It is probably the Mid Kinniny Limestone. In general appearance it is similar to the Charlestown Main. The following analysis will indicate its chemical character: CaO 47.62; MgO 2.64; Fe_2O_3 2.74; Al_2O_3 0.66; MnO 0.21; SiO_2 4.97; CO_2 37.51; SO_3 0.27; undetermined 3.38. Anal., A. Hodge & Co., Jan. 1941. Recent samples from the outcrop indicate a $CaCO_3$ content of between 85 and 89 per cent.

In 1944 boring operations were carried out by Lord Cochrane of Cults to ascertain the character of the strata below the Charlestown Main Limestone. These investigations have given valuable information regarding the development of the lower portion of the Lower Limestone Group in this area. The followine section shows the positions and characters of the limestones found:

	Ft.
Charlestown Main Limestone	13
Strata, mainly arenaceous, with a thin coal in the lower half about	54
Limestone, white, weathering rusty brown in parts, nodular and jointy, partly crystalline, partly shelly	6½
Strata, mainly arenaceous	47
Limestone, ? Charlestown Green, grey, bedded, with shells, abundant *Lithostrotion* in some beds	11½
Limestone and calcareous shale, with shells	4
Shale, limy	7½
Sandstone mainly, yellow to ochreous	23
Shale, shelly	21½
Limestone, ? Charlestown Station, dark, argillaceous, shelly, with *Productus*	4
Shale, shelly	—

Analysis of the 11½-ft. limestone in the above section gave an average of 56.57 per cent. $CaCO_3$ (Anal., A. Hodge & Co.).

Ladeddie Quarries [NO 43968 13574]: just S. of the farm steading of Backfield of Ladeddie. (49. 14 N.E.)

The following sequence can be made out in the old quarries:

	Ft.	In.
Boulder clay, stony	about 6	—
Coal	at least 1	—

Faky fireclay	about 1	—
Sandstone, rooty	about	9
Faky and sandy fireclay	1	
Sandstone, flaggy, grey-brown	3	—
Fakes, passing down into shale	about 3	—
Shale, with ironstone balls	14	—
Limestone, impure, fossiliferous	2	—
Limestone, whitish-grey	11	—

The limestone is not now exposed. Some blocks of dolomitic limestone are to be seen lying near the old kilns but it is not known from what part of the limestone they are derived. The dip of the beds is S.E. at 6° to 8°, and the ground rises gently in the same direction.

St. Andrew's Well [NO 43773 14559]: ½ m. N. of the Ladeddie Quarries and ½ m. E.S.E. of Morton of Blebo. (49. 8 S.E.)

A face of up to 20 ft. of limestone is exposed in the old quarry, immediately overlain by an intrusive sill of dolerite. The limestone is in posts of a foot or two in thickness and dips N. at 5° to 7°. It is all much ferro-dolomitized, and the dolerite transgresses downwards across the limestone, at both ends of the quarry.

St. Monans [NO 53760 02080]. (41. 22 S.E.)

The lowest beds of the Lower Limestone Group crop out on the shore ¼ m. east of Coalfarm, which lies ½ m. east of St. Monans station. The following section indicates the character of the limestones. It is based on the records in. the Survey Memoirs on E. Fife (Geikie, 1902, pp. 150–151) and E. Lothian (Crampton, 1910, p. 39), supplemented by notes made during a recent examination of the exposure.

	Ft.
Sandstone and shale	—
Limestone, hard, grey, crinoidal, weathering dark brown; nodular irony top; some giganteid *Productus* shells near base	2½
Coal position estimated thickness	2
Shale, dark, with thin impure clayband ironstone ribs	8
'Pseudobreccia Limestone,' light grey; contemporaneous disturbance and intermixture with shale in places; hollows lined with reddish-brown dolomite; 3-in. red irony nodular band at top	7
Alum shale	2
Fakes, with contemporaneous disturbance in a faky shale medium; at least one calcareous (shelly and crinoidal) faky band	3
Coal, not seen	½
'White fireclay or marl'; not seen	6½
Limestone, white, nodular, with crinoids, shells and *Lithostrotion;* brown to purplish nodular pyritic topaverage	3
Dolomite, white to buff, weathering brown, carious; replacing *Lithostrotion* limestone irregularly average	2
Limestone, white, full of *Lithostrotion*	2
Limestone, light-grey to white, crinoidal, coralline, and shelly, rather nodular about	5
Limestone, dark-grey, weathering brownish-buff, crinoidal, possibly slightly dolomitic	1½

Inverness (Mainland)

As a whole the mainland of Inverness-shire is not rich in limestone (Figure 19), (Figure 20), (Figure 21). One band of considerable size and high quality occurs in the Fort William district, while others of lesser extent and purity are somewhat sparsely scattered throughout the county. Geologically and topographically Inverness-shire is divided into two parts by the Great Glen (Glen More), and the regions to the south-east and north-west of this feature are therefore described separately.

South-east of the Great Glen

The portion of Inverness-shire south-east of the Great Glen forms part of the Grampian Highlands. It consists essentially of metamorphic rocks, intruded, at numerous localities, by granite. These are overlain, near Inverness, by Middle Old Red Sandstone sediments. The metamorphic rocks belong to two series, the Moine and the Dalradian. The rocks of the Moine Series are mainly quartzose and micaceous schists, and are rarely calcareous in character. Three occurrences of limestone probably of Moine age are, however, known, namely, near Tomatin, Aviemore and Kincraig. None is of great thickness or extent; that near Aviemore is the most important and is accordingly described below.

The main area of Dalradian schists in Inverness-shire extends from the north shore of Loch Leven to Glen Spean and Glen Roy. Two important limestones occur, namely, the Ballachulish Limestone and the Appin Limestone. The Ballachulish Limestone crops out extensively between Loch Leven and Fort William (Figure 19), but as bands of good quality and reasonable extent are not common. it is difficult to recommend any localities in this district which would repay exploitation. North-east of Fort William, on the other hand, the Ballachulish Limestone contains material of high quality which forms several outcrops of considerable magnitude. A particularly favourable occurrence for exploitation is that at Creag Aoil, 5 m. E.N.E. of Fort William [NN 18065 77642], where an old quarry has recently been reopened and is now yielding supplies of high-quality ground limestone. This locality, and another in the Spean valley where the stone is also of a high degree of purity, are described below.

The Appin Limestone crops out near Onich [NN 02469 61374], on the north side of Loch Leven. It differs from the Ballachulish Limestone in being dolomitic, but analyses of samples from the shore and from a disused' quarry farther north show it to be of poor quality. It is doubtful therefore if the Inverness-shire occurrences of the Appin Limestone are of economic value, although it should be noted that dolomites of fairly high quality occur in the same formation near Ballachulish and Duror (*see* under Argyll, p. 56).

Limestone of probable Dalradian age occurs at Kinlochlaggan [NN 53640 88969], and extends both N.N.E. to the Spey valley and S.S.W. for many miles into mountainous country. The Kinlochlaggan outcrop, which was formerly quarried, might be worth reopening on a small scale for local agricultural requirements.

A small outcrop of limestone was at one time wrought in Glenlia [NH 49924 20159], near Foyers. As the area has not been geologically surveyed in detail, the stratigraphical position of, this limestone is doubtful, but it probably belongs to one of the metamorphic series. The limestone is of poor quality and small extent, and is not of economic importance.

In the Middle Old Red Sandstone of the Inverness neighbourhood there are a few other bands of impure limestone of no economic value. Marl is recorded as having been dug in the same district but the exact localities (near Dochfour [NH 60306 38599]) from which it was obtained are not known.

To sum up, it may be said that in south-eastern Inverness-shire supplies of high-quality limestone in considerable quantities are assured for a long period in only one district, namely, that north-east of Fort William. At other two localities, Kinlochlaggan and Aviemore, limestone might be exploited on a small scale for local requirements.

Ballachulish Limestone

A large outcrop of the Ballachulish Limestone is to be found in the crag known as Creag Aoil, E.N.E. of Fort William (Figure 20) [[NN 18065 77642]]. North-east of Creag Aoil the limestone is hidden for several miles under thick morainic deposits, but it reappears in the bed of the River Spean, east of Spean Bridge. Here the total thickness of the limestone is very considerable, but the band of material of high quality is narrower than at Creag Aoil. The Ballachulish Limestone is also exposed at Tom an Aoil, 1¾ m. E.N.E. of Spean Bridge.

Creag Aoil (Torlundy) [NN 18065 77642]: 5 m. E.N.E. of Fort William and 2½ m. E. by N. of Bridge of Lundy on the main Fort William—Spean Bridge Road. (62. 140 S.W.)

An old quarry on the north face of the crag has recently been reopened and ground limestone is being produced. Access to the quarry is by a track from Bridge of Lundy, near which there is a siding of the L. & N.E.R.

The limestone (SL 85) [NN 1800 7763] is a medium-grained, light-grey, banded type with very thin micaceous partings. It carries, as impurities, a little quartz, muscovite and biotite. On bulk analysis it showed: $CaCO_3$ 95.09; $MgCO_3$ 1.01; Insol. Res. 4.15. It dips W.N.W. at 70 ° to 80° and is at least 350 ft. thick. The face of the crag is from 75 to 100 ft. high and there is no overburden. Reserves are immense, as the main crag is 400 yds. long, and smaller crags show the outcrop as a whole to be 1,000 yds. long.

Tom an Aoil [NN 25040 82175]: 1¾ m. E.N.E. of Spean Bridge. (62. 141 N.W.)

The limestone (SL 229) [NN 2492 8244] is similar to that at Creag Aoil and showed on analysis: $CaCO_3$ 96.59; $MgCO_3$ 1.41; Insol. Res. 2.38. The bedding of the limestone is vertical and strikes N.N.E. to N.E. The thickness of the band of high-quality limestone is at least 25 to 30 ft. in the quarry, which is nowhere more than 15 ft. deep. Overburden consists of a variable thickness of morainic gravel, probably not more than 6 ft. thick and less in places. Reserves are very considerable, as the band of high-grade limestone, 20 to 30 ft. wide, can be traced by means of stream exposures for at least a mile to the north-east. There is some morainic overburden throughout the area, but it does not appear to be thick. The disused quarry is about 1,000 yds. from road and rail, about 500 yds. from a track to the nearest croft, and 300 yds. from a very rough track to an old kiln on Tom an Aoil.

A bulk sample (SL 230) [NN 2418 8157] was also collected from a 26-ft. band of limestone exposed on the north bank of the River Spean 350 yds. upstream from the railway bridge. It showed on analysis: $CaCO_3$ 97.03; $MgCO_3$ 1.30; Insol. Res. 2.42.

Kinlochlaggan Limestone

Limestone of probable Dalradian age is exposed at a number of localities near Kinlochlaggan (Figure 21).

Kinlochlaggan [NN 54798 89754]: 1 mile E. of the end of Loch Laggan. (63. 115 S.W.)

There are several disused openings where the stone was formerly wrought for burning. The most important is a quarry adjacent to the Spean Bridge –Newtonmore Road, just N.W. of Kinlochlaggan post office [NN 53908 89718]. The limestone (SL 14) [NN 55143 89751] is a coarse, highly crystalline, white type with accessory oligoclase, quartz, tremolite and pyrite. Biotite is seen in some bands. The bulk analysis showed: $CaCO_3$ 91.37; $MgCO_3$ 5.00; Insol. Res. 2.64. The bedding is vertical and strikes N.N.E. The face of the quarry is 30 ft. high. The limestone has a maximum thickness of 45 ft., but is only 30 ft. thick at the quarry face and, as suggested by recent exploratory work, may narrow still further along the strike. The overburden is slight at the quarry but rapidly increases to the north-east. In spite of the narrowing of the seam and the possibility of schist intercalations, considerable reserves of limestone probably exist along the strike to N.N.E., but how far they could be economically exploited owing to the heavy overburden is doubtful.

East of the post office there is another disused quarry in limestone of similar type, flanked by mica-schist. In all about 40 ft. of rock have been worked, but, besides limestone, this thickness includes some beds of mica-schist. The total height of the face is about 30 ft. In the face of the quarry a top bench of 15 ft. has been removed, leaving the lower 15 ft. which could be readily worked forward for 50 yds. Beyond this point the limestone continues, but the overburden becomes heavy.

Still farther east there is a disused quarry on the hillside south of a sheep fold, but the limestone here is in bands 7 to 10 ft. thick.

On the hillside to N.N.E. of Kinlochlaggan limestone bands are exposed at several localities, but are too inaccessible to be economically exploited.

Limestone is also seen in a small disused quarry at Shirrabeg on the south side of the River Spey, 2¾ m. W. by S. of Laggan Bridge.

South of the River Pattack, opposite Kinlochlaggan, limestone is exposed in two wooded knolls. The more westerly rises beside a sharp bend in the river [NN 54649 89419], on the line of strike of the post office exposures, and the other about 300 yds. to the east on the strike of the outcrops east of the post office [NN 54926 89133]?. Both knolls are surrounded by alluvium and both contain a limited, although quite considerable, reserve of limestone free from overburden. Not far south of these knolls the limestone bands are cut off by a fault and do not reappear until exposed in rather inaccessible country some distance farther to the south.

Mid-Strathspey Limestones (Figure 19)

Amongst the limestones of probable Moine age in Mid-Strathspey the most promising is that at Loch an Eilean, in Rothiemurchus Forest.

Loch an Eilean 2¾ m. S. by E. of Aviemore. (74. 73 S.E.)

There is a disused quarry and kiln on the west side of the north arm of the loch [NH 89656 08326]. The limestone (SL 15) [NH 937 082] is a massive, coarsely crystalline white type with numerous subordinate minerals, including quartz, alkali-feldspar, tremolite and zoisite. It showed on analysis: $CaCO_3$ 86.64; $MgCO_3$ 0.88; Insol. Res. 10.03. The limestone dips S.W. at 30° to 50° in the main part of the quarry, but near the top it turns over and dips gently W.S.W. into the hillside. The thickness is about 15 ft. The face of the quarry is variable in height. There is no overburden at the quarry but hill-scree partly hides the continuation of the limestone to N.N.W. There are probably appreciable reserves in this direction, but their exploitation might be difficult owing to folding and to the manner in which the limestone, in the flat parts of the folds, dips into the hillside under schist.

Three hundred yards N.N.W. of the north end of the loch [NH 89707 08616] there is another disused quarry in about 10 ft. of similar limestone forming one of three lenticular bands interdigitated with mica-schist.

Limestone bands also occur on the east slopes, and near the summit, of Ord Bain, immediately west of the quarries [NH 89290 08407]. They are interbedded with quartzose and micaceous schists and repeatedly folded in the same manner as the limestone at the first quarry. Owing both to the folding and to difficulties of access these bands of limestone would be awkward to quarry.

North-west of the Great Glen

The greater part of the mainland of Inverness-shire north-west of the Great Glen is made up of rocks of the Moine Series, among which limestones are extremely rare. Three small outcrops occur between Inverness and Beauly; the only one of any significance is that at Rebeg (Figure 19). This limestone was formerly quarried and burnt, but the extent of the reserves is so much in doubt that it appears unlikely that the quarry would be worth reopening except perhaps to obtain a small supply for purely local purposes.

Lewisian gneisses and schists also occur at a number of localities in northwestern Inverness and include several bands of limestone, among which may be mentioned those cropping out at Glenelg, Glen Dessarry, Inchvuilt and Glen Urquhart. Of these, the last-named is selected for detailed description. The Glenelg occurrences are referred to in the description of the outcrops south of Totaig in the section dealing with Ross and Cromarty. The Glen Dessarry Limestone showed on analysis by C. O. Harvey (Geol. Surv. Lab. No. 1401): $CaCO_3$ 92.62; $MgCO_3$ 4.60; SiO_2 2.0; Al_2O_3 1.0.

In brief, it may be said that the mainland of Inverness north-west of the Great Glen contains no limestones which would bear exploitation on any important scale and only one or two which would be worth opening up even on a small scale for local requirements.

Loch an Sgor Ghaothair, Glen Urquhart: 250 yds. S.W. of the W. end of the loch. (73. 29 N.W.) [NH 48581 31524]

The limestone (SL 106) [NH 485 314], which was formerly burnt, is of a coarse, white type, with some thin biotite-rich bands, and is flanked by green calc-silicate rocks. It contains some quartz, tremolite and phlogopite, and accessory sphene, oligoclase, apatite and pyrite. On bulk analysis it showed: CaO 47.86; MgO 2.23; Insol. Res. 14.04. Not all the lime and magnesia occur as carbonates, since a small amount of calc-silicate minerals is present. The dip of the limestone is variable, as the quarry has been worked in a sharp anticline pitching S.E. and somewhat over-turned towards the N.E. The best material is only about 10 ft. thick. The face of the quarry is from 20 to 30 ft. high and there is no overburden. The reserves are small, except possibly in depth. Above general ground-level at least half of the best material has been worked out, although a certain' amount remains and might be wrought on a small scale along with the less impure parts of the flanking calc-silicate rock.

The occurrence is relatively inaccessible, being reached by a rough track, 600 yds. long, from an old kiln at the east end of the loch. The latter is itself approached by a mile of fairly good but steeply graded track from the main Glen Urquhart road.

Other exposures of limestone occur in the vicinity but are either too small or too impure to be of economic value.

Inverness (islands)

Very large quantities of limestone, chiefly Cambrian in age, are available in the parish of Strath in Skye, and dolomite of the same formation occurs at Ord in Sleat (Figure 22) and (Figure 23). There are also Jurassic limestones in Strath and in Strathaird. Shell sand is found in many of the coastal bays, more especially on the Atlantic side of the Outer Hebrides (Figure 24).

Cambrian limestones

The Cambrian limestone outcrop in Strath (Skye) extends from Creag Strollamus (Figure 23), which lies about 2 m. N.W. of Broadford, southwards for a distance of 3 m. up Strath Suardal. Thence it is in two branches, the more northern of which runs westwards by Loch Cill Chriosd to the head of Loch Slapin at Torran whilst the other, after swelling out eastwards to form Ben Suardal, passes south and then west along the south side of Beinn an Dubhaich to the shore of Loch Slapin about a mile south of Torran.

At Torran, on Ben Suardal, and in most of Strath Suardal, the limestone is unaltered, but where it is near the intrusive granitic masses of Beinn an Dubhaich and Beinn na Caillich it is converted into marble. A similar effect is produced in contact with the gabbro intrusion north-east of Beinn na Caillich.

The Cambrian strata of Strath consist of both limestone and dolomite, but the detailed stratigraphy is not sufficiently clear to permit of any very close correlation with the Durness sequence. Fossils such as characterize Groups V and VI at Durness (*see* p. 181), however, are abundant in the limestone at some localities. Again, the lowest beds, namely, those nearest the Beinn an Dubhaich granite and altered by it, seem to be more commonly dolomitic than those of Torran which are apparently higher in the sequence. This suggestion of a lower more dolomitic group and a higher more calcareous group, the higher group yielding the same fossils as the higher calcareous groups at Durness, makes it appear most probable that in the Broadford area we have representatives of Groups V and VI, with possibly some beds near the base belonging to Group IV. There are no massive dolomites in this area.

Chert, chiefly occurring as small nodules and irregular lumps, and commonly replacing fossils in some parts of the succession, is abundant and is perhaps the greatest drawback to exploitation of the limestone for any purpose requiring

stone of considerable purity. The chert nodules occur in definite zones in the exposed rock faces, but it is not certain if these chert horizons are persistent nor if they are developed more particularly in definite parts of the succession. Choice of a good quarry site would depend, other things being equal, upon the beds to be worked being comparatively free from chert nodules. No regular bands of chert have been recorded.

The following rough generalization regarding the relative distribution of dolomite and limestone is all that can be offered on present evidence.

The ground south-west of the road between Broadford and Creag Strollamus is probably mainly dolomite, judging from specific gravity determinations. Much of it, however, is altered to brucite-marble near the gabbro intrusion, with consequent reduction of the specific gravity to below 2.60 in some cases. Farther south, both to the west of the Broadford River and on Ben Suardal, the sequence is partly dolomite and partly limestone, the former predominating. There is a considerable amount of chert in nodules and lenses in this ground.

West of Loch Lonachan, on the south side of the Beinn an Dubhaich granite, the beds near the intrusion are chiefly dolomite, converted into brucite-marble near the junction. South of the dolomite is a more calcareous zone. This ground, however, is too inaccessible to be considered from the economic stand-point.

From Cill Chriosd old church westwards to Kilbride and Torran, on the north side of the Beinn an Dubhaich granite, the limestone is for the most part low in magnesia, both where unaltered and where marmorized near the granite contact. The Cnoc Slapin–Dun Mor area, where detailed sampling was carried out, shows a range of from 1.00 to 7.53 per cent. $MgCO_3$ with an average figure of 5 per cent.

The Ord limestone in Sleat (Figure 23) represents the Durness succession from the base of Group I to the west beds of Group IV. As at Durness it consists almost entirely of dolomite, in contrast with the higher portions of the sequence found in Strath. The characters and estimated thicknesses of the Ord beds are as follows (Clough, 1907 and 1910):

			Ft.
Group	IV	Granular white dolomite with bands of white chert	—
Group	III	Mainly leaden-grey dolomite, with chert in great abundance	270
Group	II	Mainly flaggy, compact, white to cream coloured dolomite, but other types also present	500
Group	I	Impure for about 15 ft. at the base, succeeded by granular leaden-grey dolomite some 65 ft. thick, passing upwards into granular and pale banded dolomite with some oolitic beds and some chert	115
		Total over	885

Analysis shows the beds of Groups II and III to have the composition of high-grade dolomite.

Jurassic limestones

Limestone is found in two portions of the Jurassic succession of the islands of Inverness, namely, near the base of the Lias and in the higher beds of the Great Estuarine Series.

There are at least two occurrences of Liassic limestone in Raasay and one on the south coast of Minginish opposite Soay, but the chief development is in the Broadford distridt of Strath. There (Figure 22) and (Figure 23), calcareous beds are found right round the coast of Broadford Bay and extend thence eastwards to Oblusa, which lies halfway between

Broadford and Kyleakin. Southwards from Broadford this same outcrop extends for about 3 m. to near Heast and thence turns west to the coasts of Loch Eishort on the south and Loch Slapin on the west. The limestones of these strata are usually rather sandy in this district, and at Broadford they are too impure to be worth serious consideration at the present day. Nevertheless, a representative analysis of a bed at a particular locality on the Heast road, about 1 m. S. of the Broadford–Kyleakin road, showed 89.06 per cent. $CaCO_3$ and 1.40 per cent. $MgCO_3$.

There is another occurrence of Liassic limestone at Sconser, on the south side of Loch Sligachan. In this area the quality in Allt Eas Mor, at the west end of the village, is good, showing (SL 242) [NG 512 315] 91.31 per cent. $CaCO_3$ and 1.43 per cent. $MgCO_3$; but some of the other exposures appear to be fairly sandy. The Raasay occurrences are at Hallaig on the east coast of the island and near Susnish Point at its south-west corner. They are of little account, and neither of them has been worked.

Limestones belonging to the Great Estuarine Series occur in the islands of Skye, Raasay, Eigg and Muck (Figure 24). The most important exposures are to be found in Strathaird (Figure 23) where three calcareous horizons crop out for a distance of six miles on the steep slope above the west coast of Loch Slapin from the head of the loch to Elgol on the east side of Loch Scavaig. From the characteristic fossils contained in each of these beds they are known respectively as the *Cyrena, Ostrea hebridica* and *Paludina scotica* limestones. They contain among them a number of limestone beds of fair quality, but on the whole they are not sufficiently good to be worth exploitation for anything but very local use.

An interesting occurrence of contact-altered limestones in the same part of the sequence is to be found south of Strollamus, about 3 m. N.W. of Broadford. In the same area there is a limestone of Cretaceous age about 15 ft. thick; it is probably an altered chalk and is of good quality, showing (SL 244) [NG 5975 2620] $CaCO_3$ 93.33 per cent. and $MgCO_3$ 0.50 per cent.; but the outcrop is of small extent. Other Great Estuarine limestones are found on the coast north of Portree (Figure 24), and on Dun Caan in Raasay (Figure 22). Of the occurrences in the Small Isles, that on Eigg is the only one worth even cursory notice.

Shell Sand

The Outer Hebrides from Harris southwards are locally served for agricultural purposes by the numerous shell-sand beaches of the western seaboard. Details of those worth mention are given in the section dealing with particular occurrences. In the Small Isles also there are several places where useful deposits occur. The nullipore (coralline) sand that is to be found in several bays on the north-west coast of Skye is similar in character to shell sand, and is often of good quality. A noteworthy point about that of Claigan, near Dunvegan, is that it yielded 10.35 per cent. of $MgCO_3$ on analysis.

Skye

Cambrian limestone

Broadford: disused quarry, 1½ m. N.W. of Broadford Church and about ¼ m. W. of main road from Broadford to Sligachan. (71. 40 S.E.) [NG 623 248] References: Clough, 1907, p. 421; Clough and Harker, 1910, pp. 71, 172.

Durness Limestone, Group V. White marble, veined in places with grey and yellow. This locality is one of a number, between Camas na Sgianadin and the Broadford River a mile and a half farther south, in which the Durness Limestone has been invaded by gabbro. The magnesia content of the marble is very variable but appears to be high in some places. In thin section the analysed specimen consists of interlocking grains of calcite, about 0.5 mm. across, which enclose or interlock with aggregates of flaky brucite pseudomorphous after periclase. Forsterite is also present. There are dumps at the old quarry containing several hundreds of tons of clean marble, and considerable reserves occur in the vicinity. An analysis gave the following composition per cent. (SL 245) [NG 623 248]: CaO 31.63; MgO 17.66; CO, 30.83; Insol. Res. 12.28; Total 92.40.

Strath Suardal, Suardal to Kilbride: occurrences on the S.E. side of the road from Broadford to Torran e.g. [NG 61495 20049]. (71. 46 N.W., N.E., S.W., S.E.). References: Clough, 1907, pp. 421, 424, 425; Clough and Harker,

1910, pp. 69, 71, 172; Kennedy, 1941.

Durness Limestone. These occurrences lie round the north-east end of the Beinn an Dubhaich granite, and the limestone is more or less marmorized near the contact. In the case of material that was originally dolomite this has produced a brucite-marble. The beds belong to Groups V and VI, and were not invariably dolomitic in original character, so that it is probable that quarries could be opened out in areas where a limestone of considerable purity could be obtained. The reserves are very large and there is practically no drift cover.

Continuous with this area round the east end of the Beinn an Dubhaich granite and thence south and west there is a belt of ground occupied by Durness Limestone. Where this southern belt reaches the shores of Loch Slapin it consists of marble and more or less altered limestone, but contains a large amount of chert. The rest of the outcrop is too inaccessible to be worth consideration.

(a) Limestone knolls E. of road, ¼to ½ m. N. to N.N.E. of Suardal. (71. 46 N.E.)

Dark-grey limestone, comparatively unaltered, dolomitic; containing too large an amount of chert to be promising. The limestone farther east of Bealach a' Ghlinne is mainly dolomitic, or marble with an appreciable magnesian content.

(b) Marble Quarry 800 *yds. S.* 40° *E. of Cill Chriosd (Kilchrist) church (Kennedy,* 1941, *loc. b).* (71. 46 S.E.)

White crystalline limestone. Two openings, one east and the other west of the metalled tramway from near Suardal. Taken together they would make a face at least 30 ft. high. The marble contains brucite in places, but there appears to be also a good deal of non-magnesian material. Analysis gave the following figures (SL 248) [NG 621 201]: CaO 31.09; MgO 19.43; CO_3 37.43; Insol. Res. 6.78; Total (including minor constituents) 94.92. This total indicates only a limited degree of dedolomitization, confirmed by the petrographic description.

(c) Marble Quarry 950 *yds. S.* 12° *E. of Cill Chriosd church (Kennedy* 1941, *loc. c).* (71. 46 S.W.)

White brucite-marble. It has yellow and green serpeptine veining and some dark streaks. There are a few hundreds of tons of marble stacked in the quarry. The outcrop is near the granite contact, but there is a face 15 to 20 ft. high, which could be extended to the south-east.

(d) Marble Quarry 1,100 *yds. S.* 21° *E. of Cill Chriosd church.* (71. 46 S.E.)

Light-grey crystalline limestone. The quarry is at the head of the metalled tramway from near Suardal and is connected with *(c)* by a metalled track. This locality also is near the granite contact. There is a 30-ft. face in two lifts; and much marble, though not so white as that at the last locality, is lying about. Reserves are abundant to the east and south-east. There is only a small amount of chert in the limestone at this exposure. An analysis of material from a locality 140 yds. to 150 yds. south of the quarry (W. Pollard *in* Clough, 1907, p. 639) gave as follows: $CaCO_3$ 54.52; $MgCO_3$ 43.52; Insol. Res. 1.72.

There are several old quarries in an outcrop of marble surrounded by granite about 730 yds. W.S.W. of *(c)* (71.46 S.W.) and about ½ m. south of Loch Cill Chriosd. (Kennedy, 1941, lots. d and e). The marble here contains much brucite.

(e) S. side of Loch Cill Chriosd, on roadside 550 *yds. to* 650 *yds. S.W. of Cill Chriosd church. [NG 61388 20369]* (71. 46 S.W.)

The limestone is seen in a small quarry just west of a large composite dyke. A face could be opened up without much drift cover, and there are some beds with very little chert. in thin section the rock shows little sign of thermal metamorphism. Similar limestone, with buff veins and probably dolomitic, occupies the ground between here and the old manse a quarter of a mile south-east of the loch. There is an old and very small limekiln here. Analysis of material from the quarry (SL 249) [NG 613 203] gave as follows: $CaCO_3$ 89.84; $MgCO_3$ 0.69; Insol. Res. 8.00.

(f) S. side of road, 450 *yds. W. of S.W. end of Loch Cill Chriosd.* (71. 46 S.W.)

Nodular beds, nearly horizontal and probably in part dolomitic. The face is 15 ft. high and would increase in height if advanced southwards. Moderately large reserves are available.

Torran: Cnoc Slapin, E. of the Elgol road just beyond the school. (71. 46 N.W.) [NG 57355 21353]

Durness Limestone. Cnoc Slapin is composed of a white limestone, saccharoidal in parts and not containing much chert. The most accessible area is at the west end of the hill and at the knoll north of the sheepfold in the adjoining sheet (45 N.E.). There is a good scarp in which a face up to 30 ft. in height could be opened in limestone dipping S.W. at 45°. The area is adjacent to the Elgol–Broadford road. A representative sample taken over a width of outcrop of 35 ft. gave the following figures on analysis by the British Oxygen Co., Ltd.: $CaCO_3$ 94.3; $MgCO_3$ 2.74; SiO_2 2.85; Al_2O_3+Fe_2O_3 0.79.

Torran: Dun Mor and Dun Beag. (71. 46 S.W.)

Durness Limestone. Practically the whole of the Torran area is composed of limestone, for the most part low in magnesia. There is no drift cover and the limestone rises steeply from the shore with deep water close at hand on the west and south-west sides. The dip is W. at 45° to 60°. Faces of 30 to 50 ft. in height could easily be opened up. The limestone at Dun Mor itself is nearly all distinctly cherty, but the (?) overlying beds a quarter of a mile farther north and just west of the village show several non-cherty beds of good quality. Two samples, each representing 30 ft. of beds, gave as follows on analysis by the British Oxygen Co., Ltd.: $CaCO_3$ 89.2 and 89.4; $MgCO_3$ 6.90 and 4.60; SiO_2 4.63 and 6.06; Al_2O_3+Fe_2O_3 0.39 and 0.94.

Another area with beds mainly free from chert lies about 200 yds. north-east of Dun Mor. A section measured across these beds from east to west showed as follows:

	Width of Outcrop in ft.
Chert-free limestone (Anal. a.)	80
Cherty limestone	30
Chert-free limestone (Anal. b.)	20
Cherty limestone	90
Chert-free limestone (Anal. c.)	150

The details of analyses of these beds given below are furnished by the British Oxygen Co., Ltd.:-

a.	$CaCO_3$	91.5	$MgCO_3$	7.53	SiO_2	3.37	Al_2O_3 + Fe_2O_3	0.72
b.	$CaCO_3$	89.6	$MgCO_3$	7.38	SiO_2	4.38	Al_2O_3 + Fe_2O_3	0.50
c.	$CaCO_3$	95.5	$MgCO_3$	2.70	SiO_2	2.01	Al_2O_3 + Fe_2O_3	0.36

An outcrop just N.E. of this section showed as follows (SL 246) [NG 576 203]: $CaCO_3$ 93.01; $MgCO_3$ 2.28; Insol. Res. 2.55.

Dun Beag [NG 57527 19827], and the ridge running N.N.E. from it for a distance of over ¼ m., show similar limestone to that just described. Two analyses by the British Oxygen Co., Ltd., from the S. end of the outcrop, just N.W. of Dun Beag, gave as follows

a.	Width of outcrop	$CaCO_3$	92.0	$MgCO_3$	5.81	SiO_2	3.02	Al_2O_3 + Fe_2O_3	0.24
b.	Width of outcrop	$CaCO_3$	90.1	$MgCO_3$	6.82	SiO_2	4.08	Al_2O_3 + Fe_2O_3	0.30

A sample from Dun Beag itself (SL 247) [NG 575 198] gave: $CaCO_3$ 90.53; $MgCO_3$ 1.00; Insol. Res. 5.50.

On the shore south of Cnoc Dubh and just west of the granite [NG 57900 19886], a section of contact-altered limestone was sampled over a length of 80 ft. The analysis by the British Oxygen Co., Ltd., gave: CaO 33.8; MgO 22.2; SiO_2 1.87; $Al_2O_{3+}Fe_2O_3$ 0.52; loss on ignition 42.33; total 100.80.

Ord: various exposures. (71. 51 N.W., N.E., S.W., S.E.) References: Clough, 1907, pp. 422–424; 1910, pp. 68–69, 172.

Durness Limestone, mainly Groups II and III. The outcrop of limestone in the Ord district covers two separate areas totalling rather less than one square mile. The larger outcrop extends southwards from the islands off Rudha Dubh Ard [NG 61919 14254] to beyond Ord (Figure 23) [NG 61931 13114]. The smaller outcrop stretches south-westwards from near the coast about 1½ m. N.E. of Ord [NG 63672 13958]. The rocks are principally granular or compact dolomites with fairly abundant thin bands and lenses of chert, and are in various stages of metamorphism. The more highly altered rocks are in the condition of marble. The total thickness of the succession exposed is somewhat over 900 ft. Limestone does not seem to have been quarried at all in the district. The shore at Ord is' the only easily accessible spot. In thin section the rock from this locality is a grey, compact dolomite traversed by very thin cracks filled with cherty silica, occasionally quartz, and lined with limonite.

Analysis of a sample from the shore section (SL 252) [NG 617 131] showed: $CaCO_3$ 52.18; $MgCO_3$ 43.69; Insol. Res. 3.30.

Jurassic limestone

East coast of Skye north of Portree: various exposures. (81. 8 S.W.; 12 N.W., S.W.; 18 N.W., S.W.) Reference: Lee, 1920, pp. 56–57.

Jurassic (Great Estuarine) limestones. Thin beds of limestone are exposed at various points along the east coast of Skye north of Portree (Figure 24; 1-in. Sheet 81), the best exposures being between Inver Tote [NG 51965 60400] and Culnaknock [NG 51606 62497]. One band, at least 8 ft. thick, is seen in the Longfearn stream just south of Culnaknock. The limestones are usually shelly. None is known to have been worked.

Loch Sligachan: various exposures on the hill-slopes S. of the loch for about 1½ m. westwards from Sconser Lodge. (71. 35 S.W., S.E.) Reference: Wedd, 1910, pp. 110, 111, 173.

Jurassic (Lower Lias) Limestone. Blue, shelly, in places indurated and coarsely crystalline. The lowest beds in the series are exposed south of Sconser Lodge [NG 53120 32212] , and those higher in the sequence in the stream-courses about a mile farther west (Figure 22). The limestones are for the most part rather sandy and argillaceous. A representative sample, however, was collected from the lowest portion of the succession (equivalent to the Broadford Beds) in Allt Eas Mor, about 300 yds. up from the main road at the west end of the village. The limestone here crops out in the stream-bed for a distance of about 150 yds. Petrographically it is a dark calcite-mudstone of very fine grain, containing fragments of shells of very varying size down to embryonic forms. The analysis (SL 242) [NG 512 315] showed it to be a limestone of high grade with $CaCO_3$ 91.31; $MgCO_3$ 1.42; Insol. Res. 6.15. The Sconser area might repay further investigation.

Strollamus [NG 60373 26642]: various exposures. (71. 40 S.W.) Reference: Wedd, 1910, p. 127.

Jurassic (Great Estuarine) and Cretaceous limestones near an intrusion of granophyre (Figure 23). The Cretaceous limestone, about 15 ft. thick, crops out in Allt Eoghainn a quarter of a mile south of the old main road, and can be traced on the hill-slope for a distance of about 500 yds. Petrographically it is a dark-grey, very fine-grained, compact limestone. It is thought to be an altered chalk (*see* reference). It is of good quality but dips steeply S.E. Analysis gave as follows (SL 244) [NG 5975 2620]: $CaCO_3$ 93.33; $MgCO_3$ 0.50; Insol. Res. 5.03. Shelly limestones and shales of the Great Estuarine Series are exposed in the same stream-course from 200 yds. to 300 yds. S. of the old road, with dip S.E. at 42° to 65°. Some of the limestone beds appear to be of good quality but are rather thin. That nearest the granophyre intrusion is highly altered, the analysis (SL 243) [NG 597 263] showing CaO 40.57; MgO 0.30; CO, 11.22; Insol. Res. 40.55. This is a rock composed largely of a mosaic of calcite and calc-silicate minerals, and containing much wollastonite and some grossularite (lime-bearing garnet).

Broadford: disused quarries along the coast between the old pier and the corn mill ¼ m. farther E. at the mouth of the Allt a' Mhuillin. (71. 46 N.E.) Reference: Woodward, 1910, pp. 102, 173.

Jurassic (Lower Lias) limestone. Hard, dense-blue, fossiliferous limestone, formerly burnt locally on a small scale. There is a small kiln in rather poor repair beside the old pier [NG 64558 23487]. On the western shore of Broadford Bay other bands of limestone lying at a higher horizon in the Lower Lias are exposed between Rudh' an Eireannaich (40 S.E.) [NG 64605 24775] and the mouth of the Broadford River [NG 64146 23634]. These higher limestones are associated with calcareous sandstone and shaly beds. Some of the beds near the old kiln are of a fairly clean blue limestone, but, in general, the calcareous strata are too sandy to be of any value at present. They also lie for the most part between tide marks, and the ground on the shoreward side is too low to give reserves above high-water mark.

Broadford to Lochs Slapin and Eishort: various exposures. (71. 46 N.E., S.W., S.E.; 51 N.E.) Reference: Woodward, 1910, pp. 102, 173.

Jurassic (Lower Lias) limestones, similar to those quarried along the shore at Broadford (*see* previous locality), trend south and then south-west on either side of a syncline from the vicinity of Broadford to the shores of Loch Slapin [NG 56673 18477] and Loch Eishort. Throughout this tract the limestone outcrops form tiers of escarpments on either side of the fold. Wherever examined these limestones were found to be too sandy for utilization on a commercial scale. In the most favourably situated locality, just north of where the road from Broadford to Hest crosses Allt a Choire and about a mile south of the Broadford–Kyleakin road (46 N.E.), there are some fairly good bands of limestone, but it is doubtful if any quarrying could be done without going into very sandy beds. The dip is to the east and varies usually between 10° and 20°. Analysis of a representative sample of the best section (SL 250) [NG 645 210] showed as follows: $CaCO_3$ 89.06; $MgCO_3$ 1.40; Insol. Res. 8'33.

Strathaird: various exposures. (71. 45 N.E., S.E.; 50 N.W., N.E. S.W., S.E.) Reference: Wedd. 1910, pp. 121–127.

Jurassic (Great Estuarine) limestones. There are three calcareous horizons lying close together in the sequence. The lowest is the *Cyrena* limestone group, about 70 ft. thick, and consisting of massive blue, and often crystalline, limestone bands in calcareous sandstone. Above it lies a less massive group of calcareous beds with *Ostrea hebridica,* thickness, say, 20 ft. A short distance higher in the sequence are the *Paludina scotica* limestones, about 30 to 40 ft. thick, consisting of blue fine-grained smooth argillaceous limestones or cement-stones, weathering cream-coloured and alternating with shales and calcareous sandstones. These beds crop out continuously around the basalt-capped hills of Strathaird [NG 52614 14590] on all sides but the west. They are, however, only seen to advantage in a poorly accessible shore section below a steep slope about half a mile north of Elgol (50 S.W.). Analysis of the *Paludina* limestone in this section (SL 251) [NG 516 144] gave as follows: $CaCO_3$ 74.64; $MgCO_3$ 1.93; Insol. Res. 20.69. It is a dark-grey, compact, structureless rock composed of a carbonate-clay groundmass containing scattered grains of oxidized pyrite, quartz and dolomite. The *Cyrena* limestone is exposed in the banks of the Abhuinn Cille Mhaire at Kilmarie, 150 yds. W. of the church and 650 yds. S.W. of Strathaird House (45 S.E.) [NG 54599 17649]. The section shows as follows: limestone, 1½ ft.; shale, 1 ft.; limestone, 1½ ft.; shale, 1 ft.; limestone, over 1 ft. It is easily accessible and was formerly burnt in a nearby kiln.

Coralline Sand

Claigan: shore about 4 m. N. of Dunvegan Castle. (80. 15 N.W.) Reference: Haldane, 1939, p. 442.

Coralline or nullipore sand in three small bays near Claigan (Figure 24). The sand is coarsely granular and the fragments composing it have a marked coral-like appearance. The quantity varies somewhat from year to year depending on the incidence of storms. Camas Ban, the most southerly of the three bays [NG 22417 54417], is accessible by road. An estimated minimum of 2,500 tons is available at low tide, possibly less than 1,000 tons at high tide. The other two beaches are inaccessible by road; the minimum quantity available at low tide from the two beaches would probably amount to about 5,000 tons. The sand has been used locally for agricultural purposes. Analysis showed this sand (SL 6) [NG 2245 5445] to contain 84.32 per cent. $CaCO_3$ and 10.35 per cent. $MgCO_3$.

Raasay (Figure 22)

Hallaig [NG 59514 38273]: various exposures. (81. 31 S.W.) Reference: Lee, 1920, pp. 12–13.

Jurassic (Lower Lias) limestones. Beds of grey, brown and blue limestone, varying in thickness up to at least 10 ft., alternate with bands of shale. Many of the limestones are shelly and some are rather sandy. Exposures occur on the hill-slope below Hallaig down to the shore of the small bay west of Rudha na' Leac on the east coast of Raasay. The limestones here are not known to have been worked.

Dun Caan [NG 57899 39552]: various exposures. (81. 24 S.E.; 30 N.E., S.E.; 31 N.W., S.W.) Reference: Lee, 1920, pp. 52–56.

Jurassic (Great Estuarine) limestones. Thin beds of limestone are exposed at various places along the high ground for about 3 m. northwards from Dun Caan in Raasay. The limestones are usually shelly and rarely exceed 2 or 3 ft. in thickness. Other bands are oolitic, or compact and cement-like. The best exposures are to be seen a short way to the east of Dun Caan; about half a mile north-east of Dun Caan; and about a mile south-west of Screapadal [NG 58442 43640], There is no record of these beds having been worked.

Small Isles (Figure 24)

Eigg. (60. 71 N.W., S.W.) References: Barrow, 1908, p. 25; Harker, 1908, p. 193.

Jurassic Limestone. Jurassic strata, belonging to the Great Estuarine Series and the Oxfordian, underlie the Tertiary volcanic rocks on the east [NM 49226 89261], north [NM 48220 90697] and north-west coasts of Eigg. Thin limestones are found at several horizons, but the only thick bed is that which occurs above the Great Estuarine Sandstone. This band of limestone has a total thickness of about 20 ft. The upper part, 10 ft. thick, is fairly pure and is separated from 5 ft. of less pure sandy limestone by some 4 ft. of shale with layers of fibrous calcite. The best exposures are on the cliffs between Camas Sgiotain and Bay of Laic [NM 46870 89271].

In the Small Isles there are several places in which useful deposits of shell sand are to be found. The following are the principal localities noted: Canna: Tarbert Bay (68 per cent $CaCO_3$ in air-dried sample).

Sanday [NG 26621 04712]: A small bay at the north-west corner of the island has a beach of almost pure shell sand.

Eigg: Poll nam Partan Bay, Kildonan [NM 48820 84901].

Muck [NM 41154 80287]: Shell sand of a high degree of purity occurs in several small bays on the north coast. As the coast is low and gently sloping the sand has been blown inland to considerable distances and this is one of the causes of the fertility of the island, the greenest of all the Inner Hebrides.

Outer Hebrides (Figure 24)

The Outer Hebrides from Harris southwards are locally served for agricultural purposes by the numerous shell sand beaches of the western seaboard. Amongst these the following are worth mention, the figures in brackets being Percentages of $CaCO_3$, in air-dried samples:

1-in Sheet.	6-in Sheet.	Locality
58.	66 N.W.	Vatersay: Bagh Siar [NL 62944 94994], W. side of island.
58.	62 N.E., S.E. 63 N.W., S.W.	Barra: Traigh Uais [NF 69300 06756] and Traigh Mhor [NF 70391 05622], N. end of island, the former probably yielding the better material.

68 & 69.	57 N.W.	S. Uist: Daliburgh [NF 73026 21079], beach W. of, (30).	
68 & 69.	53 N.W.	S. Uist: S.W. of Stoneybridge [NF 73168 33122] and N.W. of Bornish [NF 72637 30533] (49 to 52).	
79.	48 N.W.	S. Uist: Iochdar [NF 74022 45222], S. of Ardivachar (68).	
79.	39 N.W., S.W.	N. Uist: Baleshare [NF 77505 61584] and Kirkibost [NF 77626 65572], off the S.W. coast of N. Uist.	
68.	33 S.E.	N. Uist: Balranald [NF 70874 69628] (48).	
89.	30 N.E., S.E.	N. Uist: Traigh Iar [NG 03929 96639], Sollas (65 to 67).	
89.	26 N.E., S.E.	: W. coast of island.	Berneray [NF 89994 82393]: W. coast of island.
89.	17 S.W.	S. Harris: Traigh an Taoibh Thuath, Northton [NF 99073 91942].	
98.	13 S.W.	S. Harris: Traigh Seilebost [NG 06151 98184] and Luskentyre [NG 06439 98921].	
98.	12 N.W., N.E. S.W., S.E.	Taransay [NB 02814 01185]: W. of S. Harris (66).	

Kincardine

Kincardineshire is poorly endowed with limestone, and future quarrying development, at any rate for agricultural purposes, is unlikely. The county lies partly within the Highlands and partly within the Midland Valley, the dividing line between the two regions being marked by the Highland Boundary Fault, which runs south-westwards from the coast near Stonehaven. The Highland division includes only one limestone of any importance, namely, the Deeside Limestone (Figure 2), which forms a considerable outcrop around Banchory. It is of poor to moderate quality. Along the Highland Boundary Fault itself, north of Stonehaven, there is a band of impure dolomitic limestone replacing serpentine. South of the fault the only limestone known is a cornstone in the Upper Old Red Sandstone, which was formerly quarried on the shore at East Mathers, 2 m. N.E. of St. Cyrus (1-in. Sheet 57) [NO 78210 66275]. It is of good quality, showing on analysis (SL 24) [NO 742 635]: $CaCO_3$ 92.34; $MgCO_3$ 0.82; Insol. Res. 4.94. It may be regarded as worked out, however.

Deeside Limestone

This limestone was formerly quarried at Hillhead of Arbeadie, north of Banchory, for roadstone, and to the south of the same town, at Woodhead and Bogforran, for burning ((Figure 2), p. 46). The opening at Woodhead may be taken as typical.

Woodhead Quarry [NO 7165 9418]: 300 yds. S. of Woodhead farm, l½ m. E.S.E. of Banchory. (66. New Series 9 N.W.)

This quarry lies in the midst of partly wooded ground. It was opened in a very massive, coarse, white, impure limestone, with albite, hornblende, zoisite and some quartz. Parts of the magnesia and lime are present, therefore, in other than carbonate form. On analysis (SL 80) [NO 7165 9418] the limestone shows: CaO 36.89; MgO 1.03; Insol. Res. 30.92;

$CaCO_2$ 62.38 (soluble in acetic acid). The thickness of the limestone is at least 15 ft., but the dip is obscure. The reserves are probably considerable, especially to S.S.W., where the ground rises slightly.

Highland Boundary Fault-rock

A dyke-like band of impure dolomitic limestone, replacing serpentine, runs along the Highland Boundary Fault north of Stonehaven (67. New Series. 16 S.W.). On analysis (SL 25) [NO 8896 8757] it shows: CaO 15.03; MgO 7.00; Fe_2O_3 5.47; SiO_2 39.61; Insol. Res. 46.61. It is best seen on the north side of Craigeven Bay, as a brecciated, grey, orange-weathering rock forming a band about 30 ft. wide. It continues north-east along the top of the cliff, then runs out to sea at Garron Point, where it is somewhat narrower. It is not seen on the south side of Craigeven Bay, or inland. There is no evidence of its ever having been worked. As the outcrop is not easy of access it is of doubtful economic interest, although in view of the composition of the rock it might be considered as a source of raw material for the manufacture of rock wool.

Kinross

The western edge of Bishop Hill lies in Kinross, and it is in this area alone that the county possesses workable limestone. Elsewhere, there are only two places in which limestone has been worked in the past to an appreciable extent, namely, at Vicar's Bridge, 1½ m. E. of Dollar (39. 24 S.E.) and at Westmuir, 2½ m. E. of Dollar (39. 25 S.W.), where there were once mines and quarries in the Castlecary Limestone (Figure 17). These occurrences, however, cannot be looked on as of value at the present day. In addition, an impure nodular cornstone is to be found in the Upper Old Red Sandstone at Vane, north-east of Benarty Hill (40. 26 S.E.)

The Bishop Hill occurrences are at a high altitude and only in one locality is there a reasonable prospect of opening out on a considerable scale, namely, at Clatteringwell Quarry on the top of the hill.

Clatteringwell Quarry [NO 18788 03731]: Bishop Hill, c. 1 m. N.E. of Kinnesswood. (40. 18 S.E.)

Charlestown Main Limestone. The limestone forms an outlier at the summit of Bishop Hill, resting on top of a quartz-dolerite sill about 250 ft. thick. The contact with the sill is not exposed. There appears to be an area of about 10 acres underlain by limestone. The exposed face shows about 15 ft. of limestone, but the base of the bed is not seen. The total thickness of the limestone is not likely to exceed 20 ft. The amount of cover varies from 5 ft. to over 20 ft., being greatest in the centre of the area. The overburden consists for the most part of baked shale, with some impure dolomitic limestone immediately overlying the main bed of workably stone. Road access is rough, but quite fair, from near Leslie to above West Feal, and the old track from that point to the quarry could probably be made up easily.

Analysis of a typical sample from the working face (SL 231) [NO 1854 0370] showed as follows: $CaCO_3$ 78.25; $MgCO_3$ (soluble in HCl) 6.92; Insol. Res. 14.24. The flaggy limestone overlying the main bed showed the following analysis (SL 102) [NO 1854 0370]: $CaCO_3$ 62.29; $MgCO_3$ 11.71; Fe_2O_3 2.69; Insol. Res. 25.60. A special examination for boron was made, as the position of the limestone relative to the quartz-dolerite sill is similar to that of the limestone at Chapel Quarry, in Fife (p. 104). No boron was found in the sample examined (SL. 232.)

The more dolomitic flaggy beds are composed of crinoid and shell fragments in a fine calcareous base, the crinoid fragments being greatly recrystallized (SL 102) [NO 1854 0370]. The main post of stone (SL 231) [NO 1854 0370] consists of a blue-grey to whitish, fine-grained, saccharoidal limestone in which the grains of calcite vary irregularly in size from 0.03 to 0.5 mm. The stone below the chert (SL 232) [NO 1854 0370] is similar, with numerous pseudomorphs in calcite after various types of fossil. The thin sections show no essential difference between the samples from near the sill and farther off.

The following section shows the character of the limestone seen in the quarry face. The flaggy limestone above the main bed is apparently impure and somewhat dolomitic. It might have to be discarded, either wholly or in part. The chert band in the middle of the face would require to be removed before crushing.

Sandstone, medium-grained, light-grey, seen in old openings between the two quarry-faces, probably in *situ*	—
Shale, baked, with ironstone nodules:	
In W. face	over 20
In E. face	*5* to 10
Limestone, flaggy, rather dolomitic, and limy fakes	4 to 5
Limestone, fairly massive, crinoidal, showing much alteration of similar type to that seen in Chapel Quarry, with white and green patches	7 to 10
Chert, dark grey, 4 to 6 in. thick	0½
Limestone, granular, recrystallized, whitish-grey in colour	over 5
Nothing seen below this, but the quarry appears to have gone a few feet deeper,	

Kirkcudbright

The county of Kirkcudbright is almost devoid of limestone. Carboniferous rocks occupy a narrow coastal strip to the west of the Nith estuary (Figure 14, p. 87), extending southward from Corbelly [NX 98400 62960], 2 m. N. of Kirkbean, to beyond [NX 92540 55980], 3 m. W. of Southerness Point (5 and 6. New Series 45 N.W., S.W.; 52 N.W.: Old Series 41 N.E., S.E.; 47 N.W., N.E., S,E.). The sedimentary strata are exposed on the Arbigland foreshore from Hogus Point, 1 m. E. of Kirkbean, to Southerness Point. They contain many bands of limestone from 6 in. to 3 ft. in thickness, interdigitated with sandstone and shale. The beds dip seaward and this fact as well as the thinness of the limestones makes their use impracticable. There is evidence of a former small quarry and kiln on the shore just above high-water mark, ■ m. W. of Southerness Point. Away from the coast, exposures of rock are poor. Some thin bands of limestone appear in a streamlet just north of Gillhead, ¾ m. S.E. of Kirkbean, and there is also evidence of a limekiln at Torrorie, 1½ m. S.W. of Kirkbean. Little is now to be seen at tip latter locality.

Shell sand is the only other calcareous material to be found in the county, and that merely at one or two places. A narrow strip of beach deposits fringes the coast for several miles south of Creetown. South of Kirkmabreck [NX 47202 56215] (4. New Series 47 N.W., S.W.; Old Series 42 S.E.) shell sand enters largely into these deposits and they have been dug on a small scale for spreading locally on the fields. Analysis of this material gave a value of 36.75 per cent. calcium carbonate. This is rather a low figure, but probably the shell-content could be improved by riddling to remove the mineral grains. Although the deposit is not thick it is of fair extent, and an appreciable amount of material is probably obtainable.

In Skyre Burn Bay [NX 57418 54299], an inlet of Fleet Bay, 2½ m. S.W. of Gatehouse of Fleet (4. New Series 48 S.W.; Old Series 43 S.E.), the sand just above high-water mark contains abundant shell fragments. The shell sand is not uniformly distributed but is concentrated in bands parallel to the shore and in the shelter of rocks.

Lanark

A century ago limestone was being wrought at close upon 50 localities in Lanarkshire. To-day there is not a single undertaking in production. The cause of this complete collapse was not lack of limestone but the familiar economic one, namely, the exhaustion of the readily available supplies and the increasing costs of production as mining had to be resorted to in place of quarrying.

The workable limestone deposits are contained in the Carboniferous formation; and as this formation has its widest development in the north-central part of the county most of the limestone workings were located here, along the outcrop of the Carboniferous Limestone Series (Figure 25). In all localities the most widely worked seam was the Hurlet or Main Limestone (Figure 26). A lower seam, the Big Limestone, was wrought near Coalburn. Other worked seams were the Hosie group (Calderwood Cement, Anvil, Hairmyres), Index and Calmy limestones. The outcrop of the Carboniferous Limestone Series forms a wide belt round the main industrial area, extending from north and west of Glasgow south-eastward through East Kilbride and Stonehouse almost to Lesmahagow, and thence north-eastward by

Auchenheath, Crossford and Carluke to Wilsontown and Haywood on the eastern march.

In the central portion of the county, roughly, south of a line joining Strathaven, Lesmahagow, Lanark and Carnwath and north of one through Symington, Roberton and Crawfordjohn, the geology is much more varied than farther north. The most widespread visible formation in the northern part of this area is the Old Red Sandstone. It contains a few thin limestone deposits (comstones), and the only attempt at working them appears to have been made on the River Clyde above Hyndford Bridge.

No limestones are present in the Silurian rocks that form the hill country south-west of Lesmahagow.

Central Lanarkshire also includes the considerable Carboniferous area constituting the Douglas Coalfield, and, as farther north, limestones are present here surrounding and underlying the main coal deposits. Limestone workings were extensive at Auchmeddan and other places south of Lesmahagow, Coalburn and Bankend. Limestone was also wrought at three small isolated Carboniferous outliers, viz., Limefield, Wildshaw and Drumclog.

Finally, in the high-lying pastoral and moorland country south of Biggar, Roberton and Crawfordjohn, Silurian and Ordovician rocks prevail. These contain no limestones. Within the area is one small tract of Carboniferous rocks, exposed in the Duneaton Water south-west of Crawfordjohn, and here, near Whitecleugh, there was a limestone working.

Robroyston to Bedlay:

Robroyston [NS 63101 68785]: 4 m. N.N.E. of Glasgow. (31. 1 S.E.; 6 N.E.)

The Calmy or Robroyston Limestone was worked in quarries at Robroyston, Hillhead, Barmulloch, etc., and in shallow pits at Low Balornock. It was a hard, compact, bluish to dark-grey rock, often with an ochreous weathering, wrought chiefly for blast furnace use. The thickness of the seam varied between 4½ and 9 ft., the average being 5½ ft. It was in two nearly equal posts separated by 9 to 12 in. of limy shale. The dip at Robroyston was N.N.E. at 5° to 10°. Reserves probably exist to the east but would require to be mined.

Garnkirk [NS 67737 68963], Chryston [NS 68964 69984] and Bedlay [NS 69627 70064]: 4 m. N.W. of Coatbridge. (31 2 S.W., S.E.; 7 N.W.)

The Calmy or Garnkirk Limestone was wrought mainly to supply the ironworks at Coatbridge. At Chryston there were quarries in an outcrop of the Calmy Limestone and it was also raised from shallow pits to the east of the village at Avenuehead (2 S.E.). The thickness varied from 4½ to 7 ft., the seam being in two leaves with a 12-in. parting. About 1¾ m. E.N.E. of Chryston the limestone was also wrought in pits at Leckethill and Annathill in the Bedlay field, a section of the seam showing: limestone, 1½ ft.; on shale, 15 to 18 in.; on limestone, 2½ ft.

Between Chryston and Garnkirk (2 S.W.; 7 N.W.), again, there were pits, up to 28 fms. in depth, to the Calmy Limestone at Woodhead, etc. An old record of the seam here shows: limestone, 2 to 2½ ft.; on shale, 1 ft.; on limestone, 3 ft.

East Kilbride to Quarter:

Thorntonhall Lime Works [NS 59465 54774]: 3 m. W. of East Kilbride. (22. 16 N.E.)

The Main (Hurlet) Limestone was extensively wrought here in quarries and mines, and part of the product was burnt. Work appears to have ceased about 1926. The seam is 10 to 12 ft. thick and lies almost flat. There were extensive opencast and underground workings. Two of the old mine-mouths just north of Thornton are still readily accessible and lead into a series of large, fairly dry, underground chambers. The overburden is partly of rock, partly of boulder clay. The old kilns and loading bank are adjacent. Access was by tramway to the railway south of Thorntonhall station. Reserves are large, but overburden is now heavy along the quarry faces.

The quality of the Thorntonhall limestone (SL 222) [NS 5953 5480] is high, the analysis showing: $CaCO_3$ 92.59; $MgCO_3$ 1.28; Insol. Res. 3.97.

Hairtnyres Quarry [NS 60686 54352]: Hairmyres station, 1■ m. W. of East Kilbride. (22. 16 N.E.)

The Hairmyres Limestone, formed by the coalescence of the two lowest members of the Hosie group, the Middle and Under seams, has a thickness of about 10 ft. The strata dip S. at a low angle under an overburden 15 ft. thick. This is a convenient and accessible locality with large reserves of stone, but the overburden is heavy and mining would have to be undertaken.

The Hairmyres lime was considered of special value as a hydraulic cement.

Newhouse and North Allerton: 1½ m. S.S.W. of Hairmyres station. (22. 16 S.E.)

The outcrop of the Main Limestone here, bounded to north and south by faults, extends from the Gill Burn [NS 58890 53329], near Jackton village, southwards past Newhouse [NS 59602 52450] and South Craighall to North Allerton [NS 59675 51730], a distance of about three quarters of a mile. The top of the limestone is exposed in the Gill Burn, and 8 ft. of rock under 20 ft. of boulder clay can still be seen in the long-abandoned quarry south of Newhouse. The overburden is now heavy at the quarry, but may be thinner elsewhere along the outcrop.

The Hosie limestones come to the surface to the east of Newhouse, and there are traces of at least three small quarries opened out in the Calderwood Cement (Top Hosie) Limestone near Newlands farm.

Crosshouse: 1½ m. S. of Hairmyres station. (22. 16 S.E.) [NS 60665 51890

The Main Limestone is exposed in an old quarry 300 yds. N.W. of Crosshouse farm. The bed here is 12 ft. thick and dips N. at a low angle. The overburden is slight and reserves should be considerable.

The quality of the limestone (SL 223) [NS 6066 5190] at this quarry did not on analysis prove to be so high as at Thorntonhall. The results were $CaCO_3$ 87.41; MgCO, 1.74; Insol. Res. 8.62.

The outcrop extends eastwards for over half a mile and the overburden along most of it is probably not unduly thick. There is also an old quarry in the limestone to the north-east of Crosshouse.

Limekilns [NS 62802 55135] and Murrayhill: W. of East Kilbride. (23. 16 N.E.)

There are abandoned quarries along the sinuous outcrop of the Hosie group of limestones extending from Stewartfield [NS 62881 55602] to Murrayhill [NS 62266 54189]. These are now largely overgrown, and because of the thinness of the beds are not likely to be worked again.

There is a good section of the Main Limestone and strata associated with this horizon in the Kittoch Water, south of Arrotshole [NS 61934 55294] and half a mile or so W.N.W. of Limekilns, but the Main Limestone itself has been quarried out.

Maxwelltown to Auchentibber: E. of East Kilbride. (23. 17 N.W.)

The Hosie group of limestones here comprises, in upward succession, the Under Limestone (3 to 4 ft.), the Middle Limestone (2 ft.), the Anvil Limestone (1½ ft.), and the Calderwood Cement or Top Hosie Limestone (9 to 12 in.), all included within 20 to 30 ft. of strata. They are well exposed in the gorge of the Rotten Calder (Calderwood Glen), on the west bank of the river, 430 yds. S.S.W. of Calderwood Castle [NS 66029 54870] and about 1½ m. E. of East Kilbride. They were at one time worked on a considerable scale in the neighbourhood, mainly for fluxing purposes, the more important localities being two in number.

1. S. of Brankumhall [NS 65527 55117], to the west of the Calderwood Glen exposure. Here there were formerly a number of quarries, but nothing is to be seen now except at one point, 500 yds. S.W. of the farm, where the Cement (12 in.) and Anvil (13 in.) limestones are still visible. Half a mile to N.N.W. the Cement Limestone was wrought in old mines west of Long Calderwood.

2. W. and S. of Auchentibber [NS 66811 55100], [NS 67657 54536]. Here there are a number of old quarries, mines and shafts in the Middle and Under limestones, as well as remains of the kilns in which the stone was calcined. The beds are flat or nearly so. The workings stop north of Newfield, but beyond this there are old shafts in which the Cement Limestone was wrought on a small scale. Localities listed in the Mines Department " Catalogue of Plans of Abandoned Mines, Vol. V " (1931) are: Auchentibber and Crossbasket, Dikehead, Greenblairs, and Newfield.

Shieldburn to Langlands: 2½ m. S.S.W. and S. of East Kilbride. (23. 16 S.E.; 17 S.W.)

The outcrop of the Main Limestone described under Crosshouse (p. 133) terminates against a fault 600 yds. W. of Crosshouse farm and reappears a little farther south between Shiells and Shieldburn. It then continues in a general easterly direction past Benthall to Langlands. There are traces of six quarries along this outcrop, three between Shieldburn [NS 61550 50900] and Benthall [NS 62113 50758], and three between Benthall and Langlands [NS 63321 50878]. Very little rock is now to be seen, but as the overburden appears to be slight or absent the area offers opportunities for fresh development. The limestone is recorded as about 12 ft. thick in a boring a little east of Langlands. Access to main roads is good.

Rig to West Drumloch: 3 to 3½ m. S.E. of East Kilbride. (23. 17 S.W.)

There are abandoned quarries in the Main Limestone east of Rig farm [NS 65956 50494], and, farther east [NS 66135 50525], south-west of Quarry farm [NS 66585 50491] and south of West Drumloch farm [NS 67306 50307]. Exposures are now grassed over, but there is a general northerly dip of the strata, probably at low angles. The overburden is not likely to exceed 12 ft. Access is convenient by road.

Earnockmuir to Quarter: 2 m. S.S.W. and S. of Hamilton. (23. 17 S.E., S.W.)

The four Hosie Limestones (*see* Limekiln and Murrayhill) were worked at a number of localities in the vicinity of Wakenwee [NS 68319 51114], Craigendhill [NS 68997 51298] and Boghead [NS 69395 50502] but the openings are now almost entirely obscured. The seams were thin.

The Calmy Limestone was worked at Limekilnburn [NS 70665 50683] and Crookedstone. It was only 4½ ft. thick at Limekilnburn and overburden probably becomes heavy to the dip. Partial sections of the limestone can be seen at one or two points in the stream below the hamlet.

The Crookedstone workings were fairly extensive in shallow quarries on both sides of a small stream 600 yds. S.W. of Crookedstone [NS 71959 49454]. The strata here lie in a gently undulating shallow basin. The best section available is on the right bank of the stream itself, where the basal 2 ft. of the limestone and the underlying beds can be examined.

There were also workings in the Calmy Limestone on the River Avon, south-east of Patrickholm [NS 75674 49867], l¼ m. S.W. of Larkhall (18 S.W.). The bed here was also thin (only 3 to 3½ ft. in two or three plies) and siliceous in character, and on this account it has not attracted attention in recent years.

Strathaven to Carluke

Strathaven to Stonehouse. (23. 23 S.E.; 24 S.W.)

1. River Avon, 400 yds. S. of Waukmill (23 S.E.) [NS 71978 44551]. The Main Limestone crops out in the river, 4½ ft. being seen. There are old workings here and along the Fairy Burn, half a mile farther east. [NS 72580 44465].
2. River Avon, north bank between Glassford Bridge [NS 73256 45508] and Cot Castle (24 S.W.) [NS 73899 45615]. There is an old mine here, as well as quarries along the opposite bank. The thickness of the limestone is 4 to 5 ft. at the mine, but borings in the neighbourhood record figures up to nearly 10 ft.

Lower down the Avon, about 500 yds. N.E. of Avonholm House (24 N.W.) [NS 74210 46842], the Main Limestone again appears, forming an islet in the river.

District S. and S.W. of Blackwood. (23. 31 N.E., N.W.)

The Main Limestone was mined on the left bank of the Teiglum Burn, west of Kerse [NS 80841 41858], and mined and quarried on the banks of the Birkwood Burn, 300 yds. below Kypehall Bridge [NS 79639 41770]. The thickness of the worked portion was 7 to 7½ ft.

Farther west a series of abandoned quarries marks the long outcrop of the seam round this part of the southern edge of the Central Coalfield. There are small grassed-over quarries south-east of Boghead [NS 77780 41632], and at Dykehead [NS 77122 41713], Kellylees [NS 76458 42044] and Couplaw farms [NS 75762 42908], all localities approximately 1½ to 2 m. S.S.W. or S.W. of Blackwood village, The dip is N. or N.E.

There are probably considerable reserves of limestone in this neighbourhood available to mining.

Netherton Lime Works [NS 81152 43076]: ½ m. S.E. of Auchenheath Station. (23. 24 S.E.; 31 N.E.)

The Main Limestone was most recently wrought (up to 1923) from a pit, 24 fms. in depth, situated 180 yds. S.W. of Nether Auchtygemmel and was burnt on the spot for building and agricultural purposes. The thickness of the seam in the shaft was 9 ft. The limestone lies in a shallow basin here, and has a general northerly dip. A series of old mines marks the course of the outcrop along the side of the R. Nethan north-westwards to where it crosses the river south-west of Auchenheath station.

The Foul Hosie Limestone, 5 ft. 3 in. thick, was also wrought to some small extent from Netherton Pit under the name of 'Upper Limestone'. It lies 9 fms. above the Main seam.

Auchenheath Quarry: ½ m. N. of Auchenheath [NS 80324 44430]. (23. 24 S.E.)

The Gair (Calmy) Limestone was worked here. The quarry face shows: dark shale; Gair Limestone, 3 to 3½ ft., in two posts separated by 2 in. of shale; coaly shale and fireclay, 15 in.; ganister, 3 ft. (worked); fireclay, 1 ft.; white siliceous sandstone, 6 ft. (worked); freestone, 30 to 35 ft. (worked). The upper part of the limestone is argillaceous, the lower harder and purer. The overburden is heavy.

An analysis, communicated by Messrs. Colvilles, Ltd., Motherwell, shows the sione to be a ferro-dolomite of considerable purity; as such it may have uses despite its thinness. The analytical figures are as follows: $CaCO_3$ 50.36; $MgCO_3$ 32.63; $FeCO_3$ 16.42; SiO_2 3.60.

Braidwood to Carluke. (23. 19 S.W.; 24 N.E.; 25 N.W., N.E.)

This district was for long an important centre for the production of limestone, mainly for agricultural and fluxing purposes; and there are many abandoned quarries, mines and kilns. The limestones wrought include the Main, Foul Hosie, Birkfield, and Kingshaw seams in the Lower Limestone Group. The Main Limestone, was considered the best in the district. It is typically a hard, dark-grey, very compact, encrinital stone, varying in thickness from 4 to 7 ft., with a few inches of reddish-weathering shaly limestone on top. The outcrops, however, have been practically exhausted and further developments would in general have to be by mining under increasing cover. It may be noted that a foot or two below the Main Limestone there is a coal of variable but often workable thickness. The Mines Department "Catalogue of Plans of Abandoned Mines, Vol.V" (1931) lists the following: Main Limestone at Shieldhill, Mayfield, Langshaw, Wilton, Kingshaw, Nellfield, Harestanes and Waygateshaw; Birkfield Limestone at Shieldhill and Waygate,shaw: and 2nd Kingshaw or Wee Limestone at Hallcraig and Kingshaw.

The following percentage figures of calcium carbonate content indicate the quality of the chief seams in the district (Rankin, 1843): Main Limestone, 92 to 96; Foul Hosie, 80 to 92; Birkfield, 70 to 80; Top Hosie, 70 to 80;. Gair, 80 to 86.

At Crossford (24 N.E.) [NS 82819 46545], 3 m. S.W. of Carluke, the Main Limestone had a thickness of only 4 to 4½ ft. There were mines here, and a shaft 8 fms. deep.

At Oldhill [NS 83668 48752], Braidwood [NS 84383 48099], Nellfield [NS 85201 48362] and Leemuir [NS 87120 48801] (25 N.W.) the Main Limestone was quarried. It had a thickness of 6 ft. at Nellfield; little can now be seen except some of the overlying beds at a few localities. The outcrop, somewhat folded and faulted, extended from Braidwood to 2½ m. beyond Leemuir. There were also shafts to the limestone at Oldhill and Langshaw.

At Birkfield, 1 m. S.E. of Carluke (19 S.W.) [NS 86315 49575], the principal working was in the Birkfield seam, of which a section reads: shelly limestone, 8–12 in.; hard leaden-grey limestone, 2½ ft.; calcareous shale, 6 in.; hard limestone made up mainly of encrinite fragments, 1 ft. The encrinital bed at the base was in some demand as an ornamental stone, and was known as the " Braidwood Marble."

In the quarries and mines at Craigenhill [NS 87857 47444] (25 N.E.), ½ m. S.W. of Kilncadzow, the thickness of the Main Limestone was 7 ft. 8 in. (top 20 in. ferruginous). At Fulwood it was 7 ft. thick. The outcrop here forms the southern margin of a basin of Lower Limestone Group strata which extends north to Kilncadzow, where it is truncated by the Kilncadzow Fault. In the centre of this basin, near Bishopbent, the Birkfield Limestone was formerly quarried.

Carluke to Wilsontown:

North-east of Carluke. (23. 19 N.W., N.E., S.W.)

At Hillhead [NS 86104 50963], Mosside [NS 86371 51123] and Thorn [NS 87083 51541] (19 S.W.), N.E. of Carluke, the thickness of the Main Limestone was 4 ft., of the Foul Hosie 3½ ft., and of the Hosie Limestones (Birkfield, 2 nd Kingshaw and 1st Kingshaw) 2 to 2½ ft.

Still farther north-east there were quarries at Thornmuir [NS 88144 52618] and Birniehall [NS 90836 52890] (19 N.W., N.E., S.W.). The outcrop at Thornmuir extends from a point 400 yds. N. of Thorn in a north-easterly direction for about a mile before being cut off by the Wilsontown–Carluke Fault, and is marked by a line of abandoned quarries south-west, west and north of Thornmuir. The thickness was 6 ft. and the dip N.N.W. at low angles. The quarry faces are already restricted by increasing overburden.

The limestone reappears half a mile or so farther east, in a narrow elongated basin truncated on the north by the same dislocation. There are old quarries here at Birniehall, but the sections are now obscured. An old record gives 4 ft. 3 in. of limestone at this locality, underlain almost directly by 3 ft. 4 in. of coal. Recent borings indicate a thickness for the Main Limestone of 3 ft. 1 in. to 5 ft. 9 in. The dip is in a general northerly direction.

Wilsontown, Haywood and Braehead. (23. 14 S.W.; 20 N.W., N.E., S.W., S.E.)

Outcrop workings in the Main Limestone can be traced in a half-circle round Braehead village from Browshot [NS 94272 51044] in the west to Kilpothall a mile to the east. The limestone was burnt locally, mainly for agricultural purposes, in kilns fired by the underlying coal. Most of the quarries are grassed over. The thickness was 3½ to 6 ft. A recent temporary exposure made at Kilpothall showed: shale roof, 15 ft.; Main Limestone, 3 ft. 7 in.; shale, 1 ft. 9 in.; coal, 2 ft. 11 in. The possibilities of opencast workings are now few, but there is certainly a considerable area of the limestone and coal at a comparatively shallow depth round Braehead and north of it.

A seam, probably the Foul Hosie Limestone, was worked on a small scale at Backbrae [NS 95224 51022], a little north of Braehead village (20 S.W.), and again at Croftliead (20 S.E.), ■ m. N.E. of Kilpothall [NS 96772 50909]. Attempts have also been made to work one of the Hosie Limestones (probably the Birkfield) at Hillhead [NS 96339 52552] and Rowantreehill [NS 95915 52419] (20 N.W.).

The Top Hosie Limestone was formerly quarried on the banks of the Dippool Water, a little north of Pool Farm [NS 98647 53898], about ¾ m. S.E. of Haywood (20 N.E.). Four feet of argillaceous limestone can still be seen. There are also grassed-over openings in one or other of the higher Hosie seams in the Wormlaw Burn [NS 97727 56819], near Mountainblaw, and an old quarry and kilns a little north of Upper Haywood farm [NS 96865 55659] (14 S.W.),

The Index Limestone (4 ft. 10 in.) was quarried for the former Wilsontown Iron Works [NS 95058 55050] along a considerable length of outcrop a little north-west of Forth village on the west side of the Wilsontown basin.

Central and South Lanark: Lesmahagow, Douglas, etc.:

River Clyde, south of Hyndford Mills [NS 92881 41910]: 4 m. E.S.E. of Lanark. (23. 33 N.W.)

A few bands of nodular cornstone crop out in the river. They are of no great thickness, but a mine was driven into one of the bands, 600 yds. N.E. of Millhill. There appear to be only about 3 ft. of workable rock here, and it dips towards the Clyde under a sandstone roof. There are also abandoned mines on the north side of the highway beyond Glentisset, 1 m. E. of Millhill. Another attempt at working the cornstone had been made south of the highway and half a mile farther east. Little can now be seen at these localities. The cornstone was not a thick band.

Auchren Lime Works [NS 82727 38499]: 1¼ m. S.E. of Lesmahagow. (23. 32 S.W.)

The Wee and Big limestones were formerly worked here by pits. No. 1 Pit shows the Wee Limestone, 5 ft. thick, at the surface, where it was quarried to some extent, with the base of the Big Limestone, 11½ ft. thick, 8½ fms. lower. In No. 2 Pit, separated from No. 1 by a fault, the depth to the Wee Limestone was 10 fms. The workings terminated to north and south against faults.

Auldton Lime Works [NS 82207 38277]: 1¼ m. S.S.E. of Lesmahagow. (23. 31 S.E.)

The Wee and Big Limestones were here worked from shafts. In No. 1 Pit the Wee Limestone, 5 ft. 4 in. thick, occurred at 9 fms., and the Big Limestone, 10 ft. thick, at 16½ fms. In No. 2 Pit, separated from No. 1 by a fault, the corresponding depths were 26 and 32 fms. respectively. There is good access to road and railway. The lime was used for plaster-work, etc. Half a mile to the south-west there are old workings in the Main Limestone at Hill farm.

Auchmeddan [NS 84316 39472]: 1½ m. E. of Lesmahagow. (23. 32 S.W.)

The Wee Limestone was at one time quarried at this locality. The workings are now grassed over and little or no rock can be seen.

Coalburn [NS 81162 34795] to Bankend [NS 79991 33574]: 3 m. S. of Lesmahagow. (23. 37 N.E.)

The Index Limestone was worked here. There are abandoned quarries at Shodrigg and Auchenbegg to the west of Coalburn, and quarries and mines at the Poneil Lime Works at Braehead. The section of the worked seam in the Poneil mines [NS 81227 34636] (abandoned 1914) shows: shale roof; limestone, 5 ft. 9 in.; fireclay pavement.

There was also a quarry in the Index Limestone on the south bank of the Poneil Water at the mouth of the Longhill Burn [NS 82211 33339], 1■ m. E. of Bankend, as well as opencast workings at Bankend itself.

Bankend Lime Works [NS 79504 32955]: Poneil Water, ½ m. S.W. of Bankend. (23. 37 S.E.)

The Main Limestone was wrought by mines and quarries until 1934. The seam is not completely seen now, but partial exposures give an estimated total thickness of about 30 ft. It is a dark buff or grey-blue limestone, the upper part being in massive posts and the lower part in more flaggy beds with partings of calcareous shale. The strata dip N. or N.N.E. at 25° to 30°. Access is by mineral tramway. There are large reserves but these are now practically only accessible by mining.

On the opposite bank of the stream about 35 ft. of the limestone are seen in a cliff face. Here the rock could be quarried to a considerable extent before the cover became unduly heavy.

An analysis of the rock (SL 174) [NS 8014 3302] at the abandoned quarry showed: $CaCO_3$ 87.61; $MgCO_3$ 3.28; Insol. Res. 7.49.

Ponfeigh: Douglas Water valley. (23. 38 N.E.)

The Main Limestone was worked here at one time but the quarries are now overgrown. In the Ponfeigh Burn below Muirfoot [NS 88194 35427] 12 ft. of the limestone may be seen below a cover of 20 ft. of rock. Only by mining would further working be feasible.

In the Douglas district the Calmy Limestone, usually here called the Gill Limestone, has a wide extent, but its outcrop is very generally concealed by surface deposits. One of its few outcrops is in the Craig Burn, 1½ m. S. of Ponfeigh, and 200 yds. E. of the highway at Craigburn cottage [NS 86648 34016]. It shows here a thickness of about 24 ft. A partial analysis of this rock, published by courtesy of the Coltness Iron Company, proves it to be of rather poor quality, however, with 73 per cent. of calcium carbonate and 16 per cent of silica.

Kennox [NS 79649 26935] and Glentaggart [NS 81202 25230]: 4 m. S.S.W. of Douglas. (15. 41 N.E., S.E.)

This rather remote area is occupied in part by strata of the Carboniferous Limestone Series. Limestone seams crop out at various points, especially in the upper reaches of the Carmacoup Burn [NS 77070 26103], Kennox Water and Glentaggart Burn. Quarrying on a small scale was at one time carried on in the vicinity of Glentaggart.

Limefield: 2 m. W. of Wiston. (23. 39 S.W.)

There are abandoned quarries here in a small outlier of Lower Carboniferous rocks resting on Lower Old Red Sandstone. The sections are now very much overgrown, and only 9 ft. of limestone with base hidden are visible. There are probably considerable reserves, but because of the heavy overburden they would be available only by mining.

Wildshaw Lime Works [NS 87603 28305]: Wedder Law, 3 m. E.S.E. of Douglas. (23. 42 N.E.)

This is another small isolated tract of Carboniferous similar to that at Limefield. The principal workings were in the Main Limestone. The old quarries show: limestone, nodular, at least 4 ft.; shale, 3½ ft.; limestone, 2 ft.; strata, 12 ft. 4 in.; Main Limestone, 10 ft., with 3 in. reddish nodular stone atop.

The reserves here are not very extensive. The situation is over 1,000 ft. above O.D.

Drumclog [NS 63269 39540]: 5½ m. S.W. of Strathaven. (23. 29 S.E.; 30 S.W.)

The thickness of the Main Limestone in this outlier was up to 16 ft., of which the lower 7½ ft. were of good quality and were worked. A small basin of the limestone, bounded to north and south by faults, extends from Westerburn to near Hairshawhill. There are several abandoned quarries but little or nothing is now seen. Reserves are considerable; some of the old pits to the overlying coals might be deepened to the limestone. Access by road is good; and the locality lies ■ m. from the railway.

Another outcrop occurs a mile or so to the east, just north of Snabe Bridge on the Strathaven–Galston road [NS 63953 39172], where again there are old quarries; the limestone totals 18 ft. in thickness and is overlain by 15 ft. or so of blue shale. The seam is also seen in a stream-section ■ m. N.E. of Snabe Bridge, near West Ryelandside [NS 65232 39936].

Whitecleugh Lime Works [NS 82633 20679]: 4 m. S.W. of Crawfordjohn. (15. 46 N.W., S.W.)

This is an abandoned working in the Main Limestone. In the quarry 21 ft. of limestone are now visible, overlain by 12 ft. of other strata and some boulder clay. There is also the trace of an adit. The strata dip N.W. at 10°. It is a high-lying site, 1,000 ft. above O.D., and is 1 m. from the main road. The outcrop is a small one, extending at most over 700 yds., and it is doubtful if further quarrying is an economic proposition. A good deal of stone could be made available by mining.

Midlothian

The limestone resources of Midlothian are almost wholly contained in the two lowest subdivisions of the Scottish Carboniferous formation, the Calciferous Sandstone Series and the Carboniferous Limestone Series(Figure 27) and ((Figure 41), pp. 140 and 193). Apart from these, limestone (cornstone) is developed in a small way in the Upper Old Red

Sandstone at one locality near East Calder.

The Carboniferous strata are disposed regionally in two distinct areas, situated in the east and west of the county and separated by the range of the Pentland Hills. In the western area (Figure 41) the Calciferous Sandstone Series predominates, the higher Carboniferous Limestone Series appearing only west of Cobbinshaw and Addiewell. One thick limestone seam, the Burdiehouse Limestone, is present in the lower series and at the present day is wrought at Harburn. Formerly there were also workings near Mid Calder. Of the limestones of the Carboniferous Limestone Series, the Main or Hurlet seam was worked along a line of shallow pits and mines, often in conjunction with an underlying coal seam, between Cobbinshaw and Addiewell; whilst the Castlecary or Levenseat Limestone was quarried and mined at Levenseat. No work is now going on at these localities.

East of the Pentland Hills is the important Midlothian Coalfield where the limestone-bearing Lower Carboniferous rocks surround and pass beneath the higher Coal Measures. The outcrops of the limestone seams (Figure 27) have been traced from the shore of the Forth near Portobello south-westward through Gilmerton, and thence by Penicuik to Carlops, where they pass into Peeblesshire. They appear again at Mount Lothian and continue by Side, Esperston, Middleton and Crichton to the county boundary east of Pathhead. There are also outcrops at D'Arcy and Cousland. The succession of these limestones is illustrated in (Figure 28).

The active limestone undertakings are located at Straiton, Upper Side, Esperston. and Middleton. In the past there were also extensive workings at Gilmerton, Burdiehouse, D'Arcy and numerous other places. The important seams are the Burdiehouse Limestone in the Calciferous Sandstone Series and the Gilmerton (No. 1) Limestone, North Greens (No. 2) Limestone and Bilston Burn (No. 3) Limestone in the Carboniferous Limestone Series. The Burdiehouse Limestone is being worked at Straiton. The Gilmerton Limestone was formerly worked extensively at Gilmerton, but is not now wrought at any locality. The North Greens Limestone is the seam most extensively exploited, there being workings at Middleton, Esperston and Upper Side. The Bilston Burn Limestone is quarried at Esperston.

Old Red Sandstone and Calciferous Sandstone Series

Selms Quarry [NT 08452 66067]: 1¼ m. S. of East Calder. (32. 5 S.E.)

A seam of cornstone in the Upper Old Red Sandstone was formerly worked here (Figure 41). The thickness of the worked face was 11 ft., consisting of good cornstone, 3 ft.; over sandy cornstone, 3 ft.; over good cornstone, 5 ft. The beds dip S.S.E. at 20°. Overburden is very slight. Access is by farm-road closely adjacent to the railway. The analytical data (SL 180) [NT 0842 6608] are as follows: $CaCO_3$ 70.18; $MgCO_3$ 1.64; Insol. Res. 28.50. The high residue is doubtless accounted for by the sandy central portion. The upper and lower parts are of a higher standard of purity and would yield a good lime. It is doubtful, however, if much good rock could now be won here.

Linhouse Water [NT 07634 64889]: 2 m. S. of Mid Calder: cementstones in stream 120 yds. N. of railway viaduct. (32. 5 S.E.)

An excellent section of strata comprises thin ribs (up to 6 in.) of cementstone alternating with beds of marl and shale 1 to 12 ft. thick. The cementstone is a fine-grained homogeneous rock of dolomitic composition, the analytical figures (SL 181) [NT 0758 6486] being $CaCO_3$ 48.95; $MgCO_3$ 25.62; $FeCO_3$ 4.42; Insol. Res. 19.76.

Burdiehouse Limestone:

The outcrops of the Burdiehouse Limestone in the west part of Midlothian and the adjoining area of West Lothian are shown in (Figure 41). It is apparent from this figure that the trend of the main outcrop is north and south, but faulting has caused much displacement and even repetition of the seam. Further, flexuring of the strata has brought the limestone to the surface at a number of other localities, as at Pumpherston, Kirkliston and in the Hopetoun-Queensferry area.

In the extreme south-west of the county, east of Cobbinshaw, faulting takes the limestone to depth and the outcrop commences about a mile south of the present working mine of Harburn. From this point it has been traced northwards with the aid of borings and old workings to a point east of the farm of Kiprig, north-west of the railway. The thickness of

the limestone varies between 22 and 34 ft. Natural exposures are non-existent, but the top of the limestone may still be seen under 20 ft. of sandstone and fakes in the abandoned Torphin Quarry [NT 02892 59956].

About half a mile north-east of this quarry [NT 03262 60482], on the same side of the railway, the top of a limestone is seen, again under sandstone beds, in a disused small quarry, in a succession of strata closely resembling that of Torphin Quarry. This limestone has been mapped as the Burdiehouse Limestone in an outcrop detached by faulting from the main band. The extent of the detached mass is believed to be small.

At Kiprig [NT 02069 60205] the main outcrop is broken by a fault and displaced north-eastward 1½ m. to the vicinity of Muirhouse, north-west of Harburn station. With many minor displacements the outcrop continues northwards and eastwards until stopped by a fault-line east of Alderstone, south of Livingston. In this area, too, are four detached outliers of the limestone, in the neighbourhood of New Park station, Bellsquarry and Blackmire. These detached masses have been largely quarried and little is now left of them. The limestone is exposed in the railway cutting at Blackmire with a thickness of 40 ft.

East of Alderstone [NT 04401 66308] faulting terminates the outcrop, and the limestone does not reappear until east of East Calder. It has a thickness of 24 ft. where it is visible in the bed of the Almond beside the railway viaduct north of East Calder. As at Harburn a thin rib of coal is present in the limestone about 10 ft. from the top of the bed. There are now no workings in this vicinity, but formerly outlying masses of the limestone at Camps and Raw Camps [NT 10200 68244] east of East Calder were extensively quarried and mined.

From the Almond section the outcrop of the limestone continues slightly east of north to Kilpunt [NT 09812 71845], east of Broxburn. Here it is terminated by a fault and displaced nearly 4 m. eastward, almost to Gogar, south of Turnhouse station. Between the Almond and Kilpunt the dip of the strata is westerly, but within a mile this direction is reversed and the limestone is brought to the surface in the anticline of Pumpherston.

As the cross-section in (Figure 43) (p. 195) shows, the dip of the bed is steep (about 45°) on the sides of the Pumpherston anticline, and the limestone plunges to depths of between 500 and 600 ft. before flattening out and gently rising again.

The limestone has frequently been proved in bores in this district, but is not exposed in any natural section. In a deep boring near Drumshoreland station it was 22 ft. thick, cream-coloured, and with strings of chert near the base as in the river at East Calder. Near Clapperton Hall [NT 08653 69323] its true thickness is estimated to be 48 ft., which is more than in any other part of the Lothians. The stone is less massive on the west side of the Pumpherston arch and has an average thickness of 15 ft. (Carruthers, 1912, p. 46).

In the vicinity of Kirkliston [NT 12709 74367] the recorded thicknesses of the Burdiehouse Limestone are much less than those farther south. In a mine section in the Ingliston Pit [NT 15080 74370] the limestone was only 5 ft. thick. Shallow bores to the west of one of the old quarries, north of Millrig, proved it to be 7 ft. thick here. This limestone was at one time quarried on the north side of the River Almond, half a mile south-east of Kirkliston [NT 13111 73848]?.

Still farther north, towards the Forth (in West Lothian), the thickness of the limestone varies between 5 and 15 ft. There were at one time extensive workings, both mines and quarries, around Newton and Hopetoun House [NT 08914 79015], and between the shore and Echline [NT 11778 78492]?, west of Port Edgar. Synclines and anticlines here bring the limestone to the surface in several outcrops. There are no present workings.

Harburn Limestone Mine [NT 03566 59778]?: 2½ m. S.E. of West Calder. (32. 11 S.E.)

The Burdiehouse Limestone is mined here by the Glasgow Iron and Steel Co., Ltd. The thickness of the seam is about 27 ft. There is a two-inch rib of coal about 10 ft. from the top. The stone is removed in benches, and pillars are left to support the roof. The bed dips W. at about 5°.

The limestone is a fine-grained rather dark rock of uniform quality. It is used as a flux, for cement manufacture, and ground for agricultural purposes. It is not at present burnt for lime. On analysis (SL 198) [NT 0348 5793] it showed as

follows: $CaCO_3$ 93.40; $MgCO_3$ 1.26; Insol. Res. 3.55. There are ample reserves in the area.

The present Harburn Limestone Mine is the second mine of this name. The first mine was situated ¾ m. N.W. of the present one, beside Harburn Quarry. The workings, which covered about 19 acres of ground, were abandoned in 1916. Some stone was also extracted at the now disused Torphin Quarry, adjacent to the railway.

Clippens Lime Works, Straiton. (32. 7 S.E.)

The Burdiehouse Limestone was originally worked opencast in a series of quarries between Straiton and Burdiehouse Mains and also to the south of Pentland Mains. It is now wrought in a pit at Clippens by the Shotts Iron Company, Ltd. The seam dips S.E. at 30°, and has a thickness of 27 ft. It is extracted in three leaves or benches; bottom leaf, 8½ ft.; middle leaf, 7 ft.; top leaf, 11½ ft. The top leaf is the purest of the three, but the superiority is exaggerated somewhat by the presence of bituminous matter in the two lower leaves. This imparts a dark colour to the limestone but does not impair its suitability for burning. The low silica and low total insoluble residue of all three beds are noteworthy ((SL 16) [NT 2787 6727], (SL 17) [NT 2787 6727], (SL 18) [NT 2787 6727]). Analytical figures are as follows:

	$CaCO_3$	$MgCO_3$	Insol. Res.
Top Leaf	96.02	0.50	1.37
Middle Leaf	91.87	1.15	2.50
Bottum Leaf	91.39	132	162

The stone is used for iron smelting, cement-making and lime-burning, and as ground limestone for agricultural use. Five kilns of the continuous-burning, open type, are in operation. There is also a grinding plant and a ground-lime plant. The lime is prepared in the ground-lime and small-lime forms and is marketed for agricultural, plaster and building purposes. Reserves of stone available by mining are plentiful.

Carboniferous Limestone Series

District West of Pentland Hills (Figure 41, p. 193):

Addiewell [NS 99386 62406] and Cobbinshaw [NT 01109 57832]. (32. 11 N.W., S.W.)

The outcrop of the Hurlet Limestone extends in a somewhat broken line from the south-west of Cobbinshaw Reservoir northwards to the county march at Addiewell. The limestone is not now well exposed although there were formerly small quarries at more than one point, particularly near Addiewell. Its thickness rarely exceeds 6½ ft.; but as the Hurlet Coal, 4 ft. thick, lies only 3 ft. or less below the base of the limestone the two seams were worked in conjunction, by a mine at Cobbinshaw and in a series of shallow pits at Addiewell.

Levenseat Quarries [NS 94450 59346]: 1¾ m. S.E. of Fauldhouse. (31. 10 S.E.)

The Castlecary Limestone was formerly quarried for about a mile along its outcrop, and later mined extensively in depth. The dip is to W. at 10°. At its best it was 7½ to 9 ft. thick and mainly white in colour, but, as in other areas, it was irregular in development, and was said to have deteriorated to the dip in the workings. Both north and south of the old quarries the limestone is cut off by faulting, and there is little likelihood of any available reserves.

West side of Midlothian Coalfield (Figure 27):

Gilmerton Limestone [NT 29121 68111]. (32. 7 S.E.; 8 N.W.; 12 S.E.)

The workings in the Gilmerton Limestone at Gilmerton are amongst the earliest recorded in the Lothians, but they have long been abandoned. They are still, however, quite accessible for observation in quarries and mines, at Ferniehill [NT 29571 69226], west of Gilmerton, for example, and in an opencast, in which mines were also developed, south of Moredun policies [NT 28717 68420]. This opencast extends for 1,000 yds. from Hyvot's Bank farm to beyond Muirhouse. The dip of the strata is everywhere about 20°.

At Ferniehill [NT 29571 69226] (8 N.W.) the section is: sandstone, 12 ft.; limy shale, 12 ft.; massive yellow-weathering limestone, 35 ft.; blue encrinital limestone, 8 ft. The analytical data for the upper, yellow-weathering limestone (SL 19) [NT 2957 6920] are: $CaCO_3$ 78.71; $MgCO_3$ 2.92; Insol. Res. 16.51. For the lower encrinital limestone (SL 20) [NT 2957 6920] the figures are: $CaCO_3$ 94.78; $MgCO_3$ 1.81; Insol. Res. 2.98. The much higher quality of the lower bed explains why it was wrought in preference to the upper.

In the Hyvot's Bank opencast (8 N.W.) [NT 28481 68913] the section is: sandstone, 12 ft.; over limy shale with harder ribs, 12 ft.; over 8 ft. of massive limestone. It was the basal bed that was sought here also.

North-eastward, the limestone is no longer exposed between the Femiehill Quarries and the sea at Portobello. There was formerly a quarry close to Niddrie House, but this is now filled up.

The outcrop continues south-westward from Hyvot's Bank opencast, but no rock is seen until Bilston Burn (7 S.E.) is reached. The Gilmerton Limestone here is represented by a series of coarse ochre beds which in the past were worked as a source of ochre. It is partly ochreous, too, in a section at Nine Mile Burn (12 S.E.) 7½ m. farther to the south-west. In the intervening ground between Bilston Burn and Penicuik, the Gilmerton Limestone is not visible, but in a bore south-west of Mauricewood Colliery [NT 23636 61563] it has been proved to have a thickness of 48 ft.

North Greens Limestone. (32. 7 S.E.; 8 S.W.; 13 N.E., S.W.)

Along the western side of the Midlothian Coalfield the outcrop of the North Greens Limestone is very largely concealed by superficial deposits, and no quarrying of the seam on a large scale has ever been carried out.

There are no natural exposures between the sea shore at Portobello, where excavations occasionally uncover limestone, and Bilston Burn, 6 m. to the south-west; but the North Greens is seen in a railway cutting at Edgefield farm (8 S.W.), ¾ m. S. of Gilmerton. Here the limestone is a light-grey encrinital rock, 76 ft. thick, dipping at an angle of over 45°.

At its exposure in Bilston Burn [NT 27384 64741] (7 S.E.), 150 yds. downstream from the footbridge at Pathhead farm, it consists of about 90 ft. of dark limestone, limy beds, and shale, all very fossiliferous. There are signs of a certain amount of quarrying on the north side of the burn and in the fields above.

In the Glencorse Burn, 150 yds. above the mill [NT 25007 62744] (13 N.E.), about 20 ft. of encrinital limestone are seen, but only a part of the bed is visible.

South-east of Nine Mile Burn several limestones appear in the stretch of the North Esk along Habbie's Howe [NT 17050 56378], above Newhall House (13 S.W.). The most prominent of these is the North Greens Limestone, which forms a linn in Peggy's Pool [NT 17091 56323] and is visible in the banks on either side. The seam is about 50 ft. thick, the lower 20 ft. or so being good limestone. A line of old pits to the south-west of the river [NT 16643 55870] shows where the limestone was at one time quarried along the outcrop. The dip of the strata is generally high, reaching 45°.

Bilston Burn Limestone. (32. 7 S.E.)

This limestone has never been worked to any extent on the west of the coalfield. As in the case of the North Greens, its outcrop is very largely concealed by superficial deposit, and it is not now anywhere visible northeast of Bilston Burn. The exposure in Bilston Burn occurs 400 yds. downstream from the Pathhead bridge [NT 27384 64741]. The full thickness of the limestone is about 50 ft., the bottom portion being a grey coralline limestone in beds up to 2½ ft. separated by partings. The upper part is less pure and at the top is a dolomitic bed about 5 ft. thick, which decays with an ochreous crust. Farther to the south-west little is known about its thickness.

East side of Midlothian Coalfield (Figure 27):

The limestone-bearing strata on the west of the Midlothian Coalfield enter Peeblesshire at Carlops [NT 16078 55994], but soon the trend of the beds swings round to the north-east so that they reappear in Midlothian near Leadburn [NT 23531 55491] and become prominent at Mount Lothian, [NT 27056 56982] S.E. of Penicuik. From this locality to the county

boundary east of Pathhead limestone quarrying and mining have long been pursued and are still actively prosecuted at three localities, Upper Side [NT 29225 55684], Esperston [NT 34150 57485] and Middleton [NT 35430 57490] (Figure 27). The Gilmerton, North Greens and Bilston Burn seams have all been wrought, the North Greens most extensively.

In addition to the main outcrop the limestone also appear as inliers at D'Arcy [NT 35972 64715] and Cousland [NT 37807 68535], two localities on the anticlinal ridge that extends from north of Gorebridge to within a mile of the sea at Prestonpans. Limestone was extensively wrought at both places.

Mount Lothian: 3m. S.E. of Penicuik; various exposures. (32. 13 S.E.; 19 N.E.)

Shallow pits were at one time opened in the Gilmerton (No. 1) Limestone about a mile west of Mount Lothian. These are now grassed over. There were also more extensive quarries at Hillhead (ruin) just north of Cockmuir Bridge, 1 m. S. of Mount Lothian. These quarries are also grassed over or being filled up. About 20 ft. of strata were formerly visible, consisting of 14 ft. of limestone bands with partings of limy shale overlying 6 ft. of massive encrinital limestone. The lower bed was the part sought, and mining would have to be resorted to for further working on a considerable scale. The site is adjacent to a main highway.

In the same neighbourhood the North Greens (No. 2) Limestone was wrought at two quarries—Mount Lothian Quarry and Fullarton Quarry.

Mount Lothian Quarry, 1,000 yds. S. of Mount Lothian farm [NT 26840 56109], is now grassed over. There was an overburden of 6 to 10 ft. of drift. It is adjacent to the main highway.

In Fullarton Quarry, 500 yds. E. of Mount Lothian [NT 27725 56724], the section exposed is: drift, 10 to 12 ft.; nodular weathering, flaggy limestone, 15 ft.; massive limestone with wavy partings, 10 ft. (formerly, 16 ft. visible). The dip is to the N.E. at 10°. The quarry is adjacent to the main road. Reserves are large, but the good rock at the base would have to be mined.

Upper Side Quarries: 2½ m. S.W. of Temple. (24. 20 N.W.)

The present worked quarry is in the North Greens Limestone, 200 yds. N.W. of Upper Side [NT 29140 55845]. Twelve feet of limestone are exposed dipping northward at a low angle under 10 ft. of overburden. The site is adjacent to a main road. The limestone is a massive, prominently jointed bed with some weathering along the joints. Reserves are extensive in the area, but overburden is probably always very considerable. An analysis of the stone (SL 81) [NT 2931 5589] shows as follows: $CaCO_3$ 89.18; $MgCO_3$ 1.74; Insol. Res. 8.09.

The limestone is burnt at a kiln on the site of the old Side Lime Works, 500 yds. S. of Upper Side [NT 29234 55278]. Adjacent to the kiln is the original quarry, which was developed in the Gilmerton Limestone. Exposures in this quarry are poor, but at one point 16 ft. of good limestone have been bared under a thick cover of drift, sandstone and limy shale. Further development here could best be done by mining.

Esperston Lime Works, Esperston. [NT 34199 57464] (32. 14 S.E.; 20 N.E.)

The quarries originally opened up here were in the Bilston Burn Limestone, but of late not much stone has been taken from them, and a new quarry has been started in the North Greens Limestone about a mile away from the kilns, on the right bank of the North Middleton Burn, half a mile south of Esperston farm [NT 34074 56223].

At this quarry about 25 ft. of good limestone are exposed at the working face. The beds in the basal 10 ft. are clean and massive, but towards the top the courses are thinner, with some shale partings and occasional nodules of chert up to 6 in. in diameter. The beds are inclined at about 8°. There is an overburden of between 6 and 8 ft. of drift. Analysis of this rock indicates a calcium carbonate content of about 91 per cent.

The Bilston Burn (No. 3) Limestone has a thickness of about 20 ft. with, on top, an impersistent band of dolomite up to 3 ft. thick. The overburden is of drift, up to 12 ft. thick, and several feet of shale and sandstone as well. There are abundant

reserves here.

The main band of limestone (SL 43) [NT 345 573] showed the following figures on analysis: $CaCO_3$ 93.24; $MgCO_3$ 1.83; Insol. Res. 2.69. The dolomitic band on the top (SL 44) [NT 345 573] gave as follows: $CaCO_3$ 50.78; $MgCO_3$ 32.17; $FeCO_3$ (assuming the excess of CO_2 to be combined with an appropriate amount of the total iron) 7.62; Insol. Res. 5.97.

The limestone from both quarries was originally all burnt, but a plant for grinding limestone is now also in operation.

Middleton Lime Works [NT 35660 58368], Middleton. (32. 14 S.E.) (Pl. VI.)

The North Greens (No. 2) Limestone is extensively mined at this locality. The thickness of the seam is about 50 ft., of which the upper 30 ft. are disposed in thin courses with shaly partings, and the basal 20 ft. are in massive beds. It is the lower portion that is mined. There are abundant reserves.

The upper unused part is generally considered to be much more siliceous and impure than the lower part, and for this reason does not appear ever to have been utilized to any extent. The analysis of it from the quarry beside the lime workings was nevertheless an excellent one (SL 42) [NT 353 575], the analysis indicating: $CaCO_3$ 94.12; $MgCO_3$ 1.26; Insol. Res. 4.23. The lower mined portion is a stone of uniformly high quality (SL41), yielding on analysis as follows: $CaCO_3$ 94.09; $MgCO_3$ 1.95; Insol. Res. 2.53.

The limestone is burnt in vertical, continuous, mixed-feed kilns. The lime is used for agricultural and building purposes. Ground limestone is also produced.

The Gilmerton (No. 1) Limestone was at one time also wrought in this locality at a quarry on Common Hill, ½ m. S. of the lime kilns. There is considerable overburden here, and, as in the case of the No. 2 Limestone, mining would seem to be more expedient than quarrying. The analysis of the exposed portion of 18 ft. (SL 46) [NT 3578 5765] indicates as follows: $CaCO_3$ 88.84; $MgCO_3$ 1.36; Insol. Res. 8.77.

Currie Lee Lime Works [NT 38254 62384]: beside Crichton, 3 m. E. of Gorebridge. (32. 15 N.W.)

Limestones Nos. 1 and 2 are exposed here. Little quarrying has been done in the Gilmerton Limestone (No. 1), but the North Greens (No. 2) was extensively quarried and mined in the past. There are still large reserves available by mining. The thickness of the bed is about 50 ft. The upper unworked part of the limestone is rather impure and banded with shale partings. The mined portion is a massive limestone composed of the triturated debris of calcareous organisms as well as occasional larger shells. The bulk sample (SL 55) [NT 3799 6236] furnished one of the best analyses from Midlothian: CaCO, 95.36; $MgCO_3$ 1.78; Insol. Res. 3.08.

There was also a small quarry in the North Greens (No. 2) Limestone at Catcune, 1 m. S.E. of Gorebridge [NT 35651 60277]. The lower 20 ft. were as usual mined, the upper part being rejected. This site is close to the main road and to Fushiebridge railway station. Between Catcune and Currie Lee, 2 m. to N.E., the limestone is untouched.

Magazine Lime Works: 1½ m. S.E. of Pathhead. (33. 15 N.W.)

The North Greens (No. 2) Limestone was quarried and mined at this site also, but the working has long been abandoned. The thickness of the stone is about 30 ft. of which the basal 12 ft. were mined. The strata dip at from 3° to 8°. The site is adjacent to a main highway.

The development here is similar to that at Currie Lee, 1½ m. to W. The area between the two localities offers .a wide field for mining.

D'Arcy Limestone Workings: 2½ m. S.E. of Dalkeith [NT 35972 64715]. (32. 8 S.E.)

The quarries and mine, now abandoned, were developed in the North Greens (No. 2) Limestone. There was an extensive opencast (D'Arcy Quarry) north [NT 36080 65016] and south of D'Arcy farm, a smaller quarry (Mayfield Quarry [NT 35522 64378]) close to Westhouses (between D'Arcy and Mayfield) and, commencing at this quarry, a mine (D'Arcy

Mine) [NT 35513 64469]. The quarry sections show an upper portion, 12 to 20 ft. thick, of impure limestone overlying a dark, calcareous ('inky' band) shale 4 ft. thick, which rests on a massive, crystalline limestone. This lower portion, now obscure, was mined and burnt for lime. The mine workings covered about 10 acres.

The limestone section here agrees closely with that at Cousland (*see* below) and the qualities of the stone may be expected to be similar. The analysis of the shale (SL 56) [NT 3602 6498], with 9.36 per cent. of alumina, indicates its suitability as a clay basis in cement-making.

Cousland Limestone Workings [NT 37598 68562]: 2½ m. E.N.E. of Dalkeith. (32.8 N.E.)

The North Greens Limestone was also worked here. The main quarries were situated just west of Cousland village. West of the quarry boundary there are underground workings as far as the road in the hollow, covering about 20 acres. The total thickness of limestone is about 100 ft., of which about 25 ft. are visible in the quarry-face as follows: flaggy, yellow-weathering limestone, 10 ft.; blue-weathering, thick-bedded limestone, 10 ft.; calcareous shale, 2 to 4 ft.; massive crystalline limestone, now only imperfectly seen. The bottom bed was the valuable bed for burning. The worked thickness in the mine was 8 ft. Accessibility is good to road and railway. Reserves for mining are still abundant.

Analysis shows the top yellow-weathering limestone (SL 57) [NT 3761 6865] to be a very impure bed, as indicated by the following figures: $CaCO_3$ 30.77; SiO_2 51.88; Al_2O_3 7.08. The blue-weathering limestone below it (SL 58) [NT 3761 6865] is of better quality but still has much impurity. It gave as follows: $CaCO_3$ 61.62; $MgCO_3$ 6.80; SiO_2 24.27; Al_2O_3 3.44. The 4-ft. bed of calcareous shale has a character and composition similar to that at its outcrop at D'Arcy (above). The basal bed of limestone (SL 59) [NT 3761 6865] is of high quality, showing $CaCO_3$ 93.12; $MgCO_3$ 1.30; Insol. Res. 3.32.

For a period the limestone and the overlying calcareous shale were used in cement manufacture in the vicinity, but this business has long since ceased. The top and middle beds of limestone are decidedly siliceous and argillaceous. The analysis of the middle bed in particular would suggest its suitability for the manufacture of rock wool.

Moray and Nairn

The two counties of Moray and Nairn may for the sake of convenience be considered together. Both are exceptionally poor in limestones (Figure 29). Geologically, they consist in the main of metamorphic rocks intruded in places by granite. A broad belt south of the Moray Firth is occupied by Middle and Upper Old Red Sandstone sediments. The latter are in turn overlain, near Elgin and Lossiemouth, by sandstones of New Red Sandstone (Permo-Triassic) age.

The majority of the metamorphic rocks belong to the Moine Series and are completely barren of limestones. In the extreme south of Morayshire, rocks of a somewhat different character occur, which may be of Dalradian age. They are referred to as the Grantown. Series, and include several outcrops of limestone which are not of sufficiently good quality to be of present economic value.

A calcareous band belonging to the Middle Old Red Sandstone is exposed at several localities near Lethen, about 5 miles south-east of Nairn, but is of no economic value. The cornstones in the Upper Old Red Sandstone are, however, of somewhat more importance. One of these, at Cothall, near Forres, was formerly quarried on a considerable scale. Other cornstones, with cherty bands, which crop out near Elgin were also wrought in the past.

Both the Cothall and Elgin cornstones might possibly be worth consideration for the production of ground limestone.

Cothall Quarry [NJ 01298 55987]: 2½ m. S.W. of Forres. (84. Moray 10 S.E.)

This is a disused opening on the east bank of the R. Findhorn, where the cornstone was formerly wrought for burning. The face is now much obscured and the following section is from an old record: green and purple beds, impure, and confusedly mixed with gravel; sandy marl, about 1 ft.; green marl and concretionary limestone, 4 ft.; irregular, broken, sandy bed, with green stains, 1 ft.; irregular bed of concretionary limestone, very impure, and much mixed with green, red and violet-coloured marls, some of which are penetrated by veins of carbonate of lime, and much mixed with pyrites, 8 ft.;

strong bed of yellowish-grey limestone, 10 ft.

Material for analysis was collected from the lowest bed. The rock (SL 105) [NJ 013 559] is composed of granular calcite containing much brownish (? clayey) matter disseminated through it and locally sufficiently abundant to form a thin cement. Subangular quartz grains up to 0.5 mm. across are scattered through the rock. On analysis the cornstone showed: $CaCO_3$ 92.77; $MgCO_3$ 0.46; SiO_2 4.81.

The beds dip N.N.W. at a very gentle angle. Their total thickness is about 25 ft., and they form a face about 200 yds. long and from 25 to 35 ft. high, including the overburden, which consists of 6 to 10 ft. of gravel. Reserves doubtless exist along the strike, but their economic exploitation would be handicapped by the gravel, unless the latter could be disposed of profitably.

Stonewells [NJ 28028 65582] and Nether Meft [NJ 27131 64137]: E.N.E. of Elgin. [(95. Moray 8 N.W., S.W.)

Immediately west of Stonewells there is a small opening in cornstone, now very much obscured, only a few feet of rock being seen. A partial analysis (SL 275) showed 88.5 per cent. of calcium carbonate. The cornstone, a cream-coloured, nodular, fairly soft type, is very variable in grain and contains inclusions of chert. The latter were excluded from the analysed material. At the south end of the old quarry there is a soft, greenish sandstone, which may overlie the cornstone.

Comstone was also exposed recently in a small pit immediately north-west of Stonewells, and fragments of the same rock are abundant along the face of a ridge about 20 ft. high which runs for at least a quarter of a mile to N.N.E. Unfortunately there is no evidence as to the actual thickness of the cornstone bed. This would require to be determined by boring.

South of Stonewells a similar ridge with abundant fragments of cornstone extends southwards to Innes House. Here the outcrop turns south-west to Nether Meft, immediately west of which it appears tohavebeenworked, although no rock is now seen in place. Cornstone fragments are very abundant on the surface of the Hill of Meft, west of Nether Meft. As this hill shows a face up to 80 ft. high to the north it would be better for quarrying than the low ridge at Stonewells, although the actual thickness of the seam would first require to be proved.

Orkney

The Orkney Islands consist almost entirely of Old Red Sandstone rocks. These contain no limestone even of the smallest consequence. At many localities, however, the coastal sands consist largely of shell fragments, and these constitute the only local source of lime except for one or two very small deposits of freshwater shell marl.

The shell sands were investigated by Mr. A. Leask of Kirkwall (Leask, 1928, pp. 57–58). The following list gives those that appear to show the greatest promise of usefulness, the figures given for $CaCO_3$ being taken from Mr. Leask's paper. As all these deposits are coastal they are subject, potentially at least, to interference by tidal and storm action. None of them has been examined for the Purposes of this account.

	1-in and 6-in sheets	$CaCO_3$ per cent.	Extent	Remarks
Mainland				
Birsay Bay [HY 24368 27273], S. of the township	119. 88 S.E.	96	About 150 acres	Very coarse; accessible; depth unknown
Sands of Evie, Aiker Ness [HY 37658 26263]	119. 89 S.E.	68.8 (beach) 72.5 (links)	Considerable	Fine-grained; accessible
Wester Sands, Sandside Bay, Deerness [HY 58934 06760]	120. 110 S.W.	93.3 (beach) 89.9 (links)	Considerable	Fine-grained; accessible

Hoy				
Melberry [ND 26367 88682], ½ m. S.W. of Melsetter, Walls	117. 122 S.E.	91.9	Limited	Coarse-grained: accessible
Egilsay				
Netherskaill [HY 22816 24290]	119. 90 N.E.	87	Small patches	Coarse-grained
Linkars and Mae Banks [HY 48016 30359]	119. 90 N.E.	87	Large area	Coarse-grained
Westray				
Bay of Pierowall [HY 43822 48193]	119. 75 N.W., N.E.	83.5	Considerable	Fine-grained; soft; accessible

The only freshwater marl deposit of which there are particulars is that at Durkadale, 4 m. E.S.E. of Birsay (119. 89 S.W.) [HY 29953 24833]. The marl, which is shelly, lies under 1 ft. of peaty soil, but there is no record of its depth or extent. It is easily accessible and is still occasionally dug. On analysis by Messrs. Gemmel and Thin, it gave percentages as follows: calcium carbonate 94.50; aluminium and iron oxides 0.60; insoluble in HCl 2.65; loss on ignition 2.22; organic matter, trace; Total 99.97.

Peebles

Less than 12½ per cent. of the area of Peebles is classed as "arable" and more than 70 per cent. as "mountain and heath for pasture" (Cambridge County Geographies, Scotland: Peebles and Selkirk, 1914, p. 53). The high-lying pastoral country is occupied mainly by rocks of Ordovician and Silurian age. These formations do not contain within the county useful seams of limestone. In the Ordovician there is one band of volcanic rocks with which limestone, in the form of boulders in a breccia, is associated. This breccia is to be seen near Glencotho [NT 08892 29276], Wrae [NT 11685 32365] and Winkston [NT 24485 43092] and at these localities the larger blocks of limestone were at one time quarried on a small scale and burnt for lime (Eckford nnd Ritchie, 1931, p. 49).

Limestones of economic value, however, are present and worked in the extreme north of the county, where a small area between Carlops, Macbiehill and Whim (Figure 27, p. 140) is occupied by Carboniferous strata. These limestones belong to the Lower Limestone Group, the sequence being the same as that already given for Midlothian (Figure 28). The North Greens Limestone is now being worked at Bankhead Quarry, south of Macbiehill Station. In the past the Gilmerton Limestone also was worked.

Carlops Quarry [NT 16525 55698]: disused quarry 500 yds. S.E. of Carlops, on S. side of Carlops Burn. (24. 5 N.W.)

The Gilmerton Limestone was worked here, but the quarry is now grassed over and no good exposures are available for inspection. Extension southwestward for a few hundred yards along the outcrop might be possible, but mining would have to be resorted to for a large output.

Whitfield Lime Works: disused quarries in the neighbourhood of Deepsykehead, 1 m. S.E. of Carlops. (24. 5 N.E.) The Gilmerton Limestone was wrought along its outcrop in a series of quarries over a distance of nearly ¾ m. The thickness of the bed is about 40 ft., but only the basal 12 ft. (SL 183) [NT 172 542] of which little is now seen, are of high quality. The upper part (SL 21) [NT 171 543] is distinctly poorer, as the analyses indicate. Analysis of upper part (12 to 15 ft. seen in quarry): $CaCO_3$ 62.45; $MgCO_3$ 5.80; Insol. Res. 27.64. Analysis of lower part (3 ft. now visible): $CaCO_3$ 93.96; $MgCO_3$ 2.04; Insol. Res. 3.77.

The strata dip at a gentle angle, but further development would have to be by mining.

Deepsykehead [NT 16824 54653]: limestone in stream, 800 yds. E. of Deepsykehead. (24. 5 N.E.)

The Bilston Burn Limestone crops out in the stream here, but only the top foot or so is available for analysis. This proved to be an irony dolomite rather similar to the same bed in Esperston Quarry, Midlothian (p. 146). Its analysis (SL 22) [NT 182 541] reads: $CaCO_3$ 40.18; $MgCO_3$ 25.30; $FeCO_3$ 6.44; Insol. Res. 24.10.

Bents Quarry [NT 18448 52012] and Bankhead Quarry [NT 18856 51736]: 700 yds. S. of Macbiehill station. (24. 5 S.E.)

These two quarries are practically adjacent, and parts of both are in working condition. The North Greens Limestone is worked on a face 12 ft. high. The bed dips E. at 5° under a cover of 4 to 8 ft. of drift at present (1945). The quarry is adjacent to a main road and accessibility is good. The stone is burnt on the site. Its analysis (SL 23) [NT 184 519] reads: $CaCO_3$ 86.95;$MgCO_3$ 1.45; Insol. Res. 8.72.

The recorded thickness of the North Greens Limestone in neighbouring mineral bores is about 60 ft. The basal 12 to 20 ft. are always of better quality than the higher part, and it is this lower portion that is quarried here.

Macbiehill: various exposures. (24. 5 S.E.)

Small quarries were at one time opened in the Gilmerton Limestone 200 yds. N.W. of Macbiehill House [NT 18299 51581], at Braefoot [NT 18977 51482] and Whitemuir [NT 19136 51114], and close to Lamancha. The exposures now are poor, but the limestone in this area may be expected to have much the same character as at Whitfield Lime Works and at Whim.

Whim [NT 21619 53247]: several quarries. (24. 5 N.E.; 6 N.W.)

Former workings in the Gilmerton Limestone and the North Greens Limestone are indicated by quarries close to the railway in the vicinity of Whim farm [NT 21555 53239].

The analysed sample (SL 182) [NT 216 531] is of the Gilmerton Limestone collected at the mouth of a day-level in the quarry, 200 yds. S.E. of the farm and on the south side of the railway. The thickness of the worked portion of the limestone here is 8 ft. The dip of the strata at the level-mouth is 15° but eastward this increases to 70°. The steep dip is likely to persist as the outcrop is followed north-eastward past Leadburn.

The quality of the limestone is good, the analysis being: $CaCO_3$ 92.18; $MgCO_3$ 1.62; Insol. Res. 4.51.

Perth

Perthshire lies mainly within the Grampian Highlands, but also partly in the Midland Valley. The geological division between the two regions is marked by the Highland Boundary Fault, which enters the county near Blairgowrie and follows a south-westerly course to Aberfoyle. The portion of Perthshire north-west of the fault is rich in limestones, some of which are of good quality. The part of the county south of the fault, on the other hand, possesses no limestones of economic importance.

The Dalradian schists, which make up the greater part of the Perthshire Highlands, contain two important bands of limestone, namely, the Loch Tay Limestone and the Blair Atholl Limestones (Figure 30).

Near the Highland Boundary Fault there are also narrow outcrops of a group of rocks referred to as the Highland Border Series, which includes strata both of Cambrian and of Ordovician age. Thin limestones belonging to this series were formerly worked near Callander and Aberfoyle, but they are not of present economic value. Along the fault itself there is a discontinuous band of impure dolomitic limestone replacing serpentine. This rock is of too low a grade to be used for agricultural purposes, but it might serve as raw material for the manufacture of rock wool. It is well exposed in an old quarry at Upper Dounans, Aberfoyle.

The Highland division of Perthshire contains abundant supplies, of limestone suitable for grinding for agricultural purposes. The eastern part of the county, and the neighbouring districts of Angus, are already served by a quarry at Kirkmichael. For the requirements of central and northern Perthshire one of the Blair Atholl Limestones is being worked at Shierglas. To satisfy the needs of western Perthshire, and also, possibly, those of the nearby parts of the Lowland division of the county, it would be advantageous to have a quarry in the Loch Tay Limestone near Loch Tay or Loch Earn. The Loch Tay Limestone, the epidiorite associated with it in many places, and the Blair Atholl Limestones are all generally suitable for roadstone.

Loch Tay Limestone

The Loch Tay Limestone is of only moderate purity. There is always an appreciable amount of silica present and calc-silicate minerals sometimes occur, although, in general, in small amounts. It is low in magnesia. In eastern Perthshire it forms a crescentiform outcrop open to the north, east of Kirkmichael, near which there is a working quarry, described in' detail below. North of Kirkmichael the outcrop of the Loch Tay Limestone is interrupted by a fault and reappears 5 m. to the north-west. Thence it continues through rather inaccessible country until it crosses the Tummel valley just north of Pitlochry. One mile west of the last-named locality there is a large disused quarry near Clunie Cottage.

From Pitlochry the Loch Tay Limestone continues on a west-south-westerly course, parallel to, but from two to three miles north of, the Tay valley to a point above Fortingal in Glen Lyon, where it meets the Loch Tay Fault. There are several old quarries in this neighbourhood, none of which is of economic importance at the present time.

West of the Loch Tay Fault the distribution of the Loch Tay Limestone is complex (Figure 30). To the north there are a number of discontinuous outcrops near Bridge of Balgie in Glen Lyon. The presence of old kilns indicates that some of these outcrops must once have been worked for local purposes, but owing to their comparatively remote situation they are not of present economic value.

A more important outcrop runs along the north side of Loch Tay to Killin (Figure 31). Exposures near the latter village which might be opened up are described below. Other outcrops of the Loch Tay Limestone occur south of Loch Tay. They extend past Glen Ogle to Balquhidder and Loch Earn. There is a large disused quarry at Dalveich on the north side of Loch Earn, a little over a mile from Lochearnhead.

In the west of Perthshire there are also outcrops of the Loch Tay Limestone near Crianlarich, but they are either too remotely situated or too restricted in extent to be of economic value.

Throughout its outcrop the Loch Tay Limestone is associated with mica-schist and intrusive sheets of epidiorite, a metamorphosed basic igneous rock.

Wester Bleaton [NO 11477 59886]: 2 m. E.S.E. of Kirkmichael. (56. 33 S.W.)

A working quarry is situated on the south side of the road, 500 yds. S.W. of the farmhouse of Wester Bleaton. The bulk of the stone is a medium-grained, light blue-grey limestone, massive in some places, in others banded or flaggy. The total thickness is at least 50 ft., but the top 5 to 10 ft. consist of less pure material, in part limestone with layers of white quartzose schist, in part green calc-silicate rock. The development of the calc-silicate minerals is irregular and extends farther downwards in some places than in others. For this reason analyses of the rock show some variation, but the average calcium carbonate content may be taken as about 75 per cent. The entire output is ground limestone, which is produced in a modern crushing and grinding plant, electrically driven; handling throughout is by conveyors. The limestone dips N.N.W. at 25° in the quarry face, which is about 40 ft. high. There is no overburden. Regarding reserves it should be pointed out that to N.N.W. not only does the impure material referred to above come on, but a quartz-dolerite dyke and then a thick epidiorite sill, overlying the limestone, are soon encountered. It would not therefore be practicable to work along the steep face which rises immediately above the road. Ample reserves of stone exist, however, along the strike to W.S.W. in which direction the quarry could be extended for at least 350 yds. towards Dunidea farm.

Dunie [NO 08819 59020]: 1m. S.E. of Kirkmichael. (56.32 S.E.)

The Loch Tay Limestone is also exposed in a small disused quarry, with a face (12 ft. high, on the moorland 1,250 yds. E. by S. of Dume, 1 m. S.E. of Kirkmichael. It is at least 15 ft. thick and dips N. 25° W. at 20°. The presence of a kiln shows that the limestone must once have been burnt. An analysis of a bulk sample (SL 138) [NO 111 588] showed: $CaCO_3$ 90.39; $MgCO_3$ 0.88; Insol. Res. 7.66. The stone is thus purer than that at Wester Bleaton, but although there are plentiful reserves, it is unattractive from a commercial point of view, owing to the difficulty of access, there being nothing more than a rough moorland path from Dunie.

West Craig of Soilzarie [NO 12858 59908]: 3 m. E. of Kirkmichael. (56. 33 S.W.)

East of Wester Bleaton the Loch Tay Limestone was formerly worked in a quarry at West Craig of Soilzarie, 500 yds. N.W. of Soilzarie. It is at least 50 ft. thick and dips W. 15° N. at 30°. Its purity is about the same as that of the Wester Bleaton rock, as a bulk sample (SL 137) [NO 115 598] showed on analysis: $CaCO_3$ 72.93; $MgCO_3$ 0.55; Insol. Res. 24.32. Although reserves of limestone are considerable, exploitation would be hindered by the fact that epidiorite comes on a short distance up the hillside.

Clunie Cottage [NN 92517 58248]: 1 m. W. of Pitlochry. (55. 40 N.W.)

There is a large, disused quarry in a wood 150 yds. S. of Cluniemore. The limestone is a grey, coarse-grained type with a few thin mica-schist partings and many quartz veins. Its impurities consist of quartz and white mica, with some pyrite, sphene, probably zoisite and possibly graphite. It showed on analysis (SL 5) [NN 921 581]: $CaCO_3$ 75.18; $MgCO_3$ 2.41; Insol. Res. 21.26. The limestone beds dip N. 25° W. at 35° and are at least 40 ft. thick, probably more. The face of the quarry *is* 50 ft. high, wholly in rock. Overburden is absent. Very considerable reserves exist at this locality.

Loch Tay: along the north side of the west end of the loch. (46. 68 S.E.)

The Loch Tay Limestone is exposed almost continuously alongside or immediately north of the main road between the Burn of Edromachy and Tirarthur (Figure 31). Not all the outcrops consist of good limestone, for there is much impure calcareous schist. Another factor which must be taken into account is the presence of epidiorite sills. At several localities, however, there are small crags showing from 20 to 40 ft. of good massive limestone in positions where quarrying might be started. These include the following:

1. Crags immediately north of the road, 150 yds. S.W. of the Allt a'Mhoirneas [NN 61454 36182].
2. Crags 125 yds. up the hillside from the road, 100 yds. N.E. of Tomocrocher [NN 61008 35746].
3. Crag on the north side of the road opposite Morenish [NN 59872 35229].
4. Roadside crag 100 yds. N.E. of Allt Tir Artair [NN 59661 35152].

Dun Beag, Killin [NN 57007 33558]. (46. 80 N.W.)

Limestone which could readily be quarried is exposed in crag and stream sections on the west side of the main road, ■ m. S. of Bridge of Lochay. The limestone is a fairly fine-grained, grey type, with subordinate quartz in nests with which graphite is associated. Accessory zoisite, yellowish mica, and a serpentinous mineral are also present, and some pyrite and a little limonite. The bulk analysis (SL 3) [NN 569 334] showed: $CaCO_3$ 86.75; $MgCO_3$ 0.80; Insol. Res. 12.20. The limestone beds dip N.W. at 20°. A thickness of 20 ft. is exposed in the crag, and of 40 ft. in the stream to the south. Overburden consists of a certain amount of scree piled against the hillslope. The reserves present are probably considerable, as the limestone could be worked along the slope for 150 yds. between the crag and the burn, and could also be opened up south of the latter. To the west the limestone dips under epidiorite about 100 yds. up the slope.

A bulk sample (SL 2) [NN 559 321] was also collected from 25 ft. of limestone exposed in a small disused quarry at Craignavie, ¾ m. W.S.W. of Bridge of Dochart, Killin. It proved to be less pure than the Dun Beag material, and showed on analysis: $CaCO_3$ 67.61; $MgCO_3$ 2.20; Insol. Res. 30.00.

The Loch Tay Limestone is also exposed in an old quarry at Glenoglehead, but owing to overlying epidiorite and morainic drift could not readily be quarried.

Dalveich [NN 60918 24289], Loch Earn. (46. 92 N.E.)

There is a large disused quarry 550 yds. W. of Dalveich farm. Access is by a track leading under the adjacent L.M. & S. railway from the nearby main road. The limestone occiirs in alternating fine-grained flaggy bands and coarse-grained, highly crystalline bands. The fine bands are composed of calcite with quartz, white mica and some pyrite; the coarse bands of calcite, quartz, accessory graphite, pyrite, colourless and pale brown micas and occasional plates of albite–oligoclase. Bulk analysis of a mixture of both types (SL 1) [NN 609 202] showed: $CaCO_3$ 78.20; $MgCO_3$ 1.74; Insol. Res. 18.80. The limestone was formerly quarried for burning and may also have been used for roadstone. It dips E. 15° N. at 20° at the east end of the quarry, and N.W. at 20° at the west end. It is 30 to 40 ft. thick and is overlain by 10 to 12 ft. of epidiorite, but the overburden of drift is slight. Unless mining were resorted to, only a small amount of limestone could be won without quarrying the epidiorite as well, but if the latter could be worked and sold as roadstone large quantities of limestone would be available.

Blair Atholl Limestones

The Blair Atholl Limestones are, on the whole, purer than the Loch Tay Limestone. Moreover they are free from epidiorite sills. They form part of an extensive group of rocks termed the 'Blair Atholl Series,' which can be readily divided in most districts into two groups, termed the 'Pale Group' and the 'Dark Group,' each containing distinctive types of limestone. The limestones of the 'Pale Group' are of varying character and include saccharoidal marble and cream or salmon-coloured limestone with dark micaceous stripes. The 'Pale Group' also contains one band of white dolomite, traceable for two miles at Loch Moraig, north-east of Blair Atholl. The limestones of the 'Dark Group' are grey in colour and carbonaceous, and are associated with black graphitic schist. All the limestones in the immediate vicinity of Blair Atholl belong to this group.

In north-eastern Perthshire, the Blair Atholl Limestones are first seen in the vicinity of Glen Shee (Figure 30). A small working quarry in this district is described below. Farther west there are considerable outcrops in and near Glen Tilt, but they are rather inaccessible. The Glen Tilt exposures include a band of marble, which was formerly quarried as an ornamental stone.

Around Blair Atholl itself limestone forms a number of outcrops; two, one of which is worked, are described below. To the west, the Blair Atholl occurrences are cut off by the Loch Tay Fault, by which they are shifted four to five miles to the south-south-west where they form another intricate outcrop around Schiehallion. On the eastern side of this mountain there is a disused quarry at White Bridge, which is described below.

Gleann Beag [NO 13902 75686]: 2/3 m. S.S.W. of the Devil's Elbow and 4 m. N.N.E. of Spittal of Glen Shee (see (Figure 2)). (65. 15 N.W.)

A small quarry, adjacent to the main road, and probably at one time worked for roadstone, was re-opened in 1946 for agricultural purposes. The stone is transported to Wester Bleaton (p. 154) for grinding. The limestone (SL 139) [NO 139 756] belongs to the 'Pale Group' of the 'Blair Atholl Series' and is a light blue-grey, fairly massive type with accessory quartz, muscovite and small granules of magnetite. It showed on analysis: $CaCO_3$ 89.62; $MgCO_3$ 1.18; Insol. Res. 8.28. The bedding is vertical and strikes E. 35° N. The face of the quarry is 15 to 20 ft. high. Overburden is slight at the quarry but might increase along the hillside, where there are many boulders covering the surface. The reserves are probably considerable along the strike to the south-west.

Shierglas: 1 m. S.E. of Blair Atholl and 2 m. W.N.W. of Killiecrankie station. (55. 30 N.E.) (Plate 7B)

At Shierglas [NN 87842 63974] a conspicuous cliff of limestone, known as Creag Odhar, rises above the south bank of the River Garry. The limestone belongs to the 'Dark Group' of the 'Blair Atholl Series,' and for the most part is a grey, medium-grained type with accessory quartz and colourless mica. A bulk sample (SL 12) [NN 880 642] collected from 40 ft. of rock at the east end of the crag showed on analysis: $CaCO_3$ 88.52; $MgCO_3$ 1.03; Insol. Res. 10.02. The limestone, which is cut by a few thin quartz and pegmatite veins, has a general south-easterly dip at 30° to 40°. Its total thickness is 400 to 500 ft.

Recently a quarry has been opened in the east end of the crag. At the time of writing (1945) about 40 ft. of limestone are being worked. The rock is mainly a grey medium-grained type, but a finer-grained somewhat flaggy type also occurs, particularly towards the north-west end of the face. A few thin partings of graphitic mica-schist are also present. The strata dip S.E. at 30°. There is no overburden, and the reserves are immense.

The quarried rock passes through a primary crusher near the quarry before being transported down the hillside by means of a conveyor to the main plant immediately south-west of Shierglas farm. Here it is dealt with in two further crushers; part of the product is then conveyed to large storage bins which deliver various grades of chippings for roadstone and part is further processed to ground limestone for agricultural purposes.

Upper Strathgroy: 1½ m. E. of Blair Atholl. (55. 21 S.E.)

At Upper Strathgroy on the north side of the River Garry, limestone similar to that at Shierglas is exposed in a disused quarry. A bulk sample (SL 11) [NN 891 665] showed on analysis: $CaCO_3$ 92.19; $MgCO_3$ 1.87; Insol. Res. 6.28. The reserves are, however, not nearly so great as those at Shierglas, and the access is awkward.

White Bridge or Tomphubuill [NN 77716 54276]: disused quarry on the east side of the main road, 3½ m. S. by E. of Tummel Bridge and 6 m. W.N.W. of Aberfeldy. (55. 38 S.E.)

The limestone, which belongs to the Dark Group ' of the Blair Atholl Series, is a fairly massive grey type with thin micaceous partings and abundant quartz and mica, along with some pyrite, a little sphene and possibly graphite. On bulk analysis (SL 4) [NN 776 541] it showed: $CaCO_3$ 87.65; $MgCO_3$ 0.76; Insol. Res. 10.74. At one time it was burnt, and, later, up till 1935, used for roadstone. It dips E. 10° N. at 50° to 60° and is 60 ft. thick. The face of the quarry, which is free from overburden, is 40 ft. high. There are reserves which could be worked northwards along the strike for 150 yds. to the edge of another old quarry.

Glen Tilt Marble [NN 90339 71875]: 4½ m. N.N.E. of Blair Atholl. (55. 12 S.E.)

In Glen Tilt the Blair Atholl Limestone has been locally metamorphosed to marble by an igneous intrusion. This stone was formerly highly esteemed as a decorative marble but is now of doubtful value. Old workings can still be seen on the left bank of the River Tilt, 250 yds. upstream from Gow's Bridge near Marble Lodge. The best stone is here only about 10 ft. thick and dips S. 20° E. at 30°. It is a white marble with streaks and blotches of bright green of varying intensity, giving rise to numerous types, many of great beauty. Unfortunately the readily available reserves are very small, as the marble strikes along the stream and in the direction of dip quickly passes under schist. A considerable amount of the latter would therefore have to be removed before any large quantity of marble could be wrought.

Limestones close to the Highland Boundary Fault

Loch of Clunie [NO 11505 43512]: 4 m. W. of Blairgowrie . (56. 63 N.W.)

Brecciated dolomitic limestone, replacing serpentine along the Highland Boundary Fault, is exposed in a disused quarry between the south end of the Loch of Clunie and the farm of Hawkhill, at a locality once known as Limestonebank. It is cut by a quartz-dolerite dyke, which has also been worked. The dolomitic limestone, which is at least 30 ft. thick, was formerly burnt. An analysis is not available, but it is probably of approximately the same composition as similar rock near Stonehaven in Kincardineshire (p. 128), near Aberfoyle (*see* below) and at Balmaha in Stirlingshire (p. 176).

The dolomitic limestone is traversed by minor fault-planes inclined steeply N.W., associated with which are thin barytes veins. The dyke is unaffected by the fault movement.

The dolomitic limestone probably continues along the fault, but it is very doubtful if it would be worth working unless the dolerite were being extracted at the same time. It is almost certainly of suitable composition for the manufacture of rock wool.

Leny Quarries [NN 61493 09842]: 1¼ m. N.N.W. of Callander. (38. 114 S.E.; 115 S.W.)

Limestone, occurring in thin bands of shale of Middle Cambrian age, just north of the Highland Boundary Fault, is exposed in the disused Leny Quarries. It is practically worked out, but is mentioned on account of its historic interest. It was quarried at least as, far back as 1745. The coming of the railway to Callander in 1858 made it cheaper to bring lime from the south, and the quarries closed down entirely a few years later.

Upper Dounans [NN 53374 01884], Aberfoyle. (38. 123 S.W.)

Sedimentary limestone, of Cambrian or Ordovician age, was once wrought in a quarry half a mile north-east of Upper Dounans, Aberfoyle. It occurs immediately on the north-west side of the Highland Boundary Fault, here occupied by a thick, brecciated dolomitic limestone replacing serpentine. The two rocks appear to have been worked together. An analysis of the dolomitic rock, communicated by Messrs. Colvilles, Ltd., gave the following results: CaO 17.56; MgO 10.60; FeO 3.56; SiO_2 39.08. Reserves of this rock, which is of suitable composition for the manufacture of rock wool, are probably considerable.

Renfrew

In the eastern half of the county of Renfrew there has in the past been a considerable amount of limestone obtained both by quarrying and by mining (Figure 32). In the Paisley, Johnstone and Barrhead districts the Hollybush, Blackbyre, Hurlet, Blackhall and Top Hosie limestones were wrought, whilst farther east, in the Thornliebank—Nitshill area, the chief workings were in the seams of the Upper Limestone Group, namely, the Index at Cowglen and Cathcart, the Lyoncross at Waulkmill, the Orchard at Giffnock and the Arden or Calmy at Darnley. The positions of the various limestones in the Carboniferous sequence are shown in (Figure 33) and (Figure 34). Nodular cornstone in the Upper Old Red Sandstone at Inverkip on the Firth of Clyde was also worked at one time. Of all these activities the only survivor is to be found in the Darnley Quarries near Nitshill, where the Calmy Limestone is still being worked. It produces a building lime with high cementation index.

The Hurlet was perhaps the best known and most widely worked limestone in Renfrewshire. It is in general of good quality. In most places, however, it is not thick enough to be worth working on its own, being seldom much over 5 ft. in thickness. It owed most of its use to the fact that the underlying alum shale and mg were also of economic value and that the three different minerals could profitably be mined together (Carruthers, 1920, pp. 13–18, 29–39; also Carruthers, 1925, pp. 18–32, 35–39).

In contrast with the Hurlet, the limestones of the Upper Limestone Group are argillaceous in character and give a good hydraulic lime for building purposes. It is to this circumstance that they owed the very considerable popularity that they long enjoyed, leading to extensive workings underground even in seams only 2 to 3 ft. thick.

Inverkip [NS 20495 71915], etc. (29. 5 N.E.)

Cornstones in the Upper Old Red Sandstone. A nodular conglomeratic limestone, with pebbles of quartz, was at one time worked and calcined at old quarries and kilns a little W.S.W. of Inverkip House. The calcareous portion is concentrated into nodules, and these were sufficiently abundant to allow of the bed being worked as a whole. Montgomery (1839, p. 427) described it as a 'bed of limestone, 8 to 10 ft. thick, which has been wrought to a considerable extent'.

This occurrence is selected as an example of the nodular concretionary limestones of the Inverkip–Gourock–Loch Thom district.

Paisley and Johnstone. (30. 7 S.E.; 8 S.W.; 11 N.E., S.E.; 12 N.W., S.W.) Reference: Carruthers, 1920, pp. 13–18, 29–39.

The Hollybush and Blackbyre limestones, lying at the top of the Calciferous Sandstone Series, were at one time quarried at Limecraigs [NS 46645 60941], Elderslie [NS 44588 63117] and elsewhere, S.W. of Paisley. Each of these seams normally shows a main lower post of stone about 6 ft. thick overlain by more flaggy beds with partings of calcareous shale.

The Hurlet Seam, including under this term the limestone, alum shale and coal, was at one time an important economic horizon. In the Paisley—Johnstone district the seam was last worked in the Blackstone pits (abandoned 1901) [NS 45381 66671], 2 m. N.W. of Paisley (8 S.W.). The section here showed: limestone, 5 ft. 2 in,; shale, 10 in.; coal, 4 ft. 2 in. From the evidence of borings the coal is well developed and consistent in thickness over an area of at least six square miles to the north and west of Paisley (Figure 32), and the combined seam might be worth attention here. It is doubtful, however, if outcrop workings in the limestone are now possible. It was formerly quarried at Limecraigs [NS 46645 60941], 2¼ m. S.S.W. of Paisley Cross and at Kaimhill [NS 40390 65340], about 1 m. S.S.W. of Houston. Abandoned quarries in the Hurlet seam are also to be found between Howwood [NS 40021 60572] and Milliken Park [NS 41384 62442], about 2 m. S.W. of Johnstone.

The Top Hosie Limestone, although rarely exceeding 2 ft. in thickness, was also wrought formerly in this area in a number of quarries.

Hurlet, Nitshill and Darnley. (30. 12 N.E., S.E.; 16 N.E.) Reference: Carruthers, 1920; pp. 48–50, 66–74.

The Hollybush, Hurlet, Blackhall, Cowglen (Index), Lyoncross, Orchard and Arden (Calmy) limestones all take their names from localities in this area, and all have been worked to a greater or less extent, even seams such as the Orchard, which is only 2½ ft. thick in the old mine and quarry workings at Giffnock.

At present only the Calmy Limestone can be looked upon as an economic proposition. It is worked and burnt at the Darnley quarries [NS 52803 59435], about 1 m. S.E. of Nitshill station. Its thickness is 11½ ft. in three posts, separated by thin partings of limy shales. The dip is gently undulating. Overburden, consists of shale 0 to 6 ft. under boulder clay up to 10 ft. Access is good; the kilns are close to road and are served by a full-gauge mineral railway. Reserves are large, especially for mining.

The limestone is a grey, compact, fine-textured rock, often in massive blocks. The bottom and middle posts, each 4 ft. thick, are similar in quality and produce a building lime which is highly valued. On analysis it shows as follows (SL 141) [NS 524 586]: $CaCO_3$ 72.30; $MgCO_3$ 3.10; SiO_2 19.72; Al_2O_3 1.64. The top post, 3½ ft. thick, is generally of somewhat poorer quality and is ground to chip size. It gave the following figures on analysis (SL 140) [NS 524 586]: $CaCO_3$ 69.05; $MgCO_3$ 5.00; SiO_2 19.17; Al_2O_3 2.55. The analyses reflect the impure character of this stone and indicate why a lime with a high cementation index is produced. A limestone of this nature, together with the shale also available constitute the raw materials necessary for the manufacture of rock wool.

Old quarries in this seam were at one time in operation at Arden [NS 54010 58782], near Darnley Bridge; near Dovecothall [NS 51011 59524] to the north-east of Barrhead; and near Davieland [NS 55310 58313] to E.S.E. of the present quarries.

Of the other limestones in the Upper Limestone Group in this area the Lyoncross is worthy of mention in that it was worked as lately as 1914. In the abandoned mines at Waulkmill it had a thickness of 4½ ft. but only the lower 2½ to 3 ft. were of suitable quality for working. The dip is slightly W. of N. at about 16°. The limestone is a grey ochreous-weathering rock and burns to a natural cement. The product had the property of setting quickly and was used for fire-proof ceilings, etc., but had only half the strength of Portland cement. An analysis of the stone (J. S. G. Wilson, 1920, p. 69) shows SiO_2 8.18; Al_2O_3 4.85; Fe_2O_3 9.34; MgO 11.31; CaO 27.89; MnO 0.38; CO_2 38.26; Cementation Index 0.79.

The Lyoncross Limestone was also wrought a little over 2 m. farther east on the left bank of a small stream between Whitecraigs House and Cleuch [NS 56174 57214], 1½ m. W.N.W. of Busby.

In the Thornliebank—Giffnock area (13 S.W.), the Index Limestone was formerly worked opencast between Cowglen [NS 54224 61271] and Kennishead [NS 54464 60234] with a thickness of 5 to 6 ft. and was both quarried and mined to a small extent near Cathcart. The Orchard Limestone was quarried along the outcrop on both sides of Orchard farm, Giffnock, and was also mined to some extent. The section formerly visible showed 2 ft. of cement Milestone under 15 ft. of blue, shelly shale.

Ross and Cromarty

Ross and Cromarty contains little limestone, and the only occurrences of value are situated in the western part of the county where accessibility is poor. The principal types of stone available are crystalline metamorphic limestone in the Lewisian of the Loch Maree district (Figure 35) and Cambrian dolomite in the vicinity of Ullapool and of Loch Kishorn (Figure 22) and (Figure 38). There is also marble in the Loch Ailsh area.

One or two calcareous beds are to be found in the Middle Old Red Sandstone of the east coast, *e.g.,* at Geanie's House [NH 89606 79098] 'and Ethie [NH 77577 63526], but they are of no economic significance. There is a small quantity of Jurassic limestone of excellent quality at Applecross [NG 71257 44417] ((Figure 22), p. 117), and an impure limestone of the same age at Sand (91. 19 S.E. and 92. 19 N.E.)

In some of the bays of the west coast considerable quantities of shell sand are to be found, and so it is also both on the east and the west coasts of Lewis. These are valuable local sources of lime and have been used for generations. In the case of Lewis they are the only calcareous material in the island.

The *Lewisian* limestones of Wester Ross occur as a series of discontinuous bands or lenses in hard crystalline schists and gneisses. They have been highly altered, and the internal chemical reconstruction has been such that one of their chief features is a percentage of carbon dioxide lower in most cases by several units than that required to account for all the lime and magnesia as carbonate. This is because some of the calcium and magnesium is present as silicate, in such metamorphic minerals as forsterite, diopside, tremolite, etc. In this district the magnesia content is high except in one of the samples from Letterewe (SL 258) [NG 952 719] where the most important occurrence is to be found. Other less important and for the most part poorly accessible localities are at Shieldaig [NG 81096 72346] (Gairloch, not L. Torridon), Druim na Fearna [NG 82818 70980], Am Feur Loch [NG 84819 66694] and Am Marcach [NG 89461 76735(Figure 35).

In the south-west part of the county there is a noteworthy occurrence of Lewisian limestone at Keppoch [NG 90075 24306] on the north shore of Loch Duich. On the Glenelg side of Loch Duich also (Figure 22), bands of limestone or marble can be seen at frequent intervals along the hillsides southwards from Totaig [NG 87592 25332] (71. 123 S.E.).

The general characteristics of the *Cambrian* limestones are discussed in the section dealing with Durness in Sutherland. The remarks here made regarding Groups I and II apply also to the occurrences in Wester Ross, where only these two subdivisions are present. The marbles of Loch Ailsh are similar in character and derivation to those of Ledbeg in south-west Sutherland (p. 191). The unaltered dolomites are found between Strath Kanaird and Ullapool on a length of outcrop of about 5 miles (Figure 38). They also crop out at the head of Loch. Kishorn. There are in addition several other occurrences between these two areas, but everywhere in ground very difficult of access.

Amongst the *shell sand* deposits that have come to our notice the following in Lewis (Figure 24) are the most important: Valtos [NB 09540 36787], Uig Bay [NB 03918 32948] and Loch Shawbost [NB 25527 47677] on the west coast; Gress [NB 49420 41815] and Melbost sands [NB 47259 32666], N.E. of Stornoway; Eoropie [NB 51158 64693], 1½ m. S. of the Butt of Lewis. A sample from Shawbost contained 70 per cent. $CaCO_3$.

Several deposits of shell sand occur on the west coast of the mainland, but for the most part they are so small as to be of merely local interest. One of these, at Airdban [Ardban?] [NG 69917 39839], about 3 m. S. of Applecross, showed 86 per cent.

$CaCO_3$ in a sample taken above high-water mark and 94 per cent. $CaCO_3$ in a sample between tide marks. The latter includes 2 to 3 per cent. $MgCO_3$.

Loch Ailsh [NC 32018 10811]: various exposures. (102. 5 N.E., S.E.) References: Peach and Horne, 1907, p. 403; Knox, 1941, p. 8.

Durness Limestone. Calcareous rocks of various types occupy a broad tract of country between Loch Ailsh [NC 32018 10811] and the main road from Lairg or Bonar Bridge to Lochinver. They also extend along a narrow belt into the hills of

Sutherlandshire north-eastwards from the loch for about a mile and a half (Figure 38).

The rocks are limestones and dolomites, greatly, hardened in places and rendered schistose by movement under pressure. They are very largely contact-altered by igneous rocks into marble with occasional calc-silicate bands. The marbles include brucite-, forsterite-, and diopside-bearing varieties. Good exposures of brucite-marble are to be found on the western side of the cart track leading to Loch Ailsh, within half a mile of the point where it leaves the main road from Bonar Bridge. Considerable quantities of brucite-marble could probably be obtained at this locality. Quarrying operations could be undertaken without much difficulty.

Ullapool: various exposures. (101. 8 S.W.; 14 N.W., S.W.) Reference: Gunn, 1907, pp. 409, 530–532.

Durness Limestone. Between Strath Kanaird [NC 13658 01168] and Ullapool [NH 12651 94232] (Figure 38), a distance of about 5 m., there are several detached areas of limestone belonging for the most part to Group II of the Durness Limestone. The largest outcrop of these rocks extends southwards for about a mile and a half from the high ground north of Loch na Maoile [NC 15993 00411] (4 m. N.N.E. of Ullapool) to Loch Ob an Lochain [NH 15054 98729] (8 S.W.; 14 N.W.). The outcrop varies in breadth from a few yards, west of Loch na Maoile, to nearly a quarter of a mile north of that loch. Between Loch na Maoile and Loch Ob an Lochain its average breadth is probably about 300 yds. The general dip is to E.S.E., but the rocks are considerably disturbed by numerous thrusts, and, in places, are studded with lenticular masses of grit, shale and quartzite.

A second fairly extensive outcrop of Durness Limestone, about half a mile long and up to a furlong broad, stretches across the valley of the Ullapool River about three-quarters of a mile below Loch Achall [NH 14957 95633] (14 S.W.). The rocks, which are traversed by numerous small thrusts, consist mostly of white limestone. They have been fairly extensively quarried and burnt for lime.

Overburden: In places the calcareous rocks between Strath Kanaird and Ullapool are obscured by a thin cover of drift, but in general they are bare or covered only by a short green grassy herbage which shows up in striking contrast to the surrounding dark heathery ground.

Access: The Loch na Maoile outcrop is nearly a mile from, and 500 to 600 ft. above, the main road to Ullapool as it climbs southwards out of Strath Kanaird; it is about 6 m. by road from Ullapool. The outcrop in the Ullapool River is about 2 m. from Ullapool with a road for less than half the distance.

Letterewe [NG 95161 72021]: disused quarry, on W. side of burn, about 200 yds. N.W. of the ruined house of Folais, about 700 yds. N. by W. from Letterewe. (92. 58 N.W.) References: Clough, 1907, pp. 233–235; 1913, pp. 34, 114.

Limestone in Lewisian Gneiss. The quarry, which is said to have been of considerable size, was connected with the shore of Loch Maree by means of a tramway, the remains of which are still be seen. The original quarry-face is now much obscured, however, and is difficult to make out. The limestone is probably about 20 ft. thick and dips at moderate, but varying, angles to N.E.

The upper 10 ft. or so are made up mainly of massive, fine-grained, white or pale cream-coloured limestone in which the carbonate is partly calcite and partly aragonite. Colourless phlogopite occurs as an accessory mineral. Interbedded with the massive limestone are subordinate, thinner beds of a pale cream-coloured limestone containing numerous small cavities, and a pale-brown flaggy limestone. Both types are slightly dolomitic and contain quartz and phlogopite in small amount as impurities. In the flaggy variety there is present also a small quantity of barytes, which occurs along with quartz and calcite in thin veins cutting the rock and also in the matrix of the rock itself. The lower 10 ft. or so consist mainly of pale-grey or brown flaggy dolomite, with grains of calcite set in a very fine-grained matrix of carbonate. Phlogopite, tremolite and tourmaline are abundant as accessory minerals. Towards the base of the limestone there are some very impure bands of a dull greenish colour containing biotite, chlorite and hornblende in greater abundance than carbonate. The above petrographical details are based upon specimens (SL 258) [NG 952 719] and (SL 259) [NG 951 720].

The limestone, striking N.W.–S.E., appears repeatedly higher up the burn to the north-west for about 700 yds.; while in a south-easterly direction from the quarry it can be traced intermittently for nearly 3 miles along the hill slopes above Inishglass and Coppachy (58 S.E.). A limestone, pyritic in places, is exposed about 160 yds. E. of Regoilachy [NG 98963 67952] and again about 580 yds. W.N.W. of Smiorasair [NG 99751 67074] (70 N.E.). Most of its outcrops are merely lenticles, but at the latter locality it can be traced for a quarter of a mile through several sharp folds.

Analyses of the limestone at Folais show as follows:

E. bank of Allt Folais, 620 yds. N. of Letterewe House (SL 258) [NG 952 719]: $CaCO_3$ 91.52; $MgCO_3$ 3.03; Insol. Res. 3.65.

W. bank of Allt Folais, 690 yds. N. of Letterewe House (SL 259) [NG 951 720]: $CaCO_3$ 56.94; $MgCO_3$ 32.90; Insol. Res. 7.12.

Applecross [NG 72462 44846]: old quarry on N. side of Kishorn road, 1,100 yds. S.E. of Applecross House and 1,600 yds. E.N.E. of the post office. (81. 102 S.W.) Reference: Lee, 1920, pp. 7, 12.

Limestone near the base of the Lias. The dip is N.W. at 12° to 16°, corresponding to the average slope of the ground in the area. Over 6 ft. of limestone can now be seen and much quarried rock is lying about. The drift cover is very variable, but there is probably at least an acre of ground in which it is very thin. The limestone is of good quality and low in magnesia. Road access is good. There is a small kiln which could easily be reconditioned. At Camasterach, 1½ in. S. of Applecross by road, there is a sheltered pier and reasonable facilities for coastwise shipment. The limestone is a grey, compact, oolitic rock with buff crust. The ooliths are 0.5 to 1.5 mm. diameter and are embedded in a very fine-grained matrix of calcite-mudstone with a few thin-walled shells and scarce grains of quartz. Analysis of the rock from the quarry (SL 253) [NG 727 447] gave $CaCO_3$ 93.96; $MgCO_3$ 2.09; Insol. Res. 2.89.

Loch Kishorn: several localities on the Lochcarron–Shieldaig road. (81. 103 S.W.; 110 N.W.) Reference: Peach and Horne, 1907, p. 416.

Durness Limestone. Limestone belonging to Groups I and II crops out from beneath the Kishorn Thrust on the left bank of the River Kishorn from Seafield [NG 83248 40361] to 1 m. N. of Tornapress [NG 84228 43301]. For about a mile in this area the limestone rises steeply up from the road and could be very easily opened out in a face of satisfactory height. Supplies are abundant. The principal drawback to its exploitation is the distance from agricultural districts of any size.

a. Roadside about 1,370 yds. N. of Tornapress Bridge. (103 S.W.)

Beds belonging to Group I crop out on the roadside near Couldoran [NG 84179 43293], at the northern end of the limestone outcrop. An analysis of limestone from this locality for agricultural purposes was carried out at the Macaulay Institute. It showed $CaCO_3$ 60.3; $MgCO_3$ 26.4; Insol. Res. 13.1.

b. Roadside 680 yds. S. of Tornapress Bridge [NG 83588 41604]. (110 N.W.)

Durness Limestone of Group II, lavender to reddish in colour, forms a cliff about 20 ft. high, the dip being to E. It is a compact dolomite with flinty fracture and containing numerous small grains of quartz. A spring issues from the limestone a short distance above the top of the cliff and forms a waterfall, depositing calcareous tufa. The tufa is sufficient in amount to be a useful source of lime for local use.

Analyses of the limestone and tufa gave as follows:

(SL 255) [NG 836 415] (limestone)	$CaCO_3$	47.76	$MgCO_3$	40.32	Insol. Res.	10.45

(SL 254) [NG 836 415] $CaCO_3$ 90.63 $MgCO_3$ 3.22 Insol. Res. 3.00 (calc-tufa)

c. Cliff on shore of Loch Kishorn 350 yds. S.E. of Seafield and about 120 yds. from the road. [NG 83237 40084] (110 N.W.)

Limestone of Group II, light-grey, mottled with red, and similar in character to (SL 255) [NG 836 415]. A face of bedded limestone about 25 ft. high, reasonably accessible. The dip is E. at 45°.

An analysis gave the following figures (SL 256) [NG 833 401]: $CaCO_3$ 49.91; $MgCO_3$ 39.74; Insol. Res. 8.39.

Keppoch: exposure on northern shore of Loch Duich, about 600 yds. W.S.W. of main road at Keppoch and about 1½ m. S.E. of Dornie. (72. 124 S.W.) [NG 89591 24122]

Lewisian limestone. Massive, pale-coloured limestone, 15½ ft. thick, dipping S.E. at about 45°. The limestone appears to be fairly pure though it probably contains a small percentage of calc-silicate minerals. It is of uniform quality except for 3½ ft. in the centre where shear planes roughly parallel to the dip render the limestone somewhat flaggy and more liable to erosion. In this central portion the percentage of impurities is likely to be rather higher than in the massive portions of the bed above and below.

The limestone can be seen at intervals on the steep hill-slope above the shore for at least 200 to 300 yds. along the strike. Access: very easy by sea, with deep water close off-shore; difficult by land.

Loch Alsh to Loch Hourn: various exposures. (71. 123 S.E.; 127 N.E., continued southwards through Inverness 47 N.E., S.E.; 62 N.E.) Reference: Clough, 1910, pp. 22–25, 172.

Lewisian limestone. Bands of limestone or marble can be seen at frequent intervals along the hill-sides between Totaig [NG 87514 25302] on Loch Alsh (Ross 123 S.E.) and Loch Hourn [NG 80555 11054]. The most common type consists of a white, rather coarsely crystalline matrix of calcite, often with some dolomite, mottled with small white, yellowish or greenish spots and streaks, formed of different silicates. It is doubtful whether a thickness of 50 ft. of limestone could anywhere be found without some admixture of other rock. None of the outcrops appears to have been quarried. Among many good exposures special mention may be made of the broad, repeatedly folded, band stretching from Totaig in a southwest direction for about 2½ m., and of a second band which crosses the Allt Easan Mhic Gorraidh [NG 85041 22130] (Ross 127 N.E.) nearly a mile W.N.W. of Beinn a' Chuim and passes southwards into Glenmore of Glenelg (Inverness 47 N.E.) [NG 84000 20098].

Roxburgh

The principal limestone resources of Roxburghshire are located in the region of Liddesdale ((Figure 14), p. 87), and at Carham east of Kelso. At one time, too, limestone was wrought at the high-lying localities of Limekilnedge, 10 in. S. of Hawick and of Carter Quarry, 10 m. S. of Jedburgh. At all the localities the limestone deposits are of Lower Carboniferous age. No quarrying has been done anywhere for many years.

Liddesdale

The limestone area of Liddesdale is a continuation of the Dumfriesshire outcrop described in pp. 90 and 91. The principal Roxburgh workings were located at Larriston [NY 54495 94440], 6 m. N.E. of Newcastleton, and at Thorlieshope [NY 57222 96406], beside Dead Water station on the Northumberland border. There are, however, numerous outcrops elsewhere on the Liddel Water and its tributaries, and the more important of these are mentioned below.

Like their counterparts in other districts, the cementstones of Liddesdale are compact, pale bluish-grey limestones, often weathering with a yellowish crust. They are typically developed in numerous thin beds, from a few inches up to two feet in

thickness, generally separated by thin courses of grey, blue or brown shale. They are characteristic of horizons in the Calciferous Sandstone Series and are present over a wide area around Newcastleton. In composition the cementstones are argillaceous, dolomitic, irony limestones. Because of their superior hardness the cementstone courses resist erosion better than the shales, and sections of these beds in cliffs and streams have a typical barred appearance, the cementstones standing out as light-coloured ribs. These beds in the past have occasionally been burnt for lime, but it is questionable if this use would be profitable at the present time. Such limestones, however, suitably mixed with shale, furnish the raw material necessary for the manufacture of rock wool.

Liddel Water and tributaries between Newcastleton and Liddel Bank (Dumfriesshire March). (11. New Series 40 S.E.; 42 N.E., S.E.: Old Series 45 S.W.; 48 N.W., S.W.)

Numerous bands of limestone, mostly thin, crop out in the Muir Burn, 5 m. S.S.W. of Newcastleton. One of these sources, however, opposite the farms of Upper Bankhead and Nether Bankhead [NY 45243 80358], has a thickness of about 8 ft. It was at one time quarried, but analysis (SL 203) [NY 453 802] shows it to be only of moderate quality: $CaCO_3$ 85.57; $MgCO_3$ 4.08; Insol. Res. 6.71. There is considerable overburden here, but 100 yds. N. of the highway the overburden is less on what is probably the same seam.

Two thicker outcrops of limestone occur at Liddelbank, on the Liddel Water 4½ m. S.S.W. of Newcastleton. One of these outcrops is 200 yds. E. of the house [NY 45780 79841], and the limestone, including shale partings, is 16 ft. thick. The other outcrop, 400 yds. N.E. of Greena Tower [NY 46334 81099], has a thickness of 15 ft. Neither is very accessible.

Limestone was formerly quarried and burnt at the confluence of the Tweeden Burn and Liddel Water, 1 m. S. of Newcastleton [NY 48261 86432]. The thickness of the seam here is 16 ft. and it passes under a cover of 8 ft. of shale and higher beds. The overburden increases away from the quarry. The limestone is disposed in massive beds alternating with shale partings. Some of the courses are rough and nodular, others are compact and horny in appearance. The analysis (SL 202) [NY 481 864] indicates a stone of moderate quality: $CaCO_3$ 82.69; $MgCO_3$ 6.48; Insol. Res. 8.45.

Newcastleton neighbourhood. (11. New Series 38 S.W.; 40 N.E., S.E.; 41 N.W.: Old Series 42 S.E.; 45 N.W., N.E.; 48 N.W.)

In the Liddel Water and its tributaries many sections of cementstones are exposed. Some of the best of these are listed below:

1. (New Series 38 S.W.: Old Series 42 S.E.) Hartsgarth Burn at Hartsgarth, 3 m. N. of Newcastleton [NY 49383 92485]; Hermitage Water, 250 yds. S. of New Greenholm (old lime kiln), 2½ m. N. of Newcastleton [NY 49951 91319].
2. (New Series 38 S.W., 41 N.W.: Old Series 45 N.E.) Harden Gill and Liddel Water at Harden [NY 51478 90342], 2½ m. N.E. of Newcastleton; Liddel Water and Liddel Castle (ruins) [NY 50972 89970], 2 m. N.E. of Newcastleton; Piper Burn, 100 yds. S. of Byreholm (old lime kiln) [NX 85125 94203], 1¾ m. N.E. of Newcastleton; Ryedale Burn at Roan [NY 48844 89589], 1 m. N. of Newcastleton; Liddel Water, ¼ m. S. of the outfall of the Ryedale Burn (old lime kiln) [NY 49102 88664], ¾ m. N. of Newcastleton; Liddel Water opposite mouth of the Black Burn [NY 48790 88416], ½ m. N. of Newcastleton.
3. (New Series 40 N.E.: Old Series 45 N.W.) Ralton Burn and Black Burn, in the vicinity of Woolhope [NY 47473 89383], 1 m. N. of Newcastleton.
4. (New Series 40 S.E.: Old Series 48 N.W.) Short Sike [NY 47789 87137], a streamlet joining Liddel Water from the west at the south end of Newcastleton; right bank of Liddel Water opposite Mangerton [NY 47614 85611], 1 m. S. of Newcastleton; stream at Cook Knowe, ¼ m. S. of Mangerton [NY 48024 85142]; Stanygill Burn [NY 45494 85700] and Black Grain [NY 45387 86061], 2 m. W.S.W. of Newcastleton.
5. (New Series 40 S.E.: Old Series 48 N.W.) Tinnis Burn [NY 46444 83537], 2½ m. S.S.W. of Newcastleton.

At all these localities typical sections of alternating cementstones and shales crop out. Lime kilns; as noted, were formerly in operation at several places, but the burning was never on a large scale.

Larriston Lime Works [NY 55644 93740]: Larriston Burn 1 m. E. of Hewisbridgeend, 6 m. N.E. of Newcastleton. (11. New Series 38 N.E.: Old Series 43 S.W.)

Limestone was at one time extensively worked and burnt here, but the quarries have long since been abandoned and the sections are now badly obscured. The best exposure reads: shale, 12 ft, (at top); limestone, 2 ft. shale, 2 ft.; limestone, 1 ft.; shale, 2½ ft.; limestone, 6 in.; shale, 1½ ft. limestone (main worked band), 8 ft. The dip is to E. at 5°. The overburden is fairly heavy, increasing in the direction of dip of the beds.

In the adjacent stream, at a lower horizon than the worked seam, two other limestone beds, 5 ft. and 3 ft. thick, crop out.

The limestone (SL 201) [NY 552 937] is of good quality, yielding on analysis: $CaCO_3$ 91.45; $MgCO_3$ 4.20; Insol. Res. 2.69.

Thorlieshope Lime Works [NY 59922 97764]: 400 yds. S. of Hob Knowe, ¾ m. N.W. of Dead Water railway station, 4 m. E. of Riccarton Junction. (17. New Series 36 S.W.: Old Series 39 S.E.)

The long-abandoned quarries are now partially obscured. There are several outcrops, in the best of which 6 ft. of limestone are exposed under 10 ft. of rock and drift. The dip is to S. at a low angle. Reserves are probably large, and working could be extended along the strike. There are old kilns in the vicinity. Access by road and rail is convenient. The analysis shows the rock (SL 200) [NY 592 975] to be a dolomitic limestone: $CaCO_3$ 79.16; $MgCO_3$ 12.61: Insol. Res. 5.33.

South and south-east of Hawick

Limekilnedge [NT 53806 01613]: 1 m. S.S.W. of Robert's Linn Bridge and 9 m. S. of Hawick. (17. New Series 35 N.W., N.E.: Old Series 39 N.W.)

Outcrops of two bands of cornstone in the Calciferous Sandstone Series have been traced for about 1½ m. on the rising ground to the east of the Hawick–Newcastleton road near Limekilnedge. The beds were quarried at Stitchhill Quarry, 600 yds. S. of Limekilnedge (35 N.W.), at Stobs Quarry, Limekilnedge (35 N.W.) and at Outer Knowehead, ¾ m. to N., on the margin of the stream leading down to Robert's Linn Bridge (35 N.E.). The beds are now largely obscured, but in Stobs Quarry 5 ft. of cornstone are still visible under a cover of rock and drift. The dip of the strata here is to E. at 11°. The quarry might be extended to the north.

The analysed sample, from Stobs Quarry (SL 208) [NT 53816 01368], indicated only a moderately pure limestone: $CaCO_3$ 83.18; $MgCO_3$ 1.30; Insol. Res. 13.97.

Carter Quarry [NT 66458 04355]: 10 m. S. of Jedburgh and 3½ m. S.E. of Southdean. (17. New Series 31 S.E.: Old Series 34 S.W.)

There is an abandoned quarry with kiln at this locality. The thickness of the seam is 13 ft. and it dips at a low angle under 15 ft. of rock. Reserves are substantial, but overburden is probably everywhere heavy. The situation is remote, 1,300 ft. above 0.D., and access is by a rough track 2 m. long joining the Jedburgh–Newcastle highway 2½ m. eastwards of Southdean.

There was an older quarry in this outcrop at Dun Tae [NT 65333 03724], an equally remote site, about 1 in. S.W. of Carter Quarry.

Kelso district

Carham Quarries: 5 m. N.E. of Kelso. (26. New Series 6 S.E.; 7 S.W.: Old Series 6 S.E.)

At this locality a dolomite, known as the Carham Limestone, was formerly extensively worked both in Roxburgh and Northumberland (Carruthers, 1932, pp. 47–51). There were two principal Scottish quarries, both in the neighbourhood of

Carham railway station.

a. Quarry at railway side, 400 yds. W. of Carham station. [NT 78875 36953]

A thickness of 16 ft. of dolomite is exposed in beds flat or inclined at a low angle under little or no overburden. The situation and accessibility are very good and reserves are extensive. The outcrop extends eastward to the south of the station, close to which the kilns are situated. In the other direction, the outcrop carries south-westward past Hadden, and there was formerly a quarry, now filled up, on the south of the road, 1,000 yds. W. of this farm.

The dolomite is a fine-grained, white or cream-tinted rock, massive and jointed in the quarry face. The analysis (SL 221) [NT 790 368] indicates $CaCO_a$ 55.33; $MgCO_3$ 38.95; Insol. Res. 5.20. There is thus an excess of 9 per cent. of calcium carbonate over that needed for the dolomitic ratio.

b. Nottylees Quarry [NT 79619 36815], 600 yds. S.E. of Carham station.

This quarry also is abandoned. The best section shows 3½ ft. of dolomite over 2 ft. of chert, over dolomite seen to 8 ft. There is a cover of sandstone in parts. The dip of the strata is to E. at a low angle. Accessibility is good, but further extension of the quarries would be difficult. A feature of this part of the outcrop is the thick band of chert in the middle of the dolomite.

The analysed sample (SL 220) [NT 795 368] shows $CaCO_3$ 53.15; $MgCO_3$ 42.31; Insol. Res. 3.30. The excess in this case is rather less than 3 per cent. of calcium carbonate over that required to satisfy the dolomitic ratio.

Selkirk

The county of Selkirk is composed entirely of rocks of the Ordovician and Silurian formations, overlain by glacial and alluvial deposits. In this part of the country these rock groups contain no 'calcareous beds either pure enough or thick enough to be of economic use.

Shetland

Shetland has very extensive reserves of crystalline metamorphic limestone with a calcium carbonate content of 80 to 90 per cent. It occurs as somewhat lenticular beds in the Metamorphic Series, the limestone zones being in some cases many miles in length and of considerable width (Figure 36). The limestone zones traverse the Mainland in a general N.—S. direction and are concentrated for the most part in the central portion of the island, between Scalloway on the south and Mossbank on the north. There is also a thinner zone of limestone in North Maven running from Brae northwards to Collafirth. Of the outlying islands, Unst and the Out Skerries are the only ones possessing limestone in workable quantity.

The principal limestones occur in three main belts: (1) the Weisdale Limestone, which extends north from Weisdale through Voe to Dales Voe (E. of Brae), a distance of 14 m. with an average width of nearly half a mile; (2) the Whiteness Limestone, which extends for 12 m. from Whiteness northwards to Petta Dale with a width of ■ m.; (3) the Tingwall Limestone, which extends north from Scalloway up the Tingwall valley and through Girlsta for a distance of 12 m. with an average width of ¼ m. The Weisdale and Tingwall limestones each divide into two branches towards their southern ends. The limestones at North Nesting and at Vassa, trending N.E.–S.W. on the east side of the Nesting Fault, are probably the equivalents of the Whiteness and Tingwall limestones respectively. In nearly all cases the beds of limestone are highly inclined, often practically vertical. As has already been noted, the development of the limestone is lenticular in character, from which it follows that the belts of limestone noted above, though continuous for miles as calcareous zones, are not in most places composed of solid limestone throughout their width of outcrop. There are, however, easily accessible areas in which limestone of good quality can be obtained, and the most promising localities are detailed below. In most cases the superficial deposits are very thin.

In hand specimen the Shetland limestones are finely to coarsely crystalline in appearance and usually dark to light grey in colour, passing in places into pink shades. Typical beds are composed essentially of anhedral grains of calcite about 1 mm. in length, interlocking or cemented by finer granular calcite. The interstitial granular calcite seems to have been produced by trituration. Quartz and muscovite are the usual accessories and are sometimes abundant. There is also usually a little, finely divided, opaque matter, mainly iron ore and including pyrites. Dolomite is not usually seen under the microscope. The impurer bands show various other minerals, but these are of little practical importance

Shell sand occurs at a few localities, as at Sumburgh [HU 39794 09739] and Scousburgh [HU 37367 18021] in the Dunrossness district, at Hillswick [HU 28162 76874] and Esha Ness [HU 22391 78741] in North Maven, at Cullivoe [HP 54322 02542] in Yell, and at Uyea Sound [HP 58851 00692] in Unst. It is not considered of much account in Shetland, however, as the lime content is not generally very high and, with the exception of the Dunrossness localities, the extent of the deposits is small. Oven-dry samples from the areas mentioned gave the following percentages of calcium carbonate: Sumburgh, 66; Scousburgh, 58 and 66; Hillswick, 58; Esha Ness, 35; Cullivoe, 39 and 50; Uyea Sound, 76 and 84.

Fladdabister [HU 44131 32288]: 6 m. S.S.W. of Lerwick. (126. 59 N.E.)

Metamorphic limestone. Pink and blue crystalline limestone forms the Ness of Fladdabister and extends thence to the south-west for a distance of over half a mile with a width of about 440 yds. It is cut off on the west by a fault. There is a good deal of schist interbanded with the limestone in some places. The dip is mainly N.W. at 20° to 35°. The locality is easily accessible from the Fladdabister–Okraquoy road. Reserves are abundant and overburden is negligible.

A smaller outcrop of the same limestone, about 300 yds. square, occurs in the Bay of Okraquoy [HU 43932 31513], half a mile south of Fladdabister on the south side of the bay. The dip in this case is mainly N.N.E. at about 40°. On analysis this limestone (SL 184) [HU 437 324] showed the following percentages: $CaCO_3$ 89.64 $MgCO_3$ 2.01; Insol. Res. 6.37.

Berry [HU 40253 39986]: ■ m. N. of Scalloway. (126. 56 N.W.)

Tingwall Limestone. Quarry in the western branch of the limestone. The outcrop of limestone is about 100 yds. wide, and the dip is W. at 70° to 80°. It is accessible by farm road and reserves are abundant. Analysis (SL 185) [HU 403 402] gave percentages as follows: $CaCO_3$ 82.37; $MgCO_3$ 1.78; Insol. Res. 13.19.

Outnabreck [HU 40987 40606]: 1 m. N.N.E. of Scalloway. (126. 52 S.E.)

Tingwall Limestone. A quarry has been opened in the eastern branch of the limestone, the outcrop of which is about 230 yds. wide. The dip is E. at 80° to vertical. This stone has been used locally for road metal and is easily accessible. There is very little cover and reserves are abundant. An analysis (SL 186) [HU 410 411] showed the following percentages: $CaCO_3$ 80.41; $MgCO_3$ 2.99; Insol. Res. 13.27.

Whiteness [HU 40074 47945]: W. side of Loch of Strom, near Whiteness Church. (128. 48 S.W.)

Whiteness Limestone. There are numerous old quarry-holes in the limestone outcrop, which is from a quarter to half a mile in width at the south end of the Loch of Strom. The beds show a good deal of contortion in many places. The dip of the foliation is W. at about 70° to vertical. The locality is easily accessible and reserves are abundant. Overburden is negligible. The percentage composition of the stone (SL 188) [HU 393 476] is as follows: $CaCO_3$ 88.26; $MgCO_3$ 2.11; Insol. Res. 9.46.

Girlsta [HU 43035 50548]: near shore of Wadbister Voe and 550 yds. N.E. of Girlsta school. (128. 48 N.E.)

Tingwall Limestone. The width of the limestone belt in this area is about 300 yds. and a quarry has been opened near the middle of the belt. The drift cover is thin. The limestone is banded and lensed with calcite and a little quartz, but was comparatively free from impurities where seen in 1931. The dip is W. at 65° to vertical. Reserves are abundant for about 440 yds. southwards to the shore of Wadbister Voe. To the north towards Loch Girlsta there may be a fair amount of drift cover in places. Easy access is provided by a cart road, both westwards to the main road and eastwards to a jetty on

Wadbister Voe about 200 yds. from the quarry. The quarry has been worked intermittently for many years, and the stone burnt in a kiln on the spot.

Analysis of material from Girlsta (SL 187) [HU 429 509] showed percentages as follows: $CaCO_3$ 76.47; $MgCO_3$ 3.41; Insol. Res. 16.73, including SiO_2 11.02.

Laxfirth [HU 43382 46835]: on the Hillswick road, 4 m. N.W. of Lerwick. (128. 48 S.E.)

Metamorphic limestone. Old quarries in the western portion of a crystalline limestone just east of the Nesting Fault. The limestone belt trends N.N.E. –S.S.W. and is about 450 to 500 yds. wide. The dip of the foliation is W.N.W. at 70° to 75°. Where seen 440 yds. S.S.W. of Laxfirth House it is much contorted. There are ruined kilns near Laxfirth House, but no records of working. Accessibility is good. Reserves are fairly considerable.

Vassa [HU 46187 53268]: 2 m. E. of the main Lerwick–Hillswick road at the N. end of Loch Girlsta [Vassa Voe?]. (128. 44 S.W.)

Metamorphic limestone, possibly a faulted portion of the Tingwall Lime stone. A zone of banded limestone about 600 yds. wide, trending N.E. from Vassa Voe to the East Voe of Skellister [HU 47315 54808], a distance of 1½ m. There is a good deal of schist-interbanding in places, but limestone is predominant. The dip is generally N.W. at 40° to 60°. There are numerous old quarry holes, but the occurrence has not been much worked. It is easily accessible from the North Nesting road, and reserves are abundant.

There are several bands of limestone, mostly thin, in the injection belt north-west, of the Vassa limestone belt.

Gletness [HU 46850 51285]: S.E. seaboard of the peninsula of S. Nesting and 1 m. S.E. of Vassa. (128. 49 N.W.)

Metamorphic limestone, apparently a continuation of that at Laxfirth, occurs in an outcrop about a mile in length from N.E. to S.W. and 100 to 300 yds. wide. It is interbanded with schist in places. The dip is N.W. at about 40° to 55°. The locality is fairly accessible. Reserves are considerable on Glet Ness [HU 47526 51959] at the north end of the outcrop.

Weisdale [HU 39457 53153]: Quarry on W. side of road, 1,050 yds. S. of Flemington. (128. 43 S.W.)

Weisdale Limestone. There is a considerable amount of interbanding with schist, and the stone as a whole was found to be poor in quality. It showed the following percentages (SL 189) [HU 392 538]: CaO 35.03; MgO 3.58; CO_3 29.07; Insol. Res. 30.85. On treatment with acetic acid it gave $CaCO_3$ 60.61 and $MgCO_3$ 4.01.

Voe [HU 40388 62765]: area S. of the village. (128. 37 S.W.)

Weisdale Limestone. In places the limestone outcrop is nearly half a mile wide, and excavations occur at Kirkhouse [HU 40269 62564], Flett [HU 40229 62100], Hamarigrind [HU 40292 61628], etc. Access is generally easy, and reserves are abundant.

Sursetter [HU 40951 65423]: 1½ m. N. of Voe. (128. 37 N.E.)

Weisdale Limestone. The limestone outcrop is about 500 yds. wide. It has been quarried in several places, both at Sursetter, in an excavation on the east side of the road 250 yds. N.E. of the farm house, and also farther to the north through Dale [HU 41174 68462] to Dales Voe (30 S.E.). It reappears on Fora Ness, still farther north-east, where it terminates against a fault. Access is easy, and reserves are very large. Analysis of the stone (SL 190) [HU 411 655] showed the following percentage composition: $CaCO_3$ 88.04; $MgCO_3$ 1.80; Insol. Res. 9.63.

North Maven: Burraland [HU 34299 75258], Sullom, 4 m. N. of Brae. (130. 24 S.E.)

Metamorphic limestone. Numerous scattered bands and lenses of limestone lie in a belt of calcareous schists that extends northwards from west of Brae to Ollaberry. There are many old quarry-holes and a ruined kiln at Burraland, but no records of working. The analysed sample (SL 191) [HU 344 744] is from an old quarry 250 yds. S. of the Loch of Burraland near its east end [HU 34506 74505]. The limestone is accessible in places and reserves are considerable. The analysis showed as follows: $CaCO_3$ 84.80; $MgCO_3$ 1.53; Insol. Res. 12.12.

Out Skerries [HU 68158 71840]. (128. 33 N.W., N.E.)

Metamorphic limestone. A belt of crystalline limestone 300 to 500 yds. wide extends from east to west across this small group of islands. The outcrop is irregular and the limestone is highly contorted in places, but there are considerable areas free from serious interbanding with the associated schists. It is readily accessible and reserves are abundant.

Unst: Westing [HP 57384 05792], 3 m. S.W. of Balta Sound. (131. 5 S.W.; 8 N.W.)

Westing Limestone. A belt of limestone interbanded with schists forming a continuous outcrop 4½ m. long in N.–S. direction with a width varying from 50 to 300 yds. There are several old quarry-holes but no records of workings. The limestone is accessible in places and reserves are considerable.

Isolated masses of limestone occur at Snarbrough and Ness of Wadbister, south-west of the southern end of the main outcrop.

Unst: Loch of Cliff [HP 60020 10436], 2 m. N.W. of Balta Sound. (131. 2 S.E.; 5 N.E.)

Metamorphic limestone. An outcrop of crystalline banded limestone about 880 yds. long by 200 yds. broad, at the south end of the east side of the loch. There are several old quarry-holes, but no records of working. The locality is accessible and reserves are considerable.

Stirling

Stirling has been a small producer of lime for many years, chiefly from the Lower Limestone beds of the Lennoxtown area [NS 62791 77811] (Figure 37). Reserves are scanty and uncertain, however, and there is little prospect of further development in the county, except possibly by mining in the ground south of the town of Stirling. Of calcareous rocks depending for potential value on characters other than a high lime content, the altered serpentine at Balmaha on Loch Lomond and the cementstones of Ballagan are worth notice.

The Upper Limestone Group of the Denny and Plean area contains no limestone of economic value. At the extreme eastern end of the county (Figure 41) the Castlecary Limestone crops out in the railway cutting just east of Manuel station [NS 97172 77178] (31 S.E.), 1½ m. W. of Linlithgow. An analysis showed as follows: $CaCO_3$ 54.64; $MgCO_3$ 31.08; Fe_2O_3 7.13; Al_2O_3 2.57; SiO_2 1.10. This indicates a ferro-dolomitic composition similar to that of the cementstones. The analysis was made by Messrs. Colvilles, Ltd.

Balmaha. (38. New Meridian and New Series 13 S.E.) Reference: Du Toit, 1905, p. 324.

A band of brecciated and carbonated serpentine, 300 ft. wide and with N.E.–S.W. trend, lies in the Highland Boundary Fault zone of disturbance on Druim nam Buraich [NS 42012 91582], 650 yds. N. by E. of Balmaha Pier (Figure 32). It was formerly worked in a small quarry just east of the road. The rock weathers a bright orange, but is grey, purplish or reddish on a fresh surface. Patches of less altered serpentine may be seen, and in places there are thin quartz veins. The rock has the composition of a siliceous dolomite and might be considered as a raw material for the manufacture of rock wool. An analysis by C. O. Harvey (Geol. Surv. Lab. No. 1343) showed $CaCO_3$ 26.8; $MgCO_3$ 25.9; SiO_2, Al_2O_3 and Fe_2O_3 46.3. It could be quarried close to the road. Reserves are immense, as the band, which is nearly vertical, has been traced to the N.E. for over a mile.

South-westwards, the continuation of this same zone of serpentine is to be found on Inchcailloch [NS 40898 90491] in Loch Lomond. Its further extension in this direction is referred to under Dumbarton (p. 86).

Similar rock occurs in a branch of the Highland Boundary Fault, half a mile to the north-east of Balmaha, on the north side of Arrochymore Point [NS 41100 91960]. It was once worked in a quarry on the north side of Creag Mhor, and calcined in an old limekiln near at hand. The band is not so wide here, and could not be so readily quarried as at the outcrop nearer Balmaha.

Dolomitized serpentine associated with the Highland Boundary Fault is also found farther to the north-east, in Perthshire (p. 152) and Kincardineshire (p. 128).

Murrayshall Limestone Mine: Cambusbarron, 1½ m. S.W. of Stirling. (39. New Meridian and New Series 17 N.W.)

The Murrayshall (Hurlet) Limestone crops out on the west side of Gullies Hill [NS 77300 90781], [NS 77019 92165], [NS 76837 91572], S. of Cambusbarron (Figure 37), and underlies the Stirling dolerite sill throughout the area. The old workings were entered by an adit driven from Cambusbarron southwards to cut the limestone through an E.–W. upthrow fault. The worked area extends under a considerable part of the hill. There are ample reserves, but as these are mostly to the dip, eastwards, they are below adit level, which is about 44 ft. above O.D. Further work would thus probably entail some pumping. The average thickness of the limestone is 6 ft. and the dip is N.E. at about 6°. Both roof and pavement are of limy shale, but the old workings have stood up well and are for the most part still accessible. The adit level also is open. Road and rail facilities are good.

The quality of the Murrayshall Limestone (SL 159) [NS 7712 9217] is shown by the following percentage figures: $CaCO_3$ 86.56; $MgCO_3$ 2.28; Insol. Res. 8.18. In petrographical character it is a black, compact, fine-grained limestone showing conchoidal fracture. Specks of pyrite and crinoid columnals are sparsely distributed. In thin section it is found to consist of a turbid, very fine-grained matrix of calcareous debris and probably some clay, in which are numerous fragments of shells, etc.

There are other old workings in the same limestone under Gillies Hill at Craigend Lime Works [NS 76666 90684], Sauchie, 2½ m. S.W. of Stirling (17 S.W.). They are not so extensive as those at Cambusbarron, however, and have not been investigated in detail. The development of the seam is similar. There is convenient access by road.

Ballagan Burn [NS 57239 80050]: 530 yds. N. of Ballagan House and 1,500 yds. N.E. of Strathblane. (30. New Meridian and New Series. 27 N.W.). Reference: Bailey, 1925, pp. 11–13.

The Ballagan Beds consist of alternating layers of cementstone, marl and manly shale. The cementstone occurs as well-defined ribs 2 to 8 in. thick and as bands of manly cementstone with relatively hard centres and soft margins merging into manly blaes. The total thickness seen in the section is about 100 ft. and the dip is N. at 10°, under a basalt escarpment. Reserves are very large. Access is through private ground from the Lennoxtown-Strathblane road.

The samples are all dull grey, compact rocks in hand specimen. In thin section they show aggregates of rhomboid and granular carbonate, chiefly dolomite, with grains of quartz and patches of brownish argillaceous matter.

Two samples of the cementstone proper have been analysed. Analysis (a) is of a single band, analysis (b) of a bulk sample of eight bands selected at random from the cliff face. The similarity in the resulting figures points to great uniformity in the composition of the cementstones. They are dolomites, with small percentages of iron carbonate, some free calcite, and a larger percentage of alumina than is usual in Carboniferous limestones, except those of the calmy ' type. Analysis (c) is of a hard manly bed with no clearly defined margins but grading into soft manly shale. Here again there is little calcite in excess of the dolomite ratio, but the analysis shows marked increase in silica, alumina and potash. Analysis (d) is of the third type of sediment in the sequence, namely, mainly shale which shows only slight effervescence in hand specimen. This is reflected in the low figure for lime. These analyses should be compared with those of the material from Murroch Glen (p. 86).

	(a) (SL 193) [NS 5221 8014]	(b) (SL 192) [NS 5221 8014]	(c) (SL 195) [NS 5221 8014]	(d) (SL 194) [NS 5221 8014]
SiO_2	6.65	7.70	13.33	46.97
Al_2O_3	2.51	2.25	4.76	14.33
Fe_2O_3	0.46	0.82	2.87*	6.01*
FeO	1.38	1.18		
MgO	17.32	15.91	15.35	6.58
CaO	28.06	29.80	23.98	5.61
Na_2O	0.10	0.08	0.12	0.20
K_2O	0.76	0.58	1.33	3.94
H_2O-	0.48	0.33	1.03	3.30
TiO_2	0.13	0.11	0.22	0.65
P_2O_5	0.10	0.02	0.10	0.06
MnO	0.13	0.12	0.19	0.05
CO_2	39.49	39.93	34.01	7.36
FeS_2	0.39	0.13	0.48	0.13
Volatile Matter	1.67	1.14	2.14	4.57
Total	99.63	100.10	99.91	99.76
Insol. Res.	10.68	11.55	21.40	71.48
$CaCO_3$	50.07	53.18	42.80	
$MgCO_3$	36.21	33.28	32.10	
Spec. Grav.	2.77	2.78	2.77	2.64

* Includes FeO

The same cementstones, lying flat, are again well exposed in Jenny's Glen [NS 55587 79860], Blanefield, 1 m. W. of Ballagan Burn.

Lennoxtown. (31. New Meridian 27 S.E.; 28 S.W.; 32 N.E.: New Series 27 N.E., S.E.; 28 N.W., S.W.; 32 N.E.) References: Dinham, 1925, pp. 40, 41; Haldane, 1937, pp. 15, 16, 141.

Hurlet Limestone. In the area around and south-west of Lennoxtown the Hurlet Limestone has been quarried and mined along with the underlying alum shale and coal for well over 200 years. The following may be taken as indicating the development at Boydsburn [NS 63166 77006] (28 S.W.) and Balglass [NS 61980 77689] (27 S.E.) where the limestone and coal were worked until a few years ago: limestone, 3 to 6 ft.; alum shale, 2 to 6 ft.; coal, 2½ to 4½ ft. The field can be considered for practical purposes as worked out, but it is possible that reserves workable by mining may exist in the shallow syncline believed to lie beneath the alluvial flats of the Glazert Water, ¾ m. W. of Milton (28 S.W.).

An analysis by J. S. G. Wilson (in Dinham, 1925, p. 245) of the Hurlet Limestone, 3½ ft. thick, from Sculliongour Mine [NS 62650 79081], ¾ m. N. of Lennoxtown (27 N.E.) showed 52.74 per cent. CaO and 0.98 per cent. MgO; equivalent to 94.10 per cent. CaCO, and 2.05 per cent. $MgCO_3$.

Sutherland

Sutherland contains very large reserves of limestone, both at Durness [NC 39904 54282] and Eireboll [NC 45379 60470] in the north-west of the county and in the Assynt district (Figure 38), (Figure 39) and (Figure 40). These localities are so far from any industrial centre, however, that the rock has not as yet been exploited, apart from very local use as a roadstone. At Durness the limestone is partly low in magnesia and partly so highly magnesian as to be in many instances almost a pure dolomite. At Eireboll and Assynt, on the other hand, the whole of the limestone sequence is composed of dolomite. In addition to the unaltered calcareo-magnesian beds, there are deposits of brucite-marble in the Ledbeg [NC 23853 13469], Elphin [NC 21421 11509] and Loch Urigill [NC 23618 10271] areas. These are produced as a result of the contact metamorphic action of intrusive igneous rock on dolomite. In the account of the limestones and dolomites of Sutherland full use has been made of the work of Mr. J. Knox (Knox, 1941).

The county of Sutherland has very little limestone apart from that of the Durness formation. At Shiness, on the west side of Loch Shin, there is a band of crystalline limestone which has attracted much attention from time to time, not primarily because of its inherent quality, but because of its situation within reasonable reach of the eastern coastal belt of Caithness, Sutherland and Ross and Cromarty. This agricultural area is, indeed, without a convenient local supply of lime if the shell sand of John o' Groat's is discounted; and until recently there was no real demand for a product of this latter type owing to unfamiliarity with its character and properties. Full examination of the Shiness occurrence makes it clear that it is of such irregular quality and disposition as to rule it out as a source of any considerable quantity of good limestone, though lenses of crystalline calcite of high quality are to be found in it.

Shell sand occurs at several places along the north and west coasts of Sutherland, chiefly near the mouths of the principal estuaries. Amongst the more accessible are those north of Durness [NC 36997 68332], on the west side of the Kyle of Tongue [NC 59261 60903], and at Bettyhill [NC 69490 61867]. Between Durness and Fair Aird [NC 39085 69244] — (Figure 39) about three-quarters of a square mile of ground is covered with sand dunes, the average thickness of sand in thee area being probably about 15 to 20 ft. The sand is highly calcareous in many places and is, indeed, a shell sand throughout its extent, but on the average it is not likely to yield over 60 to 70 per cent. $CaCO_3$. It is suitable in grain for agricultural needs, but too fine for poultry grit.

It is reported that extensive deposits of shell sand occur at Achmelvich, about 3 m. N.W. of Lochinver (1-in Sheet 107) [NC 05398 24599]. Samples obtained by the Ministry of Agriculture and Fisheries showed the following percentages of calcium carbonate: north bay, high water, 60; north bay, low water, 79; south beach (four samples), 82 to 84.

Detailed examination of the accessible shell sand deposits in Sutherland would be required in order to assess their potentialities, but on the whole it hardly seems likely that any of them could rival the John o' Groat's occurrence in Caithness.

Two other types of calcareous rock in Sutherland require mention. On the north coast a limestone in the Middle Old Red Sandstone was formerly worked between Strathy [NC 83137 65538] and Baligal [NC 85423 65912] ((Figure 13), p. 83). This material is not now worth consideration. Again, Jurassic limestone in thin beds is to be found on the east coast at Portgower, Brora and Golspie. It is of such poor quality, however, that there is little likelihood of its ever again proving of value for lime; and reserves are not sufficient to make it worth investigation as a source of cement.

Durness Limestone

Stratigraphical succession

The dolomites of Sutherland, along with the associated beds of limestone and layers of chert, constitute what is known as the Durness Limestone formation (Figure 39) and (Figure 40). It is usually referred to as being of Cambrian age, but the upper part is now generally regarded as belonging to the Lower Ordovician. The Durness Limestone is subdivided into seven lithological groups, and these are shown below in descending order. The thicknesses given are those estimated for the Dumess district, where alone the whole sequence of the formation is present. The names of the groups in brackets are derived from localities in that area, but corruption of the. Gaelic words during the process of anglicisation has been so great that it is more convenient to use the group numbers.

The descriptions and thicknesses of the different groups are based on the original mapping, with some additions and modifications introduced as a result of recent visits made for the purpose of assessing more precisely the economic possibilities of the limestone and dolomite.

	Approx. Thickness Ft.	Estimated Thickness of Group Ft.
Group VII (Durine)		

Fine-grained, light-grey dolomites and limestones, with some mottled dolomite bands. The rocks of this group are much sheared and altered because of their proximity to the zone of thrusting		150+
Group VI (Croisaphuill)		
Lilac and grey limestones (1), weathering light-grey; mainly fine-grained calcite-mudstone types. Much sheared in places, and not fully exposed	130	
Alternating beds of grey to black dolomite and white to grey limestone, in a rhythmic sequence (2), the basal dolomite bed (3) being 60 ft. thick	180	
Dark to light grey, knotty-weathering, compact limestone (4); very fossiliferous, especially near the top; the colour on weathering changes gradually from light-grey at the bottom to dark-grey at the top	140	450
Group V (Balnakiel)		
Dark-grey limestones and dolomites, alternating; individual beds not over 10 ft. thick, but sequence not fully exposed	90	
Grey limestone, compact, with black chert nodules; some beds of considerable degree of purity (5); some calcareous shale interbedding in middle	100	
Limestone, mainly calcite mudstone, with some thin beds of grey dolomite; a white limestone, 8 ft. thick, at the base, with fossils	90	280
Group IV (Sangomore)		
Grey limestone and brown to grey dolomite, in alternating beds; a very finely bedded dolomite mudstone 20 ft. thick at the top; also some fossiliferous limestone beds in top half	120	
Grey crystalline dolomite	10	
Calcite mudstone, white, cream, lilac and grey, porcellanous in texture	20	
Light-grey crystalline dolomite	20	
Two beds of chert (6), each 5 to 10 ft. thick and separated by 5 to 10 ft. of dolomite	20	190
Group III (Sailmhor)		

Alternating beds of grey and black mottled, medium-grained, crystalline dolomite (leopard stone) and grey, fine-grained, flaggy to ma..s.sive crystalline dolomite; individual beds normally ranging from 2 to 10 ft. in thickness; two very distinct mottled beds at the base (7). Beds in upper half much broken by faulting. Chert in bands and lenses, more abundant towards the top	90	
Grey, crystalline, medium to fine-grained dolomite; beds and lines of nodular chert, abundant at the base but becoming much smaller and scarcer upwards	130	220
Group II (Eilean Dubh)		
Light grey to pink, dolomitic mudstone, thin-bedded to 2-ft. posts. Small-scale 'knoll' or 'algal' structure in thin beds at intervals. Two faults of unknown size present. A bed with millet-seed sand grains about 10 ft. from the top (8)	150	
Grey to pink, finely bedded, dolomitic mudstone. A few thin millet-seed quartz grain bands and a thin lens of pisolitic dolomite near the top.		
Nodular to stylolitic dolomite band (9), at base	25	
Bedded dolomitic mudstone, grey; a few lenses several inches thick, near the top, containing millet-seed quartz grains	20	
Finely bedded, light-grey, dolomitic mudstone, rather argillaceous in appearance in some beds	60	
Massive to thick-bedded light-grey dolomite; a band of brecciated dolomite 6 in. thick about 15 ft. from the top	65	
Gap between lowest dolomite seen on Eileen Dubh and estimated position of top of Group I	20	340
Group I (Ghrudaidh)		
Dark-grey, compact, flaggy dolomite, passing into light-grey, crystalline, massive to Baggy dolomite by alternation in the top 5 to 10 ft.		100
Total estimated thickness		1730+

Notes

(1) The lilac and grey limestones are best exposed north of Durine. There does not appear to be much dolomite interbedded with them, The reddish ferruginous films mainly responsible for the lilac appearance appear to lie along the

numerous shear surfaces in the rock and seem to be due to the shearing out of nodules of more magnesian and of non-calcareous material in the unaltered rock.

(2) The rhythmic unit is composed of three members, namely (1) smooth, light-grey calcite mudstone weathering white, passing up into (2) knotty-weathering gastropod limestone as at the base of Group VI, succeeded by (3) dark-grey dolomite with chert. This is repeated at least six times in a thickness of 100 ft., the best developed examples having an amplitude of about 10 ft.

(3) A crystalline, dark-grey to black, even-grained dolomite, weathering with rounded outlines like the mottled dolomites in Group III.

(4) This limestone is in three fairly distinct bands, the lowest 40 ft. being light-grey on the weathered surface, the middle 40 ft. medium-grey, and the top 60 ft. dark-grey. The knotty weathering is chiefly due to the difference in character of the limestone composing the fossil remains from that composing the interstitial material, the former being mainly dolomite, the latter calcite (Peach and Horne, 1907, pp. 379–380); but in part it is also due to the association of chert with the fossils. The fossil form or outline is in many cases preserved in the coarser-grained dolomite, whilst the interstitial material is fine-grained and compact calcite. The edges of the fossils are in places picked out in chert.

(5) In a stratigraphical thickness of 160 ft. of beds investigated by Mr. Knox, only some 20 ft. were found to be dolomitic (*see* below regarding beds low in magnesia).

(6) These two chert beds are amongst the most conspicuous and most useful index-beds in the Durness sequence. They break up on weathering into small angular fragments which form a good surface feature. The dolomite between them is of leopard stone type in its lower half and of fine-grained dolomite above.

(7) The mottling in the leopard stone type of dolomite is strongly reminiscent of that in the knotty weathering limestones of Group VI (*see* (4) above). The lighter and darker portions respectively may represent in shadow form the fossils and the matrix after the complete dolomitization of the original limestone, the appearance of brecciation being a result of the dolomitizing process.

(8) The millet-seed quartz grain beds, both here and lower in the sequence, are only a few inches thick and the grains, though well rounded, have in many cases had some secondary silica deposition on their surfaces. The grains are not usually sufficiently abundant to form sandy layers, but lie scattered in the calcite mudstone as if they had been transported by wind action.

(9) The lenticular units in this bed are from 1 to 2½ ft. in diameter in most cases; plano-convex in section, with the convex side upwards; pisolitic to stylolitic in internal structure, showing a more or less radiating appearance upwards towards the convex surface. There is usually a good deal of associated chert in veins and nodules. Both above and below is thinly bedded dolomite mudstone. The general appearance of the bed is that of a miniature algal reef-knoll horizon with the original structure largely modified during dolomitization. The beds of ' algal ' type higher in the sequence are of similar character.

Chert

Several different varieties of chert can be distinguished in the Durness sequence, and in some cases they appear to have a certain zonal significance. The following notes indicate the most obvious features of chert character and distribution:

Group I–Only a few small cherts noted.

Group II–In the beds below the lowest 'algal' horizon chert nodules are small and very few. On Eilean Dubh they are all converted into crystalline quartz. This may be due, however, to the effect of crush, as in the case of the similar effect in Group VII. Brown chert veins and nodules are common in the 'algal' beds. Chert is very scarce, however, in the higher part of the Group II sequence except near the top, where it becomes more common upwards.

Group III–At the base there are abundant nodules, lenses, and discontinuous beds of chert, grey to white in colour, slightly iron-stained, and somewhat agate-like in internal structure. Higher up the chert is in rather smaller masses, and in the middle of the group there are chiefly small nodules, mainly white. There is little chert at the base of the leopard stone subdivision, but towards the top large bands appear and become commoner upwards.

Group IV–The two thick and persistent chert beds at the base of the group are white to pink in colour and often translucent. Each is 5 to 10 ft. thick. They are separated by 5 to 10 ft. of dolomite containing some chert. As noted above, the massive chert breaks up readily on weathering into an aggregate of small, angular, white fragments, forming a conspicuous outcrop feature which is usually almost devoid of vegetation: The chert in the rest of Group IV is for the most part in small beds and nodules, white to grey, pink, buff, or brown in colour.

Group V–Chert is not abundant in the lower part of the group, where it is mainly in nodules and not very dark in colour. The middle third of Group V, however, consisting of limestones with bands of calcareous shale, is conspicuous by reason of the black nodular chert that occurs in it. The chert in the top portion of the group is buff to light-brown in colour and occurs in rather small and not very abundant nodules.

Group VI–The lower, almost massive, limestone beds contain very little chert, but it becomes rather more common in the gastropod zone at the top. The overlying dolomite and alternating dolomite and limestone beds show small slate-grey to brownish-pink nodules. Little chert was seen in the higher lilac to grey limestones at the top of the group.

Group VII–Chert nodules are common in the exposures of this group. They are chiefly light in colour, and some consist of an outer zone of recrystallized silica surrounding a core of crystalline calcite. The group as a whole displays such evidence of shear and crush that it does not appear to be necessary to look beyond this as a cause of the recrystallization of the silica in the chert

Composition

The numerous chemical analyses that have now been made for the Sutherland area show the clearly marked distinction already noted between sedimentary dolomites and limestones throughout Scotland. The limestones show a maximum of about 16 per cent. MgCO3 calculated on a pure $CaCO_3$–MgCO, basis, with an average of less than 5 per cent.; whilst all the dolomites show values lying between 41 and 46 per cent. $MgCO_3$. There is no record of any sedimentary bed of regularly developed limestone or dolomite containing a percentage of magnesium carbonate intermediate between these two groups. From this it follows that a determination of specific gravity will give a very clear indication of the character of any specimen with 20. per cent. or less of material insoluble in acid (*see* Kennedy, 1940). The following distinction may thus be made:–

Specific Gravity > 2.82	High-grade dolomite with low percentage of impurities.
Specific Gravity 2.75 to 2.82	Dolomite with equi-molecular $CaCO_3$–$MgCO_3$ ratio but over 10 per cent. impurities.
Specific Gravity < 2.75	Limestone with less than 16 per cent. $MgCO_5$ on a pure $CaCO_3$–$MgCO_3$ basis, no deduction being possible regarding percentage of impurities.

The above distinctions are subject to three important qualifications: (1) The specific gravities of the principal impurities in both limestone and dolomite, namely, quartz, feldspar, kaolinite and the clay minerals in general, are either lower than, or not far removed from, that of calcite. If, however, iron is present to the extent of more than one or two units per cent. the specific gravity is raised by an appreciable amount. (2) The specific gravities of most of the commoner calcium and magnesium silicate minerals are higher than that of dolomite, so that an impure limestone altered by metamorphic action usually has its specific gravity raised in consequence. (3) The specific gravity of brucite is 2.39. Because of this a pure dolomite converted into brucite-marble has a specific gravity of less than 2.6. Thus a dolomite affected by metamorphic action has its specific gravity lowered unless the amount of silicate impurity is sufficient to counteract the effect of the formation of brucite.

In ordinary practice the specific-gravity test is of value because it is nearly always easy to tell in the field whether there is an excessive amount of impurity, whether the iron content is high, and whether the rock has been altered by metamorphic action. The character of the variations may be summarized-as follows:

Limestone	Sp. Gr. <	dolomite
Dolomite	Sp. Gr. >	Brucite-marble
Limestone	Sp. Gr. >	Sandy or argillaceous limestone
Dolomite	Sp. Gr. >	Sandy or argillaceous dolomite
Dolomite	Sp. Gr. <	Ferro-dolomite
Sandy or argillaceous limestone	Sp. Gr. <	Calc-silicate rock
Sandy or argillaceous dolomite	Sp. Gr. <	Magnesia- and lime-silicate rock

During a recent special investigation for limestone low in magnesia it was found to be comparatively easy in most cases to discriminate in the field between limestones with a small amount of MgO and those which approach the mineralogical composition of dolomite. Of 17 beds varying from 5 to 80 ft. in thickness and selected as being probably low in MgO, the following figures were obtained on analysis by the British Oxygen Co., Ltd.:

Range: 0.04 to 5.68 per cent. MgO, only two showing over 5 per cent.

Weighted average: 2.97 per cent. MgO, or 6.21 per cent. $MgCO_3$.

Distribution

At Durness the limestones of Groups IV and V, as distinct from the dolomitic parts of the sequence, are confined to two comparatively narrow outcrops. The more important of these forms a belt about 300 yds. in average width,, running southwards from the coast at Balnakiel church through Loch Lanlish (Lon na-h-Innse) and Loch Borralie (Borralaidh) to the Kyle of Durness at Keoldale, a total distance of about a mile and a half (Figure 39). The same limestones also crop out about a quarter of a mile east of the Sarsgrum-Drochaid Mhor road for a distance of about a mile and a half southwards from a point half a mile south of Sarsgrum.

On the basis of a careful sampling of selected beds of limestone varying from 5 to 50 ft. in individual thickness, it is estimated that the average lime content of the limestone beds in the Balnakiel–Keoldale area is 49.70 per cent. CaO, equivalent to 88.69 per cent. $CaCO_3$. The limestone might reasonably be expected to maintain this quality in large-scale working. When the estimate already given of 6.21 per cent. $MgCO_3$ in these beds is taken into account it will be seen that the average amount of insoluble residue is about 5 per cent.

Of the four stratigraphical groups composed mainly of dolomite, Groups I and IV are less easy of access than II and III, Group I having the further disadvantage of a very small outcrop. From (Figure 39), which shows the distribution and extent of the subdivisions of the Durness Limestone in the type area, it will be seen that the dolomites of Groups II and III crop out along the whole of the eastern side of the Kyle of Durness except for about half a mile at Keoldale. They are most easily accessible in the vicinity of the road from Drochaid Mhor northwards to the Keoldale road junction. They also underlie the ground from Sarsgrum to the coast near Sangomore and Smoo, half a mile to a mile east of Durness; and this area is very conveniently situated as regards access. The island of Eilean Hoan is composed chiefly of dolomite of the same two groups of strata.

Throughout the Durness district the calcareous rocks dip E.S.E. at angles of 12° to 30° and often form terraced outcrops which would greatly facilitate quarrying operations. The questions of access and transport are considered under the separate locality headings below.

In the Loch Eireboll district only Groups I and II of the Durness Limestone occur. They occupy three separate tracts, two on the eastern shore of the loch, at Eireboll and Heilem respectively, and the third on An Corr-eilean, an islet opposite Eireboll (Figure 40). The dolomite was formerly burnt at Heilem, and the old kilns there are in fairly good condition. There is a small quarry nearby showing a face of 20 to 30 ft. of stone. The Eireboll tract is shown by specific gravity determinations and by analysis of a representative bulk sample to consist of high-grade dolomite, the percentage figures

being as follows (Geol. Surv. Lab. No. 1204): $CaCO_3$ 51.8; $MgCO_3$ 43.1; Insol. Res. 4.7. Another analysis (SL 177) [NC 436 572] gave $CaCO_3$ 52.23; $MgCO_3$ 43.11; Insol. Res. 5.61. As regards access, the main road from Durness to Tongue runs along the entire length of the outcrop on its eastern side. In addition, a side road runs north from Eireboll to Inbhirean. Sea transport from the area should also be perfectly feasible. The nearest existing piers are at Heilem, 2 m. N. of Eireboll, (Figure 39). Sketch map showing distribution of limestone in the Durness district of Sutherland. and at Portnancon, on the opposite side of the loch, directly opposite Heilem. There are no obvious reasons, however, why another pier should not be built on the coast adjacent to any quarrying operations that might be undertaken.

In the Assynt district (Figure 38), covered by a special colour-printed Geological Survey 1-in. map, only the three lowest of the seven subdivisions of the Durness Limestone are present. They occupy a tract of country which extends southwards from the western slopes of Glas Bheinn, midway between Loch Glencoul and Loch Assynt, past Inchnadamph ((Plate 1), Frontispiece), to Knockan, south of Elphin, a distance of 12 to 13 miles. The continuity of the outcrop of these rocks is broken but once, for a short distance between Ledbeg and Elphin.

Around Inchnadamph the calcareous succession has been invaded by igneous material in the form of thin sills and is further disturbed by numerous thrust movements. Farther south, the rocks have suffered comparatively little mechanical disturbance and the sills appear to die out, but in the vicinity of Ledbeg the limestones and dolomites have been converted into marble by the granitic mass of Cnoc na Sroine (*see* p. 19). Again at Elphin the same thing has happened around a small intrusive body there. Where unaltered by igneous intrusions, the calcareous rocks are strikingly similar in lithological character to those of equivalent age in the Durness and Loch Eireboll districts described above. It is not surprising, therefore, to find that specific gravity determinations carried out on the samples collected from the Assynt district point to a percentage of high-grade dolomite as large as that indicated for the more northerly outcrops. The samples tested were collected from Groups I and II only, as Group III has but a very small outcrop on the plateau southeast of Inchnadamph, at some considerable distance from any road.

From the determinations carried out it may reasonably be expected that a high percentage of the accessible rock will have a specific gravity of over 2.83 and therefore a composition approaching that of pure dolomite. Two analyses of material from Ardvreck Castle showed that Groups I and II in this area consist of high-grade dolomite (p. 191).

No attempt has been made to arrive at any estimate of the quantity of rock available, on account of the mountainous nature of much of the country, the presence of rock types other than dolomite within the dolomite outcrops and finally the extent of peat cover. It can be confidently stated, however, that the reserves of high-grade dolomite are of the same order of magnitude as those available for Durness and Eireboll. Access to the area is by road, from Lairg or Bonar Bridge on the L.M. & S. railway, from Lochinver on the west coast, or from Ullapool on Loch Broom in the south.

The marbles of the Assynt district have been produced by thermal metamorphism of the dolomite of the Durness Limestone formation in the vicinity of the Cnoc na Sroine igneous intrusion (S. of L. Urigill in (Figure 38)). The principal outcrops are near Loyne and Ledbeg, a much smaller occurrence being found at Elphin. Of the several varieties of marble that occur, particular attention has been paid to that containing brucite. It is found in considerable quantity north-west of Ledbeg.

Durness and Eireboll

Sarsgrum [NC 37721 64076], 2½ m. S.W. of Durness: various exposures. (114. 5 S.E.) Reference: Knox, 1941, pp. 4, 5.

Durness Limestone. Mottled dolomites of high grade belonging to Group III form a rocky bluff at Sarsgrum, about 2½ m. southwards along the main road from Durness. A quarry-face of 20 to 30 ft. could be got here almost at once, the height increasing gradually as operations extended inland. An analysis of a bulk sample from this locality by Mr. C. O. Harvey (Geol. Surv. Lab. No. 1202) gave as follows: $CaCO_3$ 52.7; $MgCO_3$ 44.3; Insol. Res. 3.0.

Less than half a mile north of Sarsgrum, and ■ m. S. of Keoldale a section of the dolomites belonging to the upper part of Group II is laid bare along the course of a small stream flowing westwards into the Kyle of Durness. The rocks dip E.S.E. at about 25°, with strike more or less parallel to the road. A bulk sample analysed by Mr. C. O. Harvey (Geol. Surv. Lab.

No. 1203) gave as follows: $CaCO_3$ 49.3; $MgCO_3$ 40.3; Insol. Res. 9.7. A quarry could be opened here on either side of the stream, in the bank bordering the road. Transport would have to be by road at least as far as Portnancon on Loch Eireboll, a distance of about 9 m., where there is a small pier, but this is in disrepair.

Durness: various exposures. (114. 5 N.E., S.E.; 6 N.W.) References: Peach and Horne, 1907, pp. 365–366, 375–379, 387, 388–394, 635–639; Knox, 1941, pp. 1–6.

Durness Limestone, Groups II to VII. Dolomites and limestones of Groups VI [NC 39512 68188] and VII [NC 40209 67871] are exposed at several points in the immediate vicinity of Durness village. Group V (principally limestone) is fully exposed along the shore westwards from Balnakiel (Baile na Cille), 1 m. W.N.W. of Durness (5 N.E.) [NC 38877 68689]. The beds dip E.S.E. at about 15°. Striking southwards past Loch Borralie (Borralaidh), they are last seen at Keoldale on the shore of the Kyle of Durness, 1¾ m. S.W. of Durness (5 S.E.). Farther westwards from Balnakiel and Keoldale are the outcrops of Groups IV [NC 38515 68843], III [NC 38111 68825] and II [NC 37601 68770], consisting mainly of dolomites. Both Balnakiel and Keoldale are served by roads, but the former locality would offer the better conditions and facilities for quarrying, particularly with reference to the limestones of Group V. The nearest pier is at Portnancon, on Loch Eireboll, about 7 m. from Durness.

The composition of the limestone portions of the sequence (Groups IV to VI) in this area has been referred to above (p. 38). The analytical data below were kindly provided by the British Oxygen Co., Ltd.

Sample No.	Thickness of bed in ft.	CaO	MgO	SiO_2	$Al_2O_3 + Fe_2O_3$	$CaCO_3$	$MgCO_3$
Al	12	40.18	9.31	7.50	0.61	71.6	19.5
A2	10	48.30	4.95	5.46	0.83	86.2	10.4
A3	22	46.30	3.44	8.33	1.25	82.6	7.2
A4	18	45.30	4.66	7.09	1.04	80.9	9.8
A5	21	46.90	4.63	6.44	0.78	83.9	9.7
A6	7	51.87	0.69	5.05	0.50	92.5	1.4
A7	5	47.7	3.47	7.85	0.35	85.3	7.3
A8	10	51.1	2.15	5.04	0.66	91.3	4.5
A9	10	48.90	4.35	4.63	0.52	87.2	9.1
A10	12	45.70	5.68	8.06	1.18	81.6	11.9
A11	7	54.00	2.16	2.09	0.22	96.5	4.5
A12	4½	52.10	0.66	3.30	0.22	93.0	1.4
B1	50	51.6	0.58	5.21	1.60	92.2	1.2
B2	25	54.3	0.04	2.69	0.58	96.9	0.1
B3	24	51.3	2.79	2.71	0.75	91.6	5.8
B4	11	49.5	5.11	0.94	0.79	88.3	10.7
B5	25	50.7	3.00	4.07	0.92	904	6.3
B6	80	49.1	3.84	4.10	1.65	87.7	8.0

A1 to A4: Group V; coast exposures 80 to 150 yds. W.N.W. of Balnakiel. A1 is a mixed sample containing material from beds both of limestone and dolomite; it is not included in the averages given on p. 185.

A5 to A8: Group V; coast exposures 150 to 220 yds. W.N.W. of Balnakiel.

A9 to A12: Group V; coast exposures 220 to 300 yds. W.N.W. of Balnakiel.

B1: Group IV; crag on N.W. shore of Loch Borralaidh, 330 yds. N. 22° W. of N.E. tip of island in loch.

B2: Group IV; 130 yds. E.N.E. of B1, and 370 yds. N. of N.E. tip of island in Loch Borralaidh.

B3: Group IV; low scarp 150 to 200 yds. N. of B1, and 500 to 550 yds. N. of N.E. tip of island in Loch Borralaidh.

B4: Group IV; 620 yds. N. 40° W. of N.E. tip of island in Loch Borralaidh.

B5: Group VI; old quarry on W. side of road, 200 yds. S.E. of Balnakiel Church (ruin).

B6: Group VI; E. side of Loch Croisaphuill, 100 yds. N.N.W. of manse.

No analyses are available of Groups II and III in the ground west of Durness. The following figures refer to the dolomites of these groups in the area east of the village and to Eilean Hoan (Figure 38). They are quoted from W. Pollard (in Peach and Horne, 1907, p. 637).

Group No.	Sample	Locality	$CaCO_3$	$MgCO_3$	Insol. Res.
III	8129	Quarry 150 yds. E. of Sango Bay	52.95	45.21	1.83
II	8130	Eilean Hoan	53.66	42.53	2.42
II	8131	Eilean Hoan	45.36	38.30	15.81
II	8283	A'Ghoil-sgeir, ¼ m. W. of Eilean Hoan	53.73	43.74	2.01

Inbhirean [NC 43384 57566]: ¾ m. north of Eireboll. (114. 15 S.W.; 24 N.W.) Reference: Knox, 1941, p. 6.

Durness Limestone, Group II. At the northern end of the side road leading north from Eireboll to the coast at Inbhirean (Figure 40), there is a steep hill-slope extending along the coast for about half a mile and rising to a height of 50 to 60 ft. above a raised-beach platform. The rocks exposed on this slope are all high-grade dolomites. Dips are to E.S.E. at moderate angles. Access: sea transport should be feasible; the nearest existing piers are at Heilem, 2 m. N. of Eireboll on the same side of the loch, and at Portnancon directly opposite Heilem. If necessary, however, a pier could be built at Inbhirean itself.

The quality of the dolomite in this area is shown by the following analytical data (SL 177) [NC 436 572]: $CaCO_3$ 52.23; $MgCO_3$ 43.11; Insol. Res. 5.61. A bulk sample from the same area, analysed by C. O. Harvey (*quoted from* Knox, 1941, p. 4) gave as follows (Geol. Surv. Lab. No. 1204): $CaCO_3$ 51.8; $MgCO_3$ 43.1; Insol. Res. 4.7.

Heilem (or Heilam): disused quarry 2 m. N. of Eireboll [NC 44646 59659]. (114. 15 S.W.)

Durness Limestone. On the peninsula at Heilem there is a moderate-sized quarry in dolomite belonging to a horizon about the junction of Groups I and II. The rocks are on the average somewhat darker in colour than those of other localities. The quarry-face is 20 to 30 ft. in height. The total amount of rock that could be got here is limited only by the size of the peninsula, the area of which is some 12 to 15 acres.

Access: There is a pier adjacent to the quarry, but, besides being in need of repair, it would probably be necessary to extend it into deeper water if much material were to be handled. The pier at Portnancon on the opposite side of Loch Eireboll is also in disrepair, and would require considerable attention before it could be used for heavy traffic.

Assynt

Ardvreck [NC 24254 23622]: 1¼ m. N.N.W. of Inchnadamph Hotel. (107. 71 N.W.)

Durness Limestone. Dolomite of Groups I and II could be easily worked immediately on the east side of the Inchnadamph–Lochinver road opposite Ardvreck Castle. The outcrop runs parallel with the road for a considerable distance both to north and south. The dip is eastwards and generally at an angle of 45° or over. The area is traversed by several thrust-planes, in the vicinity of which the rock is disturbed and broken, and this might to some extent interfere with quarrying operations. At the locality indicated the thickness of dolomite belonging to Group I is 40 to 50 ft., and the easily accessible dolomites of the overlying Group II have a thickness of at least 150 ft. There is no overburden of any sort.

Bulk samples from the north side of Allt a' Chalda Mor, about 500 yds.

S. 75° E. of Ardvreck Castle, showed as follows:

(SL 269) [NC 24267 23635]	Group I	$CaCO_3$	54.3 per cent.	$MgCO_3$	41.2 per cent.
(SL 270) [NC 24424 23494]	Group II	$CaCO_3$	52.6 per cent.	$MgCO_3$	40.2 per cent.

Inchnadamph [NC 25264 21846] to Loyne [NC 25217 14308]. (101 and 107. 71 S.E.; 82 N.E., S.E.) References: Peach and Horne, 1907, p. 403; Knox, 1941, pp. 7–8.

Durness Limestone, Groups I and II. For most of the distance of about *5* m. from Inchnadamph to Loyne the base of the limestone outcrop is situated on a steep, and in places precipitous, hill-slope 100 ft. or more above road-level. Immense quantities of dolomite are available in the higher part of the crag feature, but there is a certain amount of disturbance associated with thrust-planes in the Inchnadamph–Stronechrubie [NC 24709 19307] ((Plate 1), Frontispiece) portion of the outcrop and one or two intrusive sills. On the whole this outcrop might present some difficulties in the opening out of a quarry face.

Knockan [NC 21203 10654]: various exposures. (101.91 N.W., S.W.) References: Peach and Horne, 1907, p. 403; Knox, 1941, pp. 7–8.

Durness Limestone. Stretching eastwards from the hamlet of Knockan there is an extensive tract of country occupied almost entirely by pale-grey or cream-coloured, hard, fine-grained, compact dolomites belonging to Group II of the Durness Limestone. The rocks are inclined steadily to E. and S.E. at moderate to rather high angles. The lower part of the succession, about 250 ft. in thickness, is well exposed in the lower reaches of the Amhainn a' Chnocain [NC 21195 11000], a small stream flowing westwards between Knockan and Elphin, and it is there that quarrying operations might best be undertaken. The area available, taking both sides of the stream into account, is at least 2 sq. m. in extent. There is little or no overburden in the western and more accessible part of the outcrop, but farther east much of the ground is peat covered. Access: the main road to Ullapool follows the western margin of the outcrop, crossing the Amhainn a' Chnocain within two or three hundreds yards of where quarrying might be undertaken.

A bulk sample was taken of the dolomite on the north side of the Amhainn a' Chnocain, between 700 and 800 yds. up-stream from the road-bridge south of Elphin ((SL 272) [NC 21843 10376] [NC 21673 10634], (SL 273) [NC 21735 10559], (SL 274) [NC 21763 10539]). On analysis it gave as follows: $CaCO_3$ 52.40; $MgCO_3$ 38.48; Insol. Res. 3.04.

Ledbeg [NC 24001 13444]. (101. 82 S.W.). Reference: Peach and Horne, 1907, pp. 403, 453–462.

Durness Limestone. The limestone in this area is all marmorized, and in some cases contains a high percentage of brucite. The following localities are noteworthy:

1. *Small disused quarry* 1,000 *yds. N.W. of Ledbeg approx. [NC 23456 13953].*–Bluish-grey, coarsely crystalline marble. The quarry is very small, with a face of only 8 to 10 ft., but could easily be enlarged. Overburden, little or none. Access is by rough track to the main road at Ledbeg.
2. *Various exposures on hill-slopes about ¾ m. N.W. of Ledbeg.*–North-west of the quarry referred to in (a), there is a fairly large area in which the outcrops are all of a white, rather fine-grained, granular marble containing a high percentage of the mineral brucite ($Mg(OH)_2$). The best exposures are to be found about 150 yds. and 500 yds. N.W. of the quarry mentioned above (*i.e.,* about 1,150 yds. and 1,500 yds. N.W. of Ledbeg). It is believed that considerable quantities of this rock are available. So far as is known it has not been worked at all. There is little or no overburden. The nearest road is at Ledbeg.
3. *Small excavation beside road,* 430 *yds. E.N.E. of Ledbeg approx. [NC 24549 13448].*–Pale, greenish-white, compact marble. Marble of the same lithological type, but greyish in colour with green patches, is exposed in the Ledbeg River about 200 yds. E. of Ledbeg.

Shiness Limestone

Shiness: disused quarries on The Airde [NC 52528 13745]. (102, 85 S.W.) Reference: Read, 1926, pp. 126, 138–140.

Limestone in Moine Series. A limestone was formerly worked in two quarries on the Airde, a conspicuous peninsula on the east side of Loch Shin at Shiness [NC 52155 13865] (Figure 38). It is at most 20 ft. thick, with granulites and schists above and below it, striking W.N.W.–E.S.E. and dipping N.N.E. at about 45°. In the more southern quarry there are 20 ft. of impure limestone, made up of alternations of dark-weathering calcite and calc-silicate rock. In the other quarry (440 yds. to W.N.W.) the limestone is purer and occurs in irregular beds up to 7 ft. thick between beds of calc-silicate rock. The limestone is very variable and lenticular, however, and impure bands of dark colour occur frequently. The calcite is white or pink in places and is often very coarsely granular.

An analysis of material from the more northern quarry gave as follows (SL 169) [NC 47156 14307]: CaO 48.99; MgO 2.52; CO_2 37.97; Insol. Res. 13.10. This indicates an appreciable percentage of calc-silicate mineral. Estimations for agricultural purposes on representative bulk samples from the more southern quarry gave the following percentages of $CaCO_3$: top 8½ ft., 42; middle 3 ft., 50; bottom 7½ ft., 81.

West Lothian

The limestones of West Lothian are all of Carboniferous age (Figure 41), and include members of the Upper Oil Shale, Lower Limestone, and Upper Limestone groups of strata.

Amongst the calcareous beds of the first-mentioned formation the Burdiehouse Limestone is the only one of economic significance. It lies at the base of the group and is well developed over most of the area. The more important outcrops are shown in (Figure 41) and include stretches in the vicinity of Hopetoun, Kirkliston, Drumshoreland and Livingston.

A detailed description of the Burdiehouse Limestone throughout the main Lothians basin of the oil-shale field is given above (p. 141). Records indicate an average thickness of about 10 ft. but it varies greatly from place to place (*see* p. 195 below). It is usually of high quality, analysing about 95 per cent. $CaCO_3$ and only 1 to 2 per cent. $MgCO_3$.

Of the other limestones in the Oil Shale Group, the Barracks Limestone, higher up in the sequence than the Burdiehouse, is similar in character but too thin to be of value. It is recorded as 5 ft. thick at Pumpherston, but this is a maximum. A number of beds of cementstone were found in the Blackness No. 1 Bore (New Series 2 S.W.) about 350 ft. above the Burdiehouse Limestone. One of these on analysis (by T. Robertson) proved to be magnesian in character, containing 22.65 per cent. $MgCO_3$ and 26.47 per cent. of insoluble matter. It thus resembles the cement-stones of the Cementstone Group.

The Lower Limestone Group contains several beds of limestone, and at least one of these, the Petershill (Blackhall) Limestone of the Bathgate Hills, has been very extensively worked (Figure 41). Another, the West Kirkton Limestone, lower in the sequence and probably the equivalent of the. Hurlet, has been worked to a smaller extent. Except in the high ground of the Bathgate Hills there are few exposures of the Lower Limestone Group, though its outcrop extends from the Firth of Forth between Bo'ness and Blackness to Addiewell, a distance of 12 miles.

Of the limestones in the Upper Limestone Group the Castlecary and the Calmy (Figure 42) are well developed in the Bo'nes's and Linlithgow districts. They have both been extensively quarried and mined at a number of localities between Kinneil.on the Firth of Forth and Carribber, S.W. of Linlithgow:

The reserves of limestone in West Lothian are almost confined to the Burdiehouse Limestone. It could probably be mined from the known outcrops owing to its high quality. The Petershill Limestone is not of such good quality as to encourage further mining in the Bathgate area, and no further quarrying on a large scale is possible. The Castlecary and Calmy limestones have been so extensively mined already that further exploitation at Kinneil or Carribber would involve deeper workings, and this would require a higher quality of stone than these limestones usually yield. An analysis of the Castlecary Limestone from the railway cutting at Manuel in Stirlingshire, l½ m. W. of Linlithgow, showed it to be dolomitic (*see* p. 175).

Kinneil [NS 97874 80513]. (31. New Meridian 3 N.W.: New Series 1 S.W.) Reference Macgregor and Haldane, 1933, pp. 112–114.

The Calmy Limestone was formerly worked, both by quarrying and mining, at Dykeneuk [NS 97480 80521] about 440 yds. W. of Kinneil House. It occurred in three bands with shale partings, the total thickness being about 7 ft. The Castlecary Limestone was extensively mined near the coast at Craigenbuck, 1½ m. W. of Kinneil House, and also on the north bank of the Avon, 1 m. S.S.W. of Craigenbuck and 150 yds. E. of the railway viaduct. The limestone was used for mortar, and also for flux at the Kinneil Ironworks. Its thickness is not recorded. Neither the Calmy nor the Castlecary has any reserves in this area except in depth to the west, the dip being westwards at about 15°.

Carribber [NS 95664 74424]. (31. New Meridian 3 S.W.; 7 N.W.: New Series 5 N.W., S.W.) Reference: Macgregor and Haldane, 1933, pp. 112–114.

The Calmy and Castlecary limestones were both worked in the Carribber –Bowden Hill area. The Castlecary was mined under Bowden Hill and is recorded as consisting of 1 ft. 4 in. of black, very hard, shaly limestone overlying 7 ft. of hard, compact, grey limestone. Of neither seam are there any reserves except in depth under a thick dolerite sill. The dip is W. at about 15°.

Petershill Quarries [NS 98489 69546]: ½ m. E. of Bathgate. (31. New Meridian 7 S.E. New Series 9 N.W., N.E.) Reference: Macgregor and Anderson, 1923, pp. 22–23.

Petershill (Blackhall) Limestone. The thickness is 40 to 60 ft. but only 15 to 20 ft. are now exposed. The limestone dips W. at 25° to 35°, and is overlain by 4 to 12 ft. of boulder clay. Access is by service road for a quarter of a mile from the main road. Reserves are large.

The stone is a cream-coloured, shelly, somewhat siliceous limestone up to 60 ft. thick. The full thickness is nowhere exposed. It was formerly extensively worked in a series of quarries from Petershill [NS 98503 69020] northwards to Wester Tartraven farm [NS 99126 71789] (New Series 5 S.E.). Because of its rather steep dip an overburden of rock as well as of drift overlies the limestone on the west side of the quarries. This overburden is probably least at Glenbare Quarry [NS 98499 69029] at the south end of the exposure. An analysis, for the use of which we are indebted to Mr. Simon P. Hodge, represents the exposed rock in this quarry. It shows $CaCO_3$ 85.20; $MgCO_3$ 1.92; SiO_2 10.45; Al_2O_3 0.95; Fe_2O_3 0.77. Where the limestone was opened out just south of this area in 1944, it was not considered to be of good quality, but it is possible that the beds tried were not in the same portion of the limestone as those seen in the quarry. Analyses of material representing a thickness of 16 ft. of limestone in this area showed percentages of $CaCO_3$ varying from 54 to 79.

The full thickness of the limestone was cut in a bore by Messrs. Bairds and Scottish Steel, Ltd., at Buchtknowe (New Series 9 N.W.) a short distance to the dip of the quarries. Systematic chemical examination of the cores showed a calcium carbonate content of between 70 and 90 per cent. Geological Survey analyses of selected specimens from the old quarry ½ m. N. of the Bathgate reservoirs gave values up to 95 per cent. $CaCO_3$.

Livingston and Broxburn. (32. New Meridian 8 S.W., S.E.: New Series 6 S.W.; 9 N.E.; 10 N.W.) References: Carruthers, 1927, pp. 42, 43, 54; Anderson, J.G.C., 1942. See also map, (Figure 41), and section, (Figure 43).

The Burdiehouse Limestone is only about 8 ft. thick at the outcrop east of Livingston station [NT 01502 68435], but it thickens southwards towards Bellsquarry [NT 04060 65216] in Midlothian. Eastwards across the Pumpherston Anticline it also thickens, and is 24 ft. in the River Almond section (p. 142), but there is no information regarding the northern part of the eastern outcrop south of Kilpunt as all this ground is under deep drift. The limestone has been quarried in the Livingston station outcrop.

East Broadlaw [NT 04456 72986] and Kirkliston [NT 12620 74383]. (32. New Meridian 4 S.E.; 8 N.W.: New Series 6 N.E., S.W.) Reference: Carruthers, 1927, pp. 62, 66.

The Burdiehouse Limestone was quarried at one time near East Broadlaw, 1 m. N.W. of Uphall, but it cannot now be seen at the surface in this area. It is said to have been 11 ft. thick. Farther east, between Kirkliston and Winchburgh, the Burdiehouse comes to the surface a short distance west of New Mains [NT 11998 74736] and was found by bores in the vicinity to be 5 ft. thick.

Blackness [NT 05188 79971], Abercorn [NT 08112 78910] and South Queensferry [NT 12938 78362]. (32. New Meridian 4 N.W., N.E.; 5 N.W.: New Series 2 S.W., S.E.; 3 S.W.) References: Carruthers, 1927, pp. 75–87; Kennedy, 1943, pp. 4–5.

The Burdiehouse Limestone has been quarried at numerous localities along a sinuous line of outcrop between Newton and Parkhead, 2½ m. W. of South Queensferry. It is flaggy in character and is said to have been about 9 ft. thick. Little is now visible. South of this area a fault throws in another outcrop which was exposed in a mineral-railway cutting near Craigton Hill. An analysis of limestone from the Hopetoun Wood Quarry, Abercorn (SL 173) [NT 0827 7806], gave as follows: $CaCO_3$ 86.46; $MgCO_3$ 2.84; Insol. Res. 5.68.

The Blackness No. 1 bore (New Series 2 S.W.) passes through the Burdiehouse Limestone. An analysis by T. Robertson gave the following percentage figures: $CaCO_3$ 95.61; $MgCO_3$ trace; SiO_2 1.48; Al_2O_3 1.12; Fe_2O_3 0.67. Details of the section are given below, indicating a thickness of 44½ ft. for this limestone. This compares with the thickness of 40 ft. proved at Rosyth (p. 99)

	Camps Shale, low-grade oil shale	
Burdiehouse Limestone	Limestone, dark-grey to dull-black, laminated, with entomostraca and plant remains	6
Burdiehouse Limestone	Limestone, hard, grey, bedded	7½
Burdiehouse Limestone	Limestone, hard, grey, broken	9
Burdiehouse Limestone	Limestone, hard, dark-grey, bedded	22
	Shale, dark	3
	Limestone, dark-grey, with spar joints	2
	Dark shale and limestone ribs, with plant remains and entomostraca	9
	Fakes, grey, limy	2
	Shale, black, badly broken	6
	Limestone, hard, dark-grey, broken	5
		71½

East of Hopetoun the Burdiehouse crops out at two places on the shore near Society [NT 09650 79051] and also just east of the Forth Bridge [NT 12919 78307]. The decrease in thickness of the limestone eastwards from Blackness can be seen from the following figures:

	Thickness of Limestone Ft.
Blackness No. 1 Bore	44½
W. side of Hopetoun Anticline	15
E. side of Hopetoun Anticline	10
E. of Forth Bridge	5

Wigtown

The county of Wigtown is chiefly composed of rocks of the Ordovician and Silurian formations, with subordinate areas of Carboniferous and Permian sediments and a few granitic intrusions. There is no limestone in these rocks; and no deposit

of shell sand is recorded in the county such as might be even of local use.

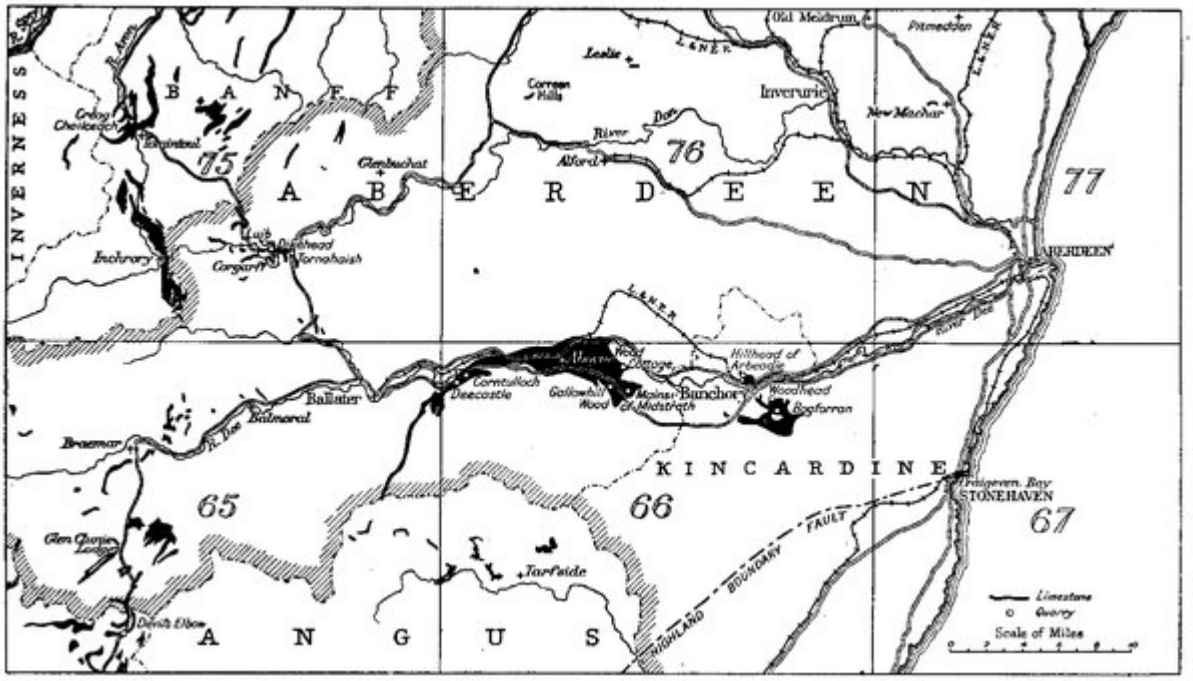

Figure 2 Sketch map showing distribution of limestone in the counties of Aberdeen and Kincardine.

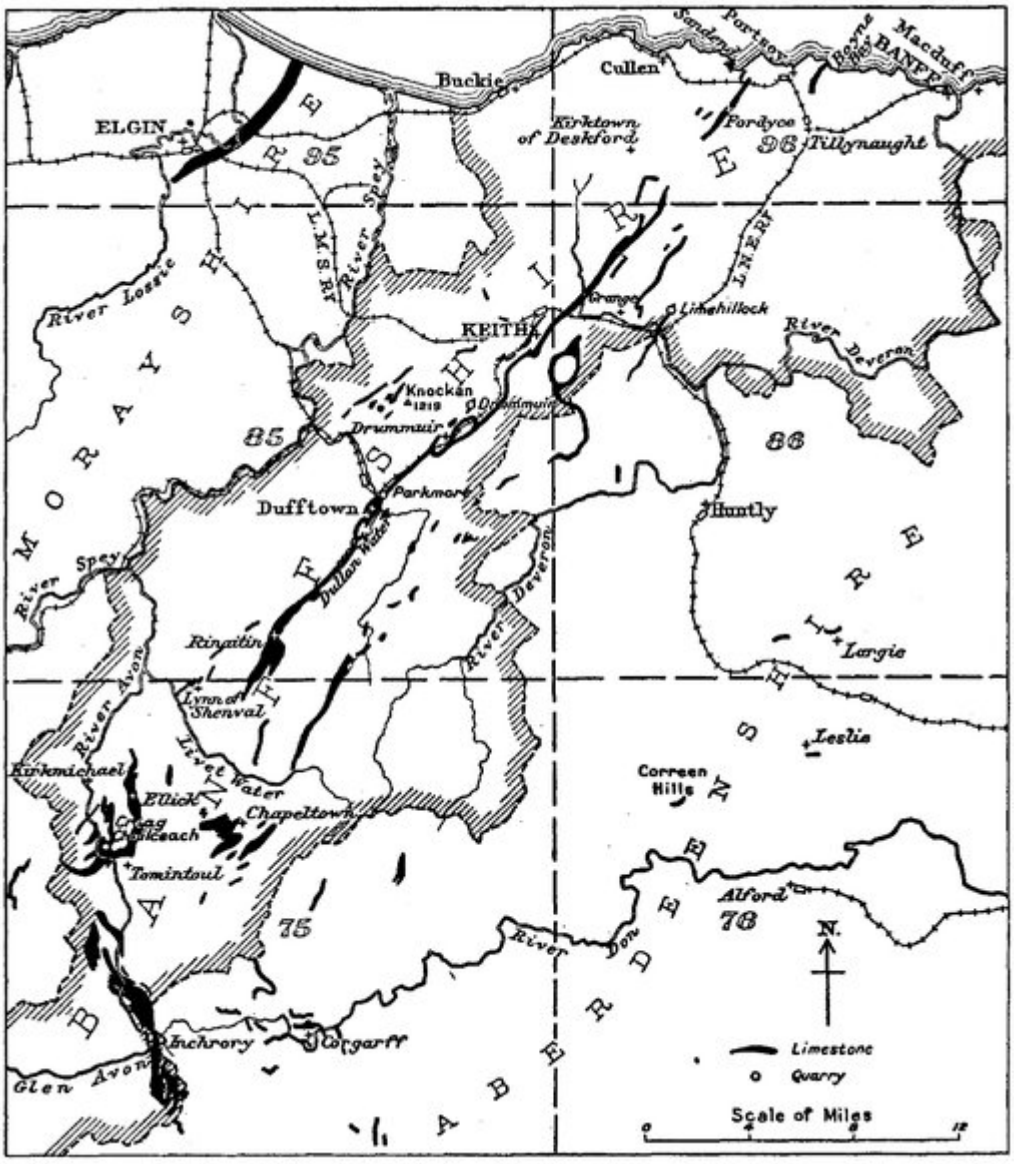

Figure 11 Sketch map showing distribution of limestone in Banffshire.

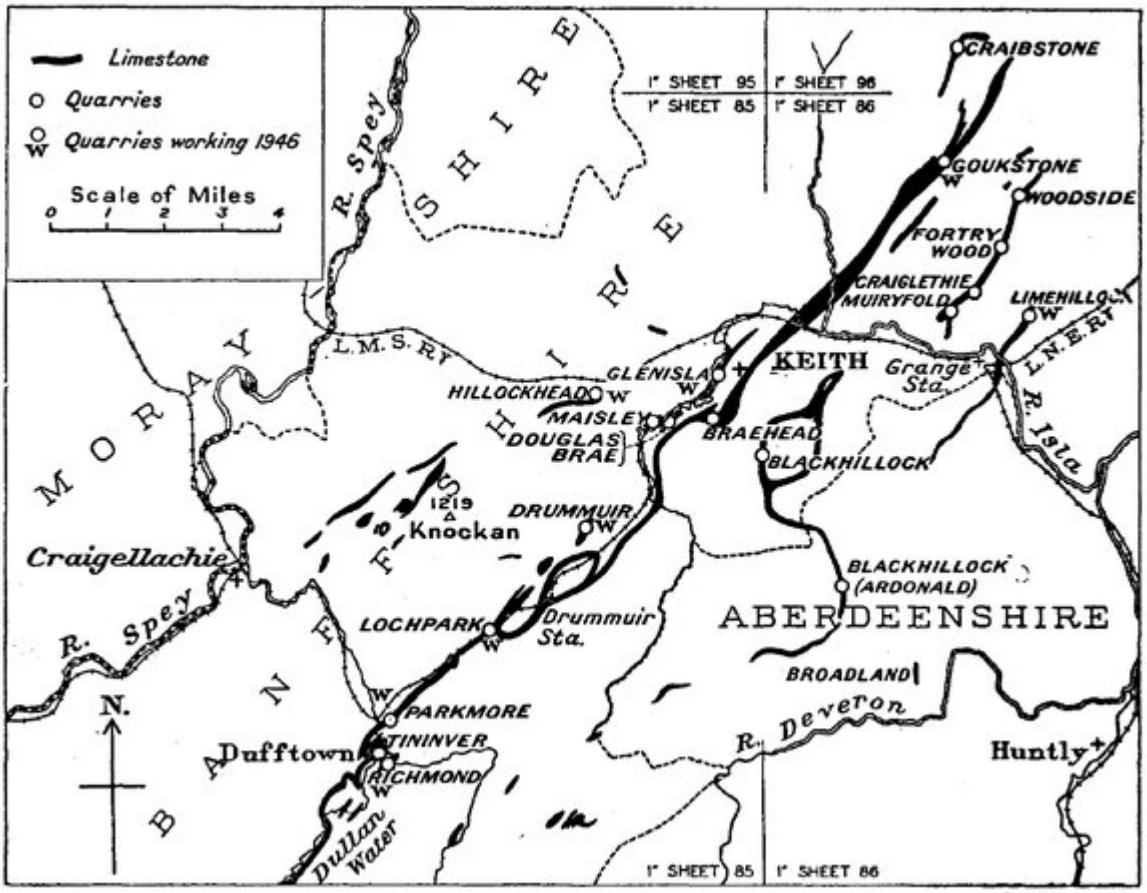

Figure 12 Sketch map showing distribution of limestone in the Keith-Dufftown district of Banffshire.

Plate 2 Map of the Main Occurrences of Limestone in Scotland.

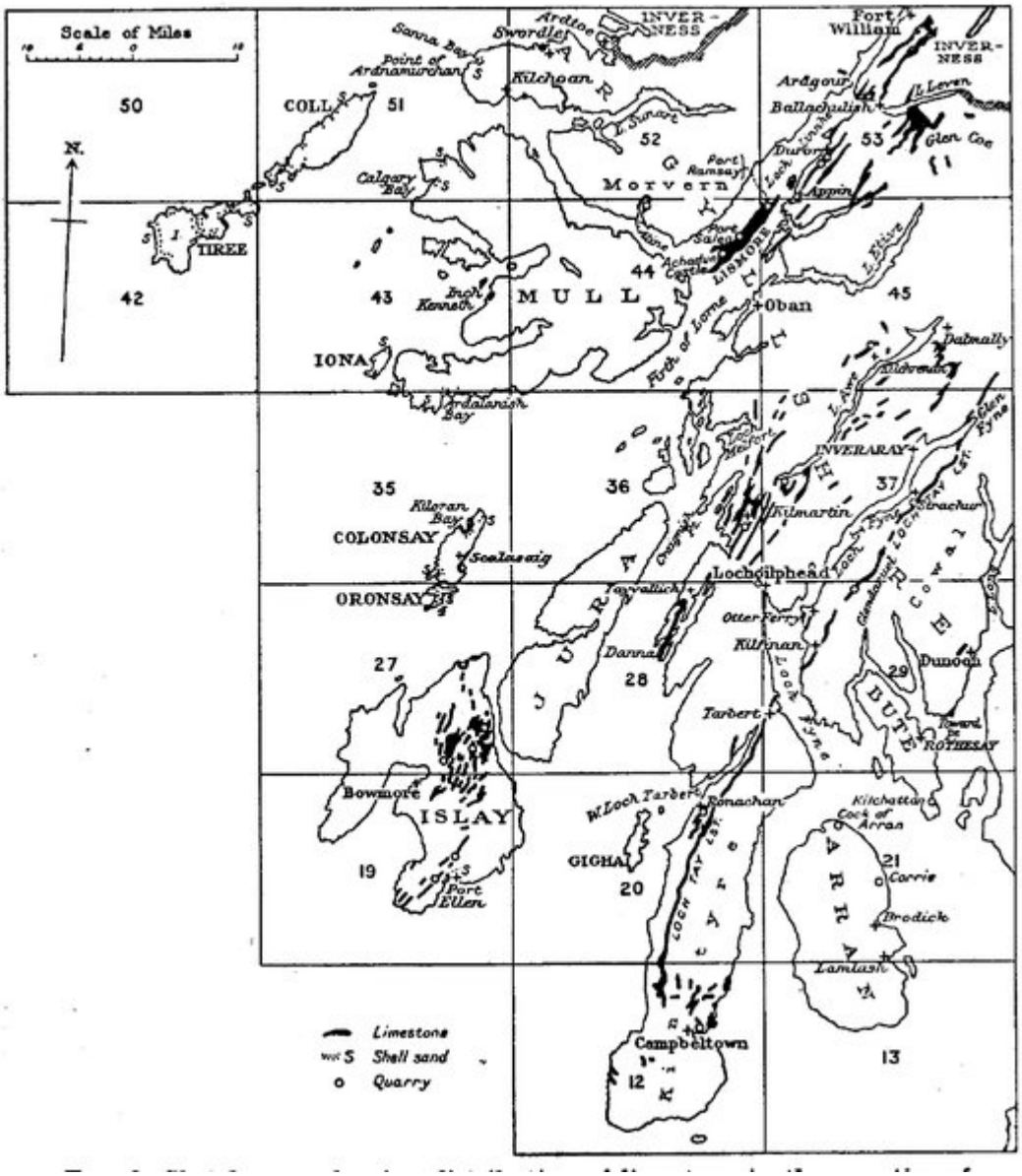

Figure 3 Sketch map showing distribution of limestone in the counties of Argyll and Bute.

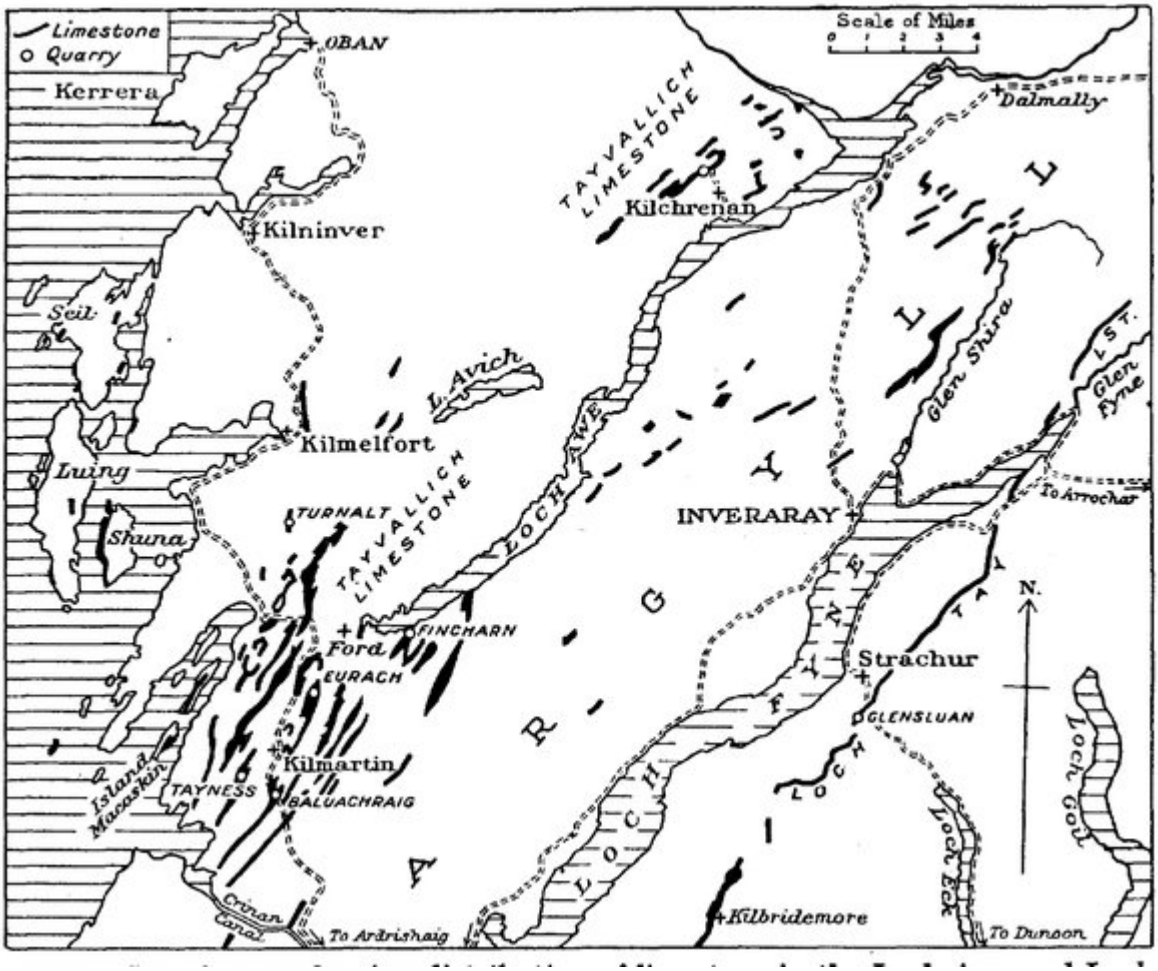

Figure 4 Sketch map showing distribution of limestone in the Loch Awe and Loch Fyne districts of Argyll.

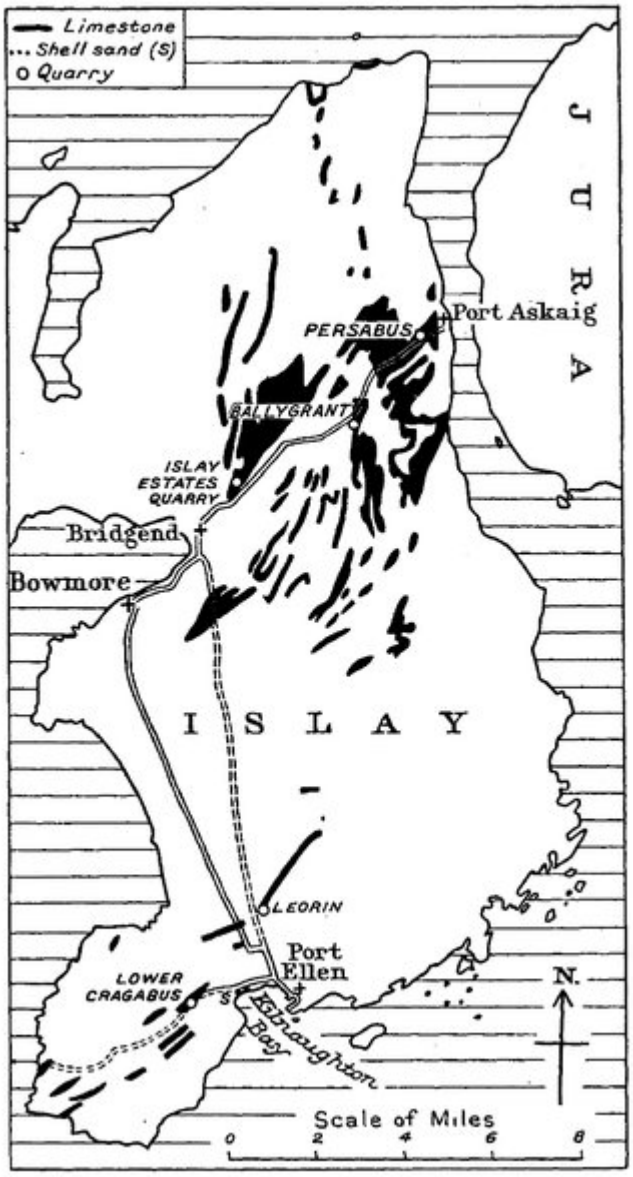

Figure 5 Sketch map showing distribution of the Islay Limestone.

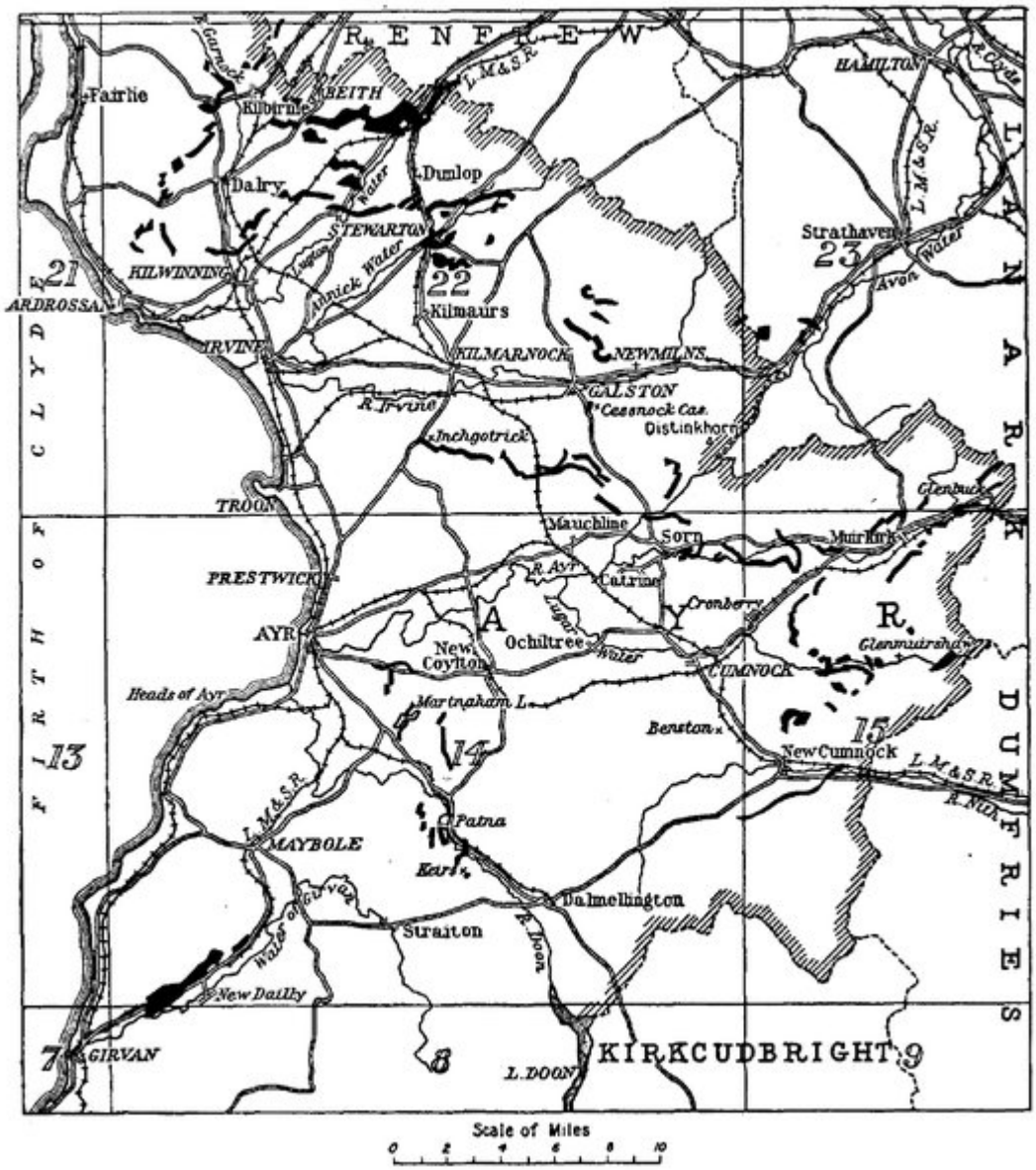

Figure 6 Sketch map showing main areas black of the Carboniferous Limestone deposits of Ayrshire.

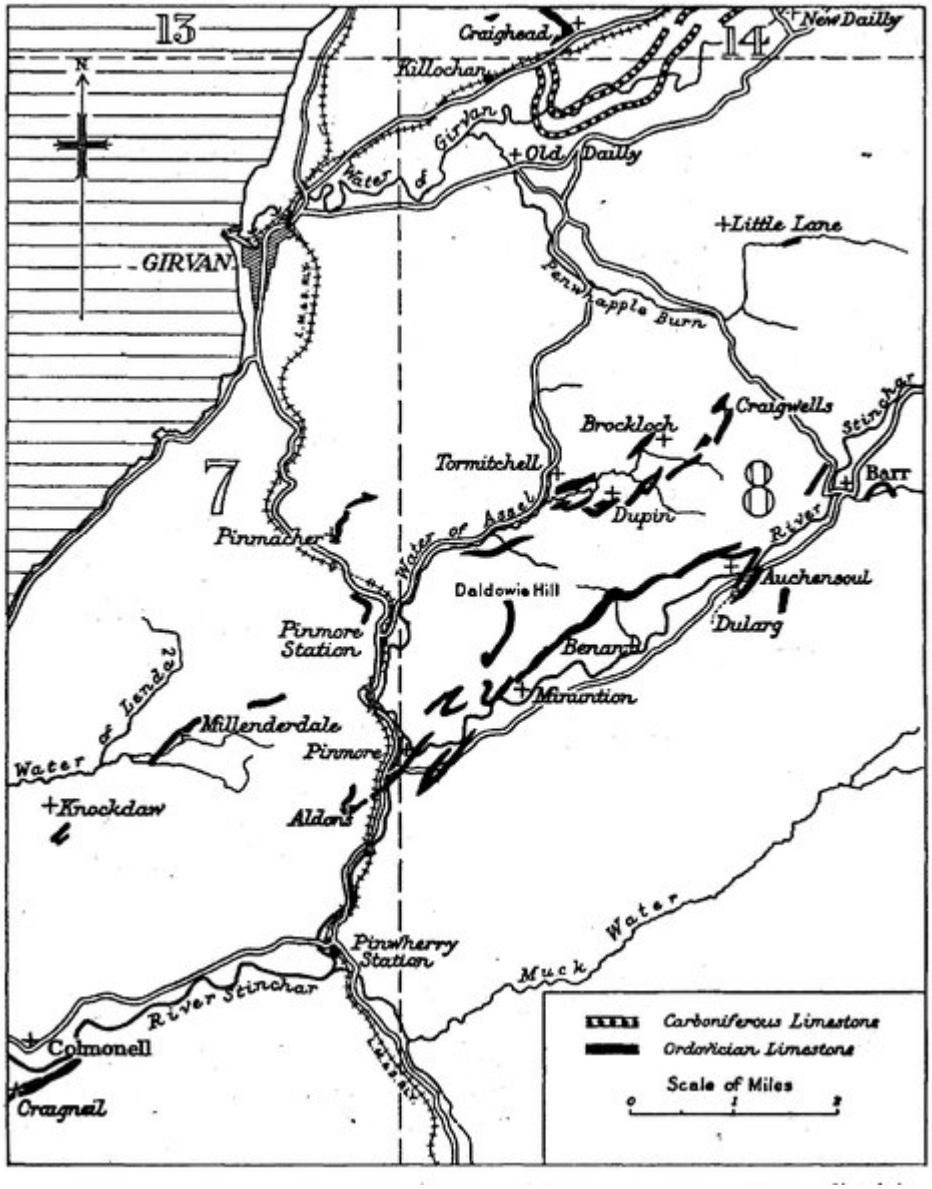

Figure 7 Sketch map showing distribution of limestone in the Girvan district of Ayrshire.

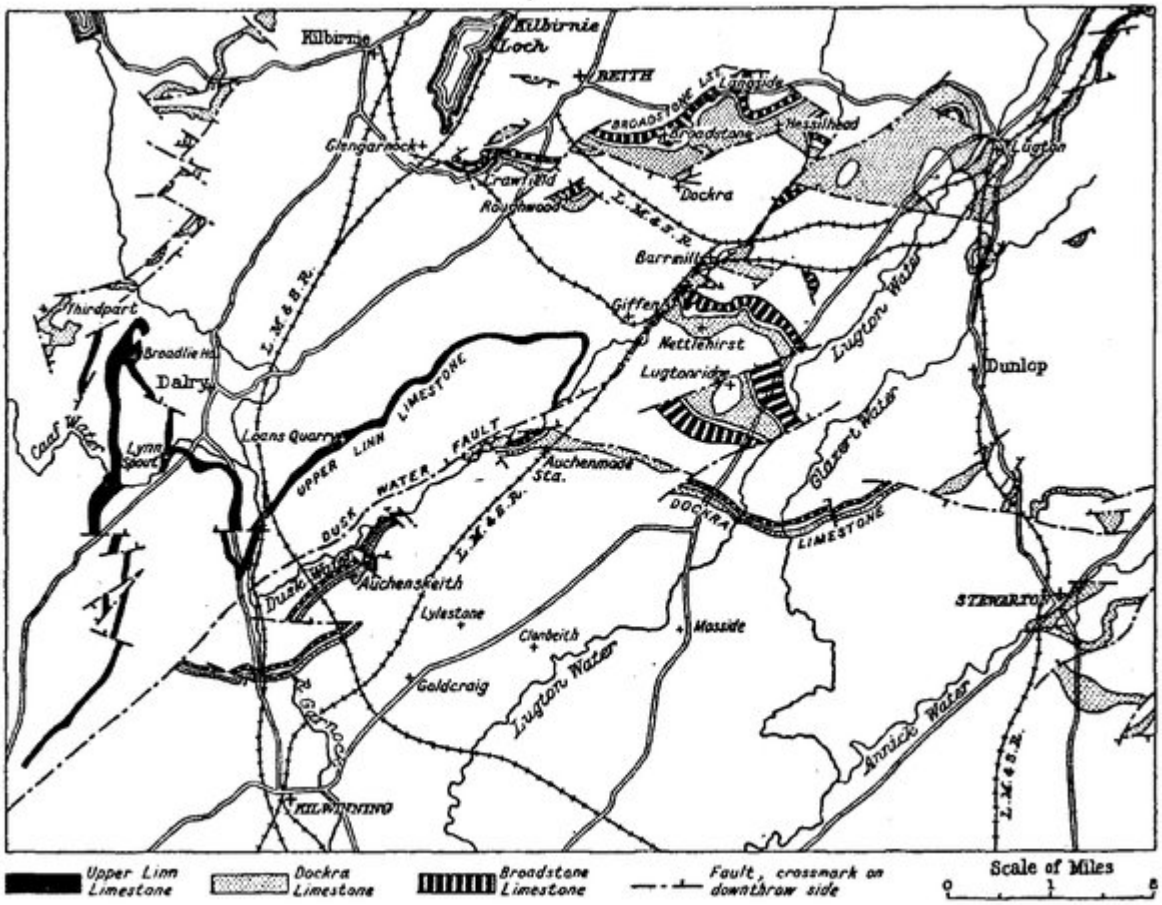

Figure 10 Sketch map showing main distribution of limestone in the Dalry, Beith and Stewarton districts of Ayrshire.

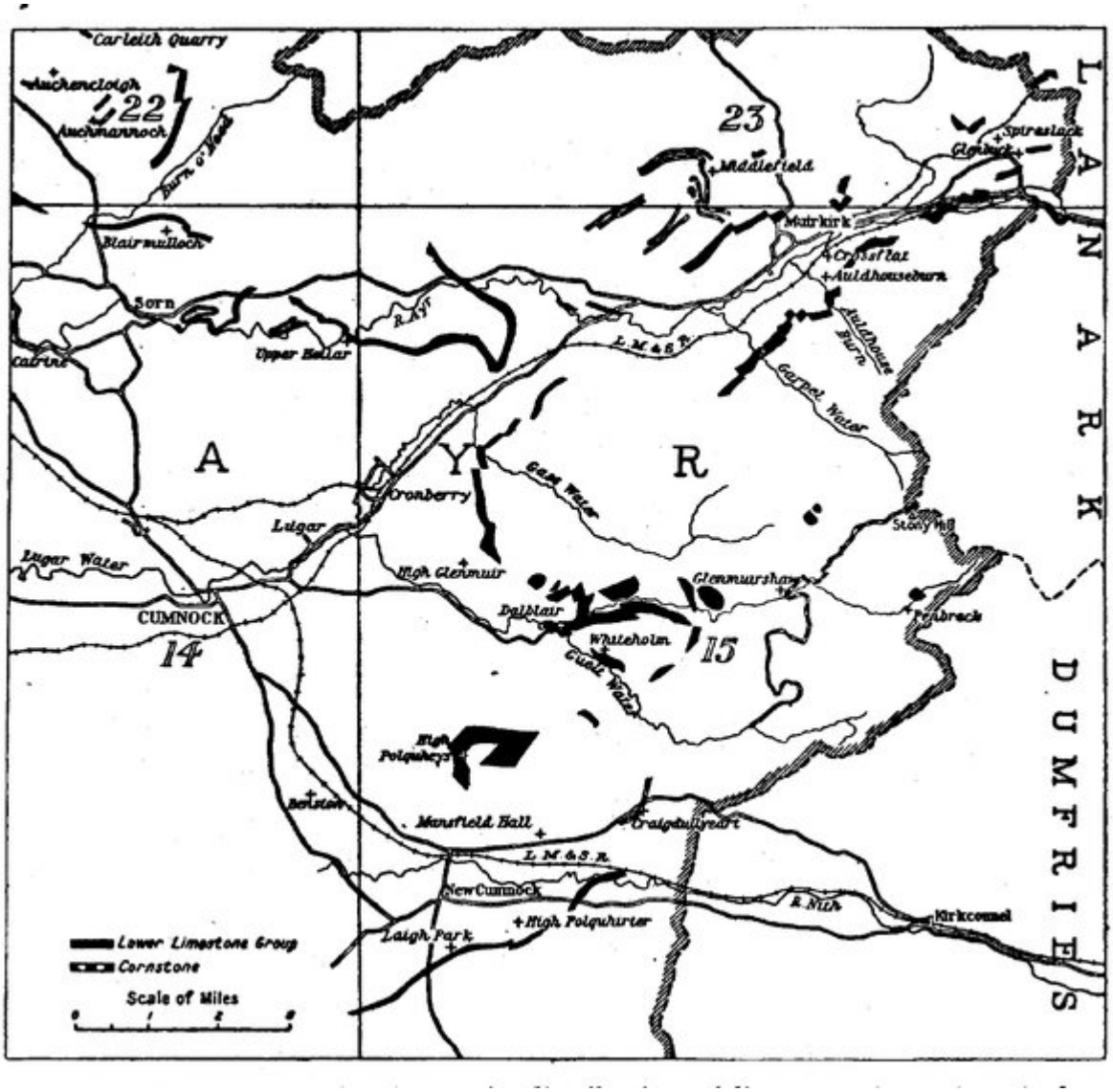

Figure 9 Sketch map showing main distribution of limestone in east-central Ayrshire.

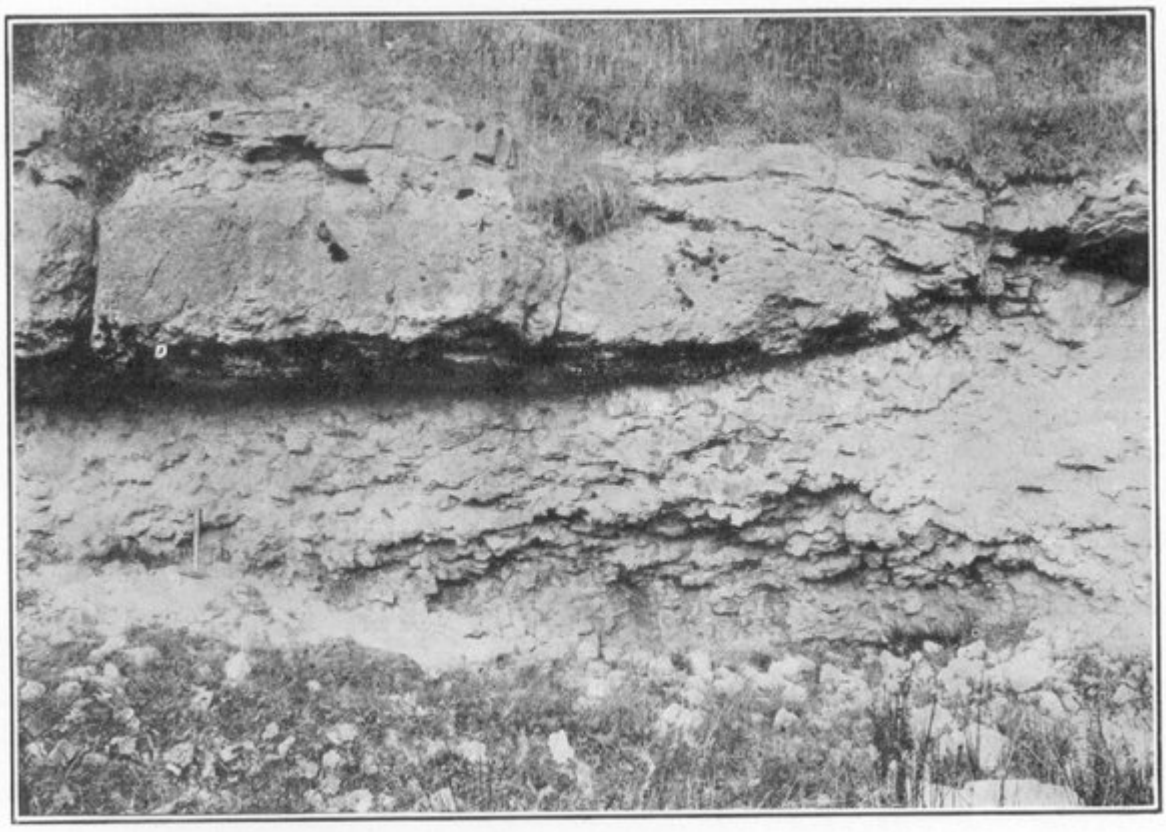

Plate 5A Carleith Quarry, Galston, Ayrshire. Quarry in cornstone of Upper Old Red Sandstone age, illustrating the concretionary nature of the rock.

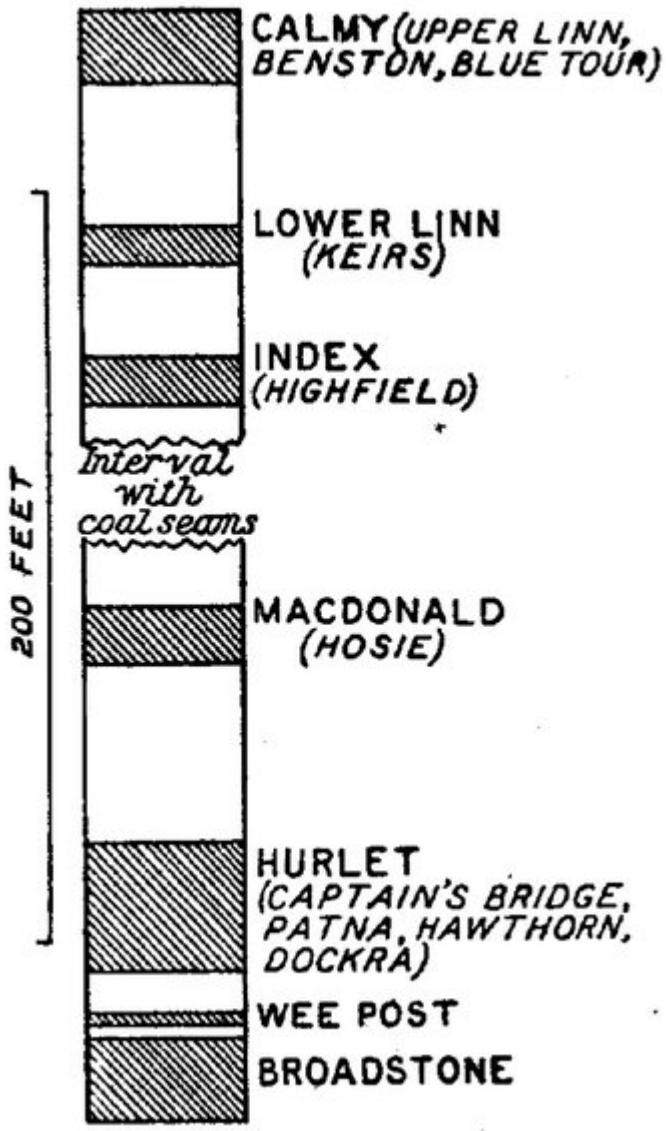

Figure 8 Vertical Section of the worked limestones in the Carboniferous of Ayrshire.

TABLE II

SYNONYMY AND DISTRIBUTION OF THE PRINCIPAL SCOTTISH CARBONIFEROUS LIMESTONES

Geological subdivisions	LIMESTONES Principal names in capitals, synonyms inset	DISTRIBUTION Counties	Localities
UPPER LIMESTONE GROUP	CASTLECARY	Dumbarton	Castlecary, Cumbernauld, Luggiebank
		Fife	Culross
	Craigenbuck	W. Lothian	Kinneil, Carribber
	Levenseat	Midlothian	Bresich
	Vicar's Bridge	Clackmannan	Vicar's Bridge
		Fife	Westmuir
	CALMY	Ayr	New Cumnock
		Lanark	Quarter, Garnkirk, Chryston, Robroyston
		Dumbarton	Cumbernauld
		Fife	Saline, Culross
	Dykeneuk	W. Lothian	Kinneil, Carribber
	Blue Tour	Ayr	Muirkirk
	Beuston	Ayr	New Cumnock
	Upper Linn	Ayr	Dalry
	Gair	Lanark	Larkhall, Carluke, Auchenheath
	Gill	Lanark	Douglas
	Arden	Renfrew	Darnley
	ORCHARD	Renfrew	Giffnock
	Lower Linn	Ayr	Dalry
	LYONCROSS	Renfrew	Waulkmill
	Keirs	Ayr	Waterside
	INDEX	Ayr	Muirkirk, New Cumnock, Sorn
		Lanark	Forth, Coalburn
		Dumbarton	Dullatur
	Highfield	Ayr	Kilwinning
LIMESTONE COAL GROUP	A few Limestones, all thin and impure		
LOWER LIMESTONE GROUP	HOSIE (Limestones of the Hosie Group)	Lanark	Haywood, Carluke
		Renfrew	Johnstone
	Calderwood Cement, Anvil, Middle and Under	Lanark	E. Kilbride
	Hairmyres	Lanark	E. Kilbride
	Macdonald	Ayr	Muirkirk, Dalblair, Penbreck
	Bilston Burn	Midlothian	Esperston
LOWER LIMESTONE GROUP	Mid Kinniny	Fife	Luscar
	BLACKHALL	Renfrew	Hurlet
	Foul Hosie	Lanark	Carluke, Auchenheath
	Petershill	W. Lothian	Bathgate
	North Greens	Peebles	Macbiehill
		Midlothian	Crustland, D'Arcy, Pathhead, Middleton, Mount Lothian
		E. Lothian	Skateraw, Saltoun
	Charlestown Main	Fife	Charlestown, Inverkeithing, Colts, Lomond Hills, Leslie, Roscobie, Chapel etc.
		Kinross	Bishop Hill
	LONG CRAIG UPPER, HURLET or MAIN	E. Lothian	Haraelaw, Oxwell Mains, Gladsmuir, Saltoun
		Ayr	Patna
		Lanark	E. Kilbride, Carluke, Wilsontown, Auchenheath, Strathaven, Lesmahagow, Douglas, etc.
		Dumbarton	Baljaffray
		Renfrew	Paisley, Johnstone, Houston, Hurlet
		Stirling	Lennoxtown, Cambusbarron, Sauchie
	Hawthorn	Ayr	Sorn, Glenbuck, Muirkirk, Glenmuir, Penbreck, New Cumnock
	Dockra	Ayr	Dalry, Beith, Lugton, Ischgotrick
	Corrie	Bute	Cock of Arran, Corrie, Brodick
	Gilmerton	Peebles	Carleps, Macbiehill
		Midlothian	Gilmerton, Middleton, Mount Lothian
		E. Lothian	Saltoun
	Charlestown Station	Fife	Lomond Hills, Little Raith, Kinghorn
	Limestones (uncorrelated) of Lower Limestone and Upper Calciferous Sandstone age	Dumfries	Thorphill, Ecclefechan, Kelhead, Harelawhill
CALCIFEROUS SANDSTONE SERIES	BALDERNOCK	Stirling	Glorat
		Ayr	Dalry
	BROADSTONE	Ayr	Beith, Dalry
		Renfrew	Johnstone
	HOLLYBUSH	Renfrew	Limecraigs, etc., Barrhead
	Big	Lanark	Lesmahagow
	BURDIEHOUSE	W. Lothian	Hopetoun
		Midlothian	Straiton, Harburn, E. Calder
		Fife	Burntisland, Rosyth
	Other limestones in Oil Shale Group	E. Lothian	E. Linton, N. Berwick, Whittinghame
	CEMENTSTONES individual beds not traceable over large areas	Roxburgh	Newcastleton, Carham
		Dumbarton	Dumbarton
		Stirling	Ballagan
		Midlothian	West Calder
		Fife	Devonshaw, Randerstone, Crail, Anstruther

Table 2 Synonymy and distribution of the principal Scottish Carboniferous limestones.

Plate 7A Drummuir Quarry, Banffshire. General view of quarry, showing method of working in two benches and dip of beds of limestone.

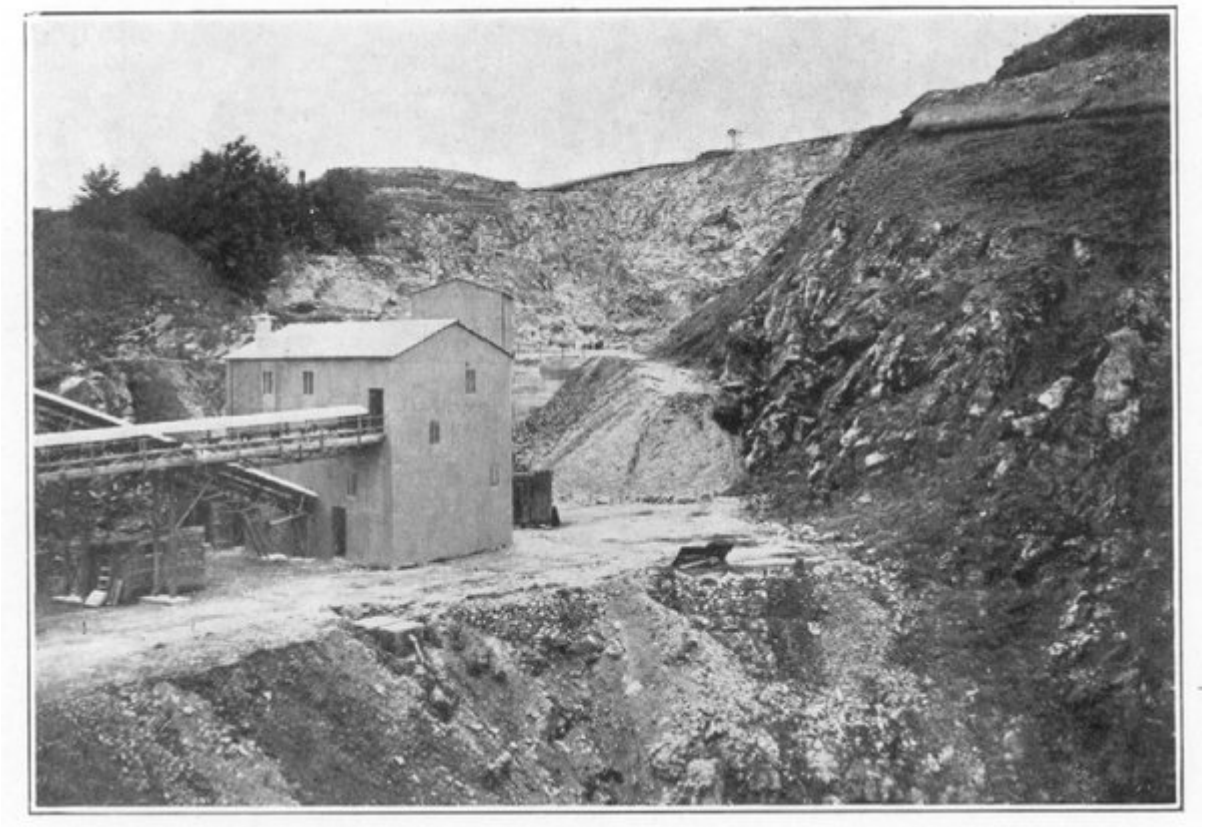

Plate 4A Parkmore Quarry, Dufftown, Banffshire. General view of quarry, showing primary and secondary crushers.

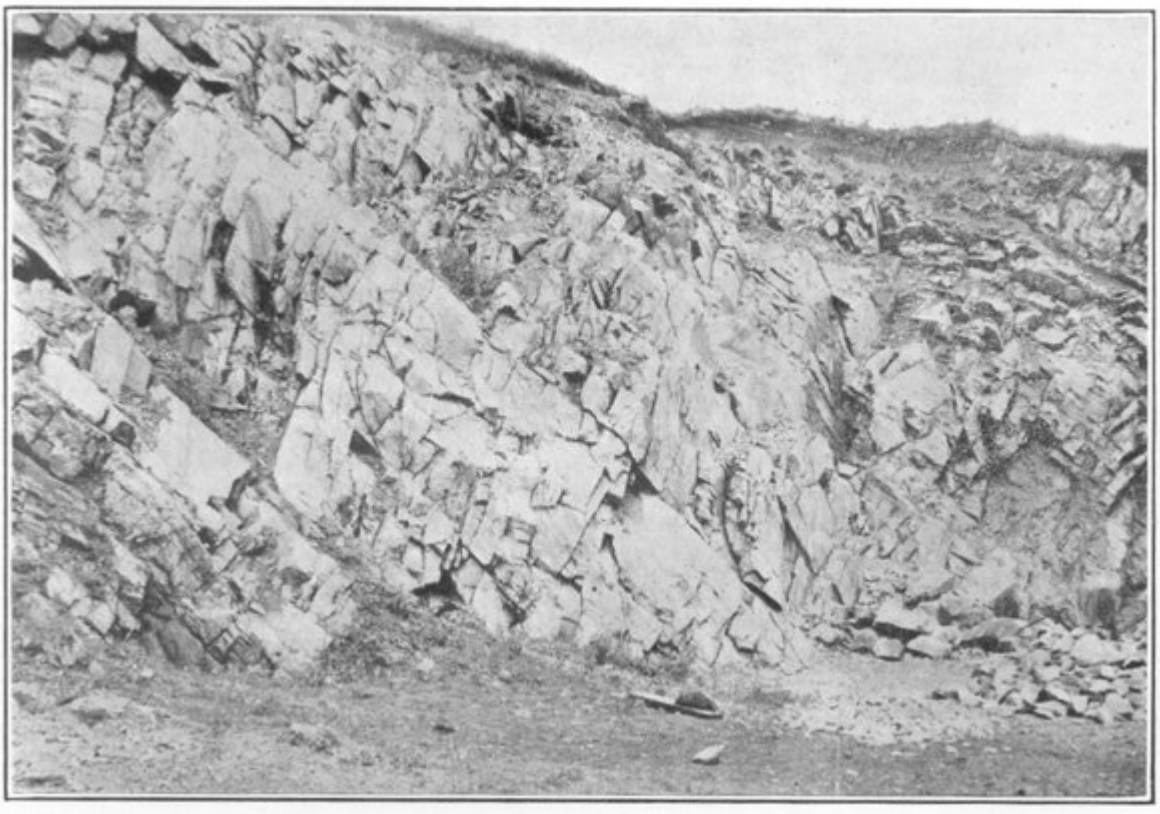

Plate 4B Limehillock Quarry, Grange, Banffshire. View of part of face, showing dip of beds of limestone.

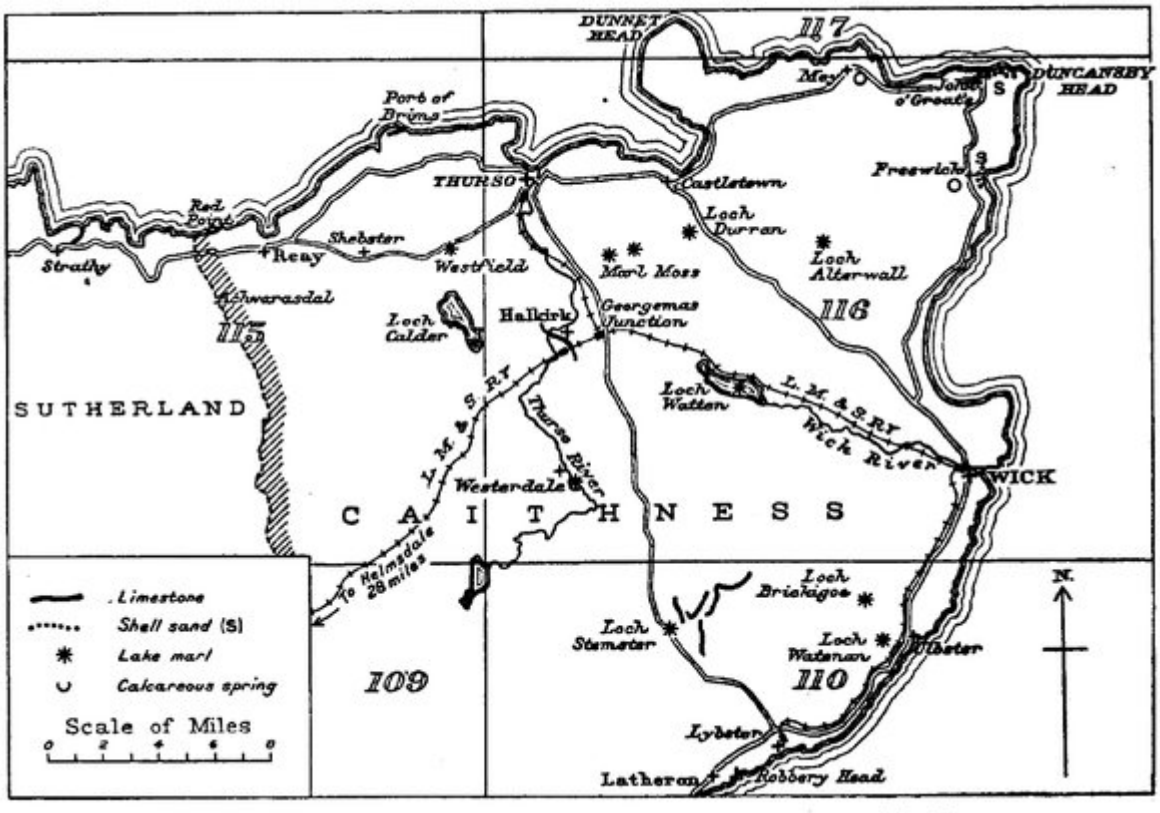

Figure 13 Sketch map showing calcareous deposits of Caithness.

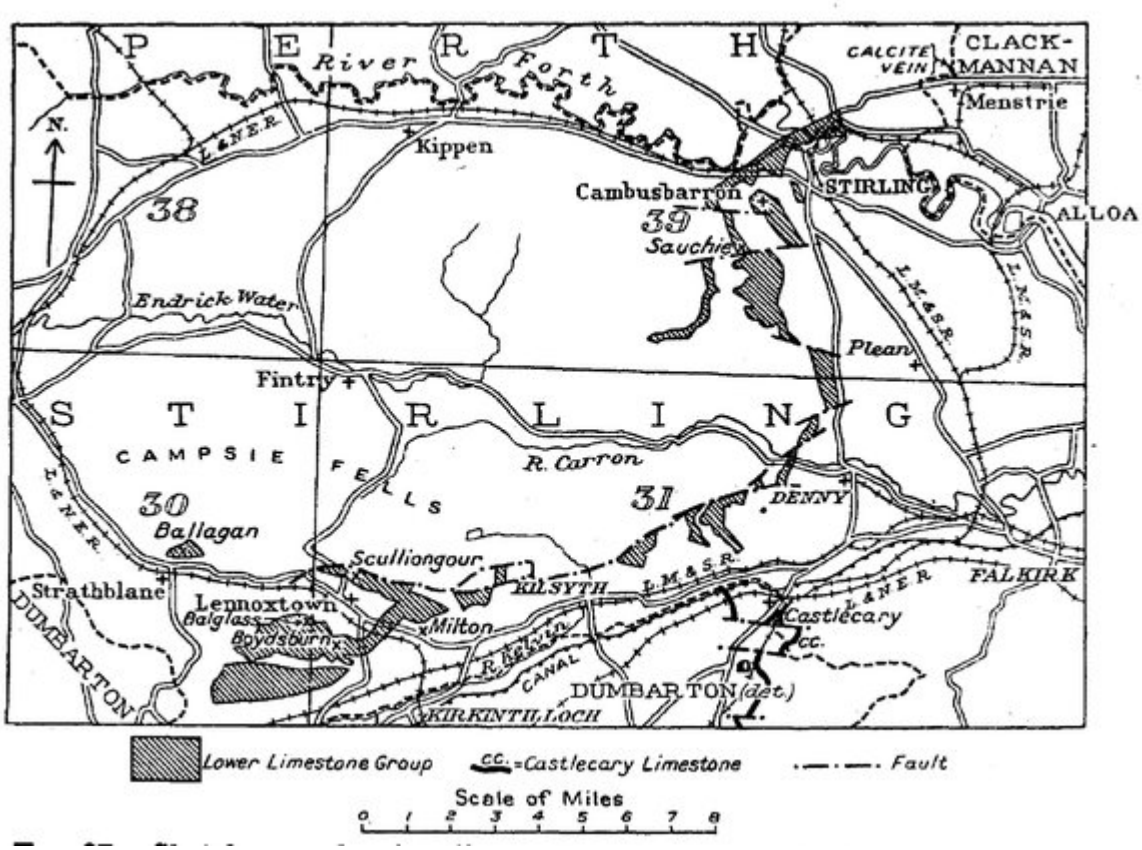

Figure 37 Sketch map showing distribution of limestone in the counties of Stirling and Dumbarton detached.

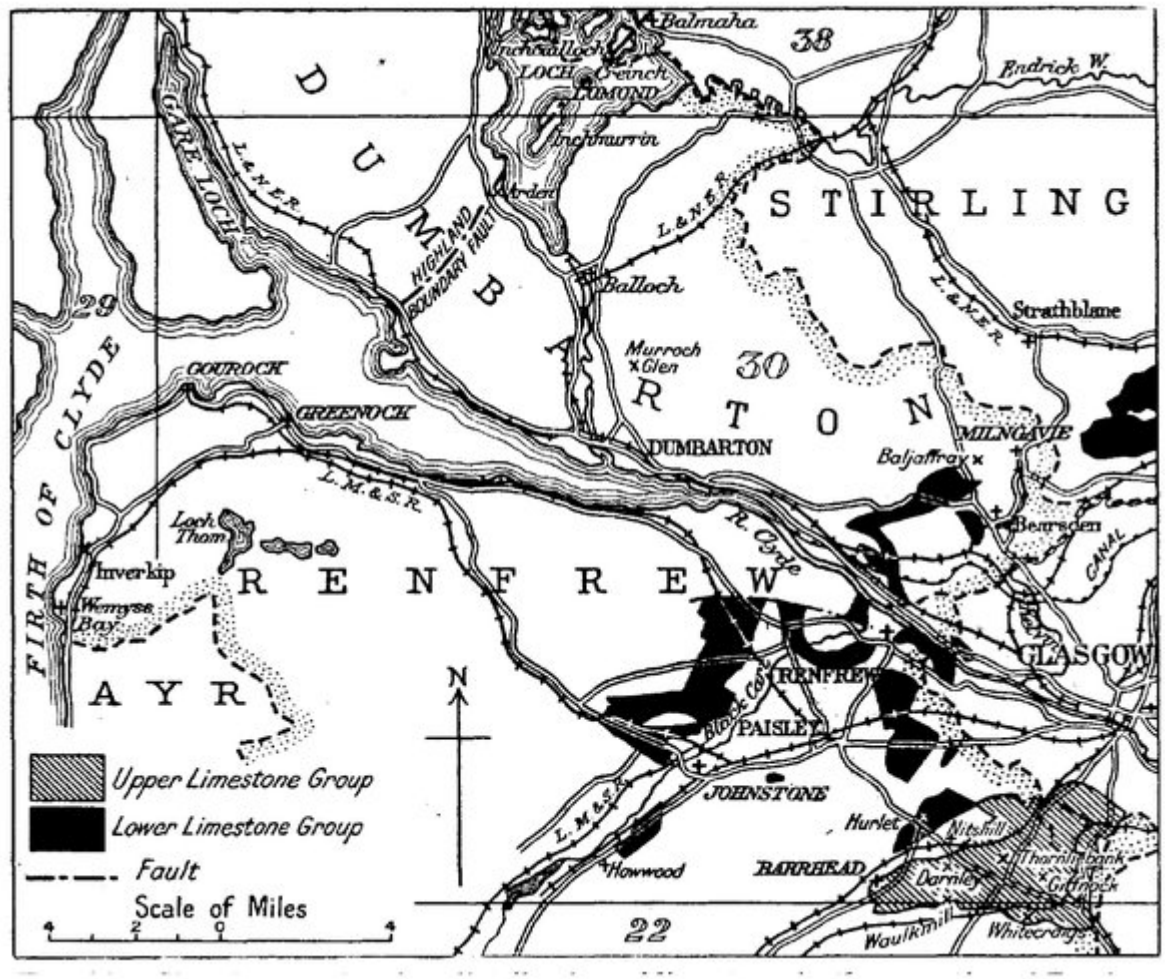

Figure 32 Sketch map showing distribution of limestone in the counties of Renfrew and Dumbarton.

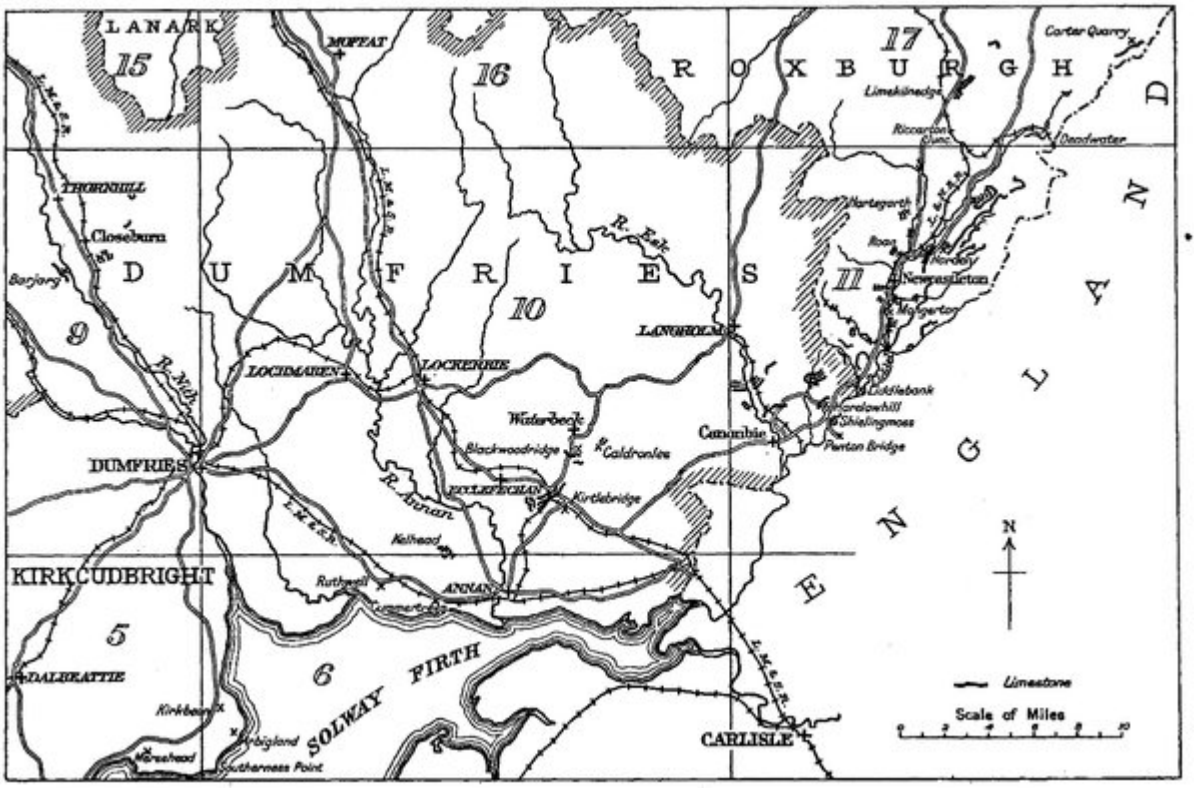

Figure 14 Sketch map showing distribution of limestone in the counties of Dumfries, Kirkcudbright and Roxburgh.

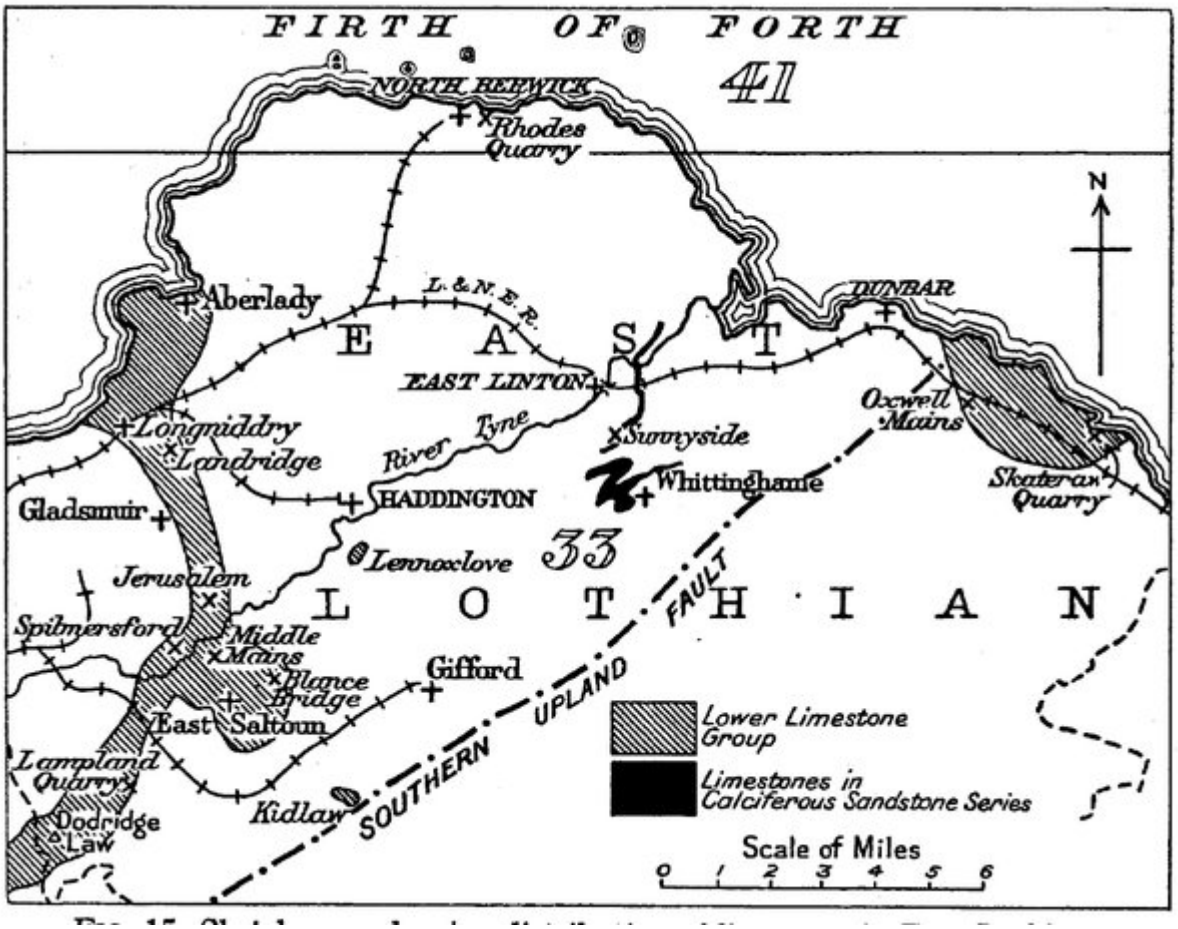

Figure 15 Sketch map showing distribution of limestone in East Lothian.

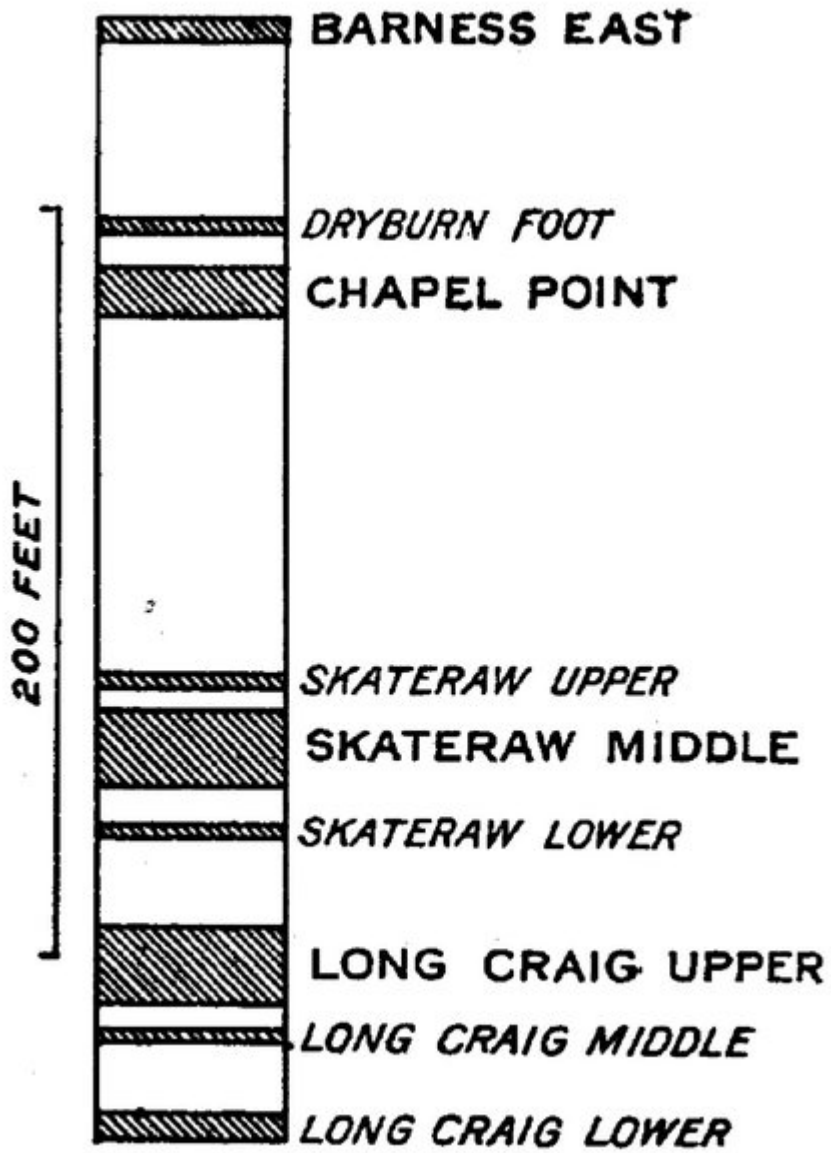

Figure 16 Vertical Section of the limestones of the Lower Limestone Group of East Lothian.

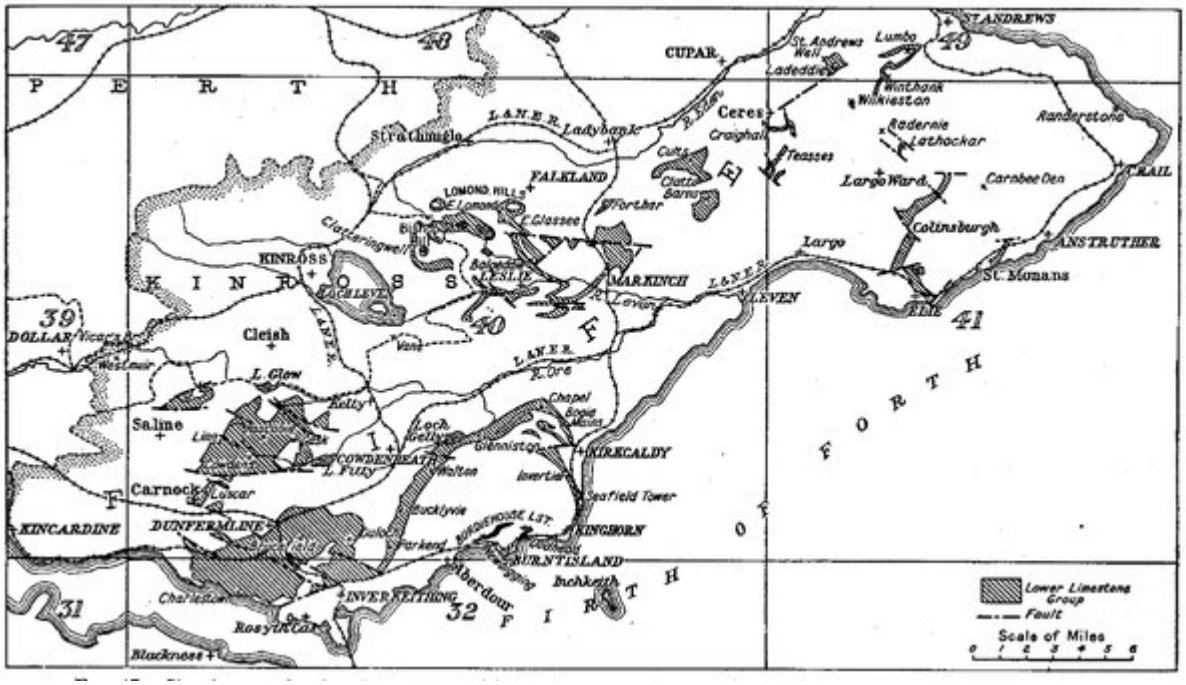

Figure 17 Sketch map showing distribution of limestone in the Carboniferous of the counties of Fife and Kinross.

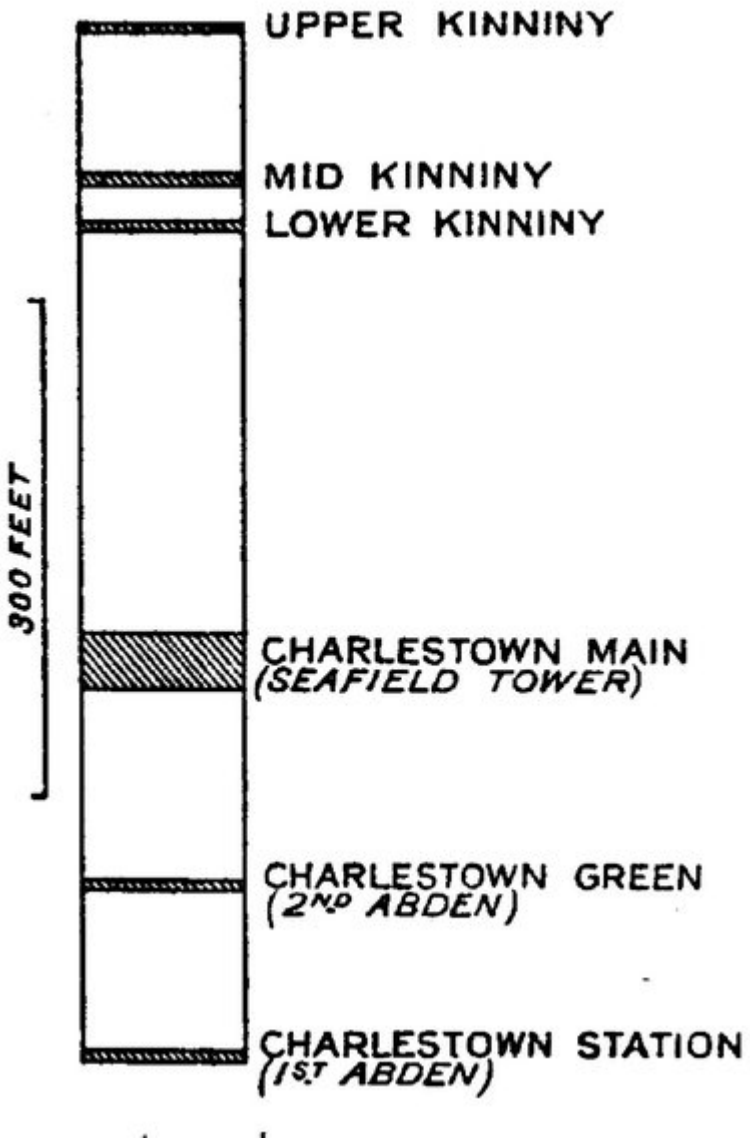

Figure 18 Vertical Section of the limestones of the Lower Limestone Group of Fife.

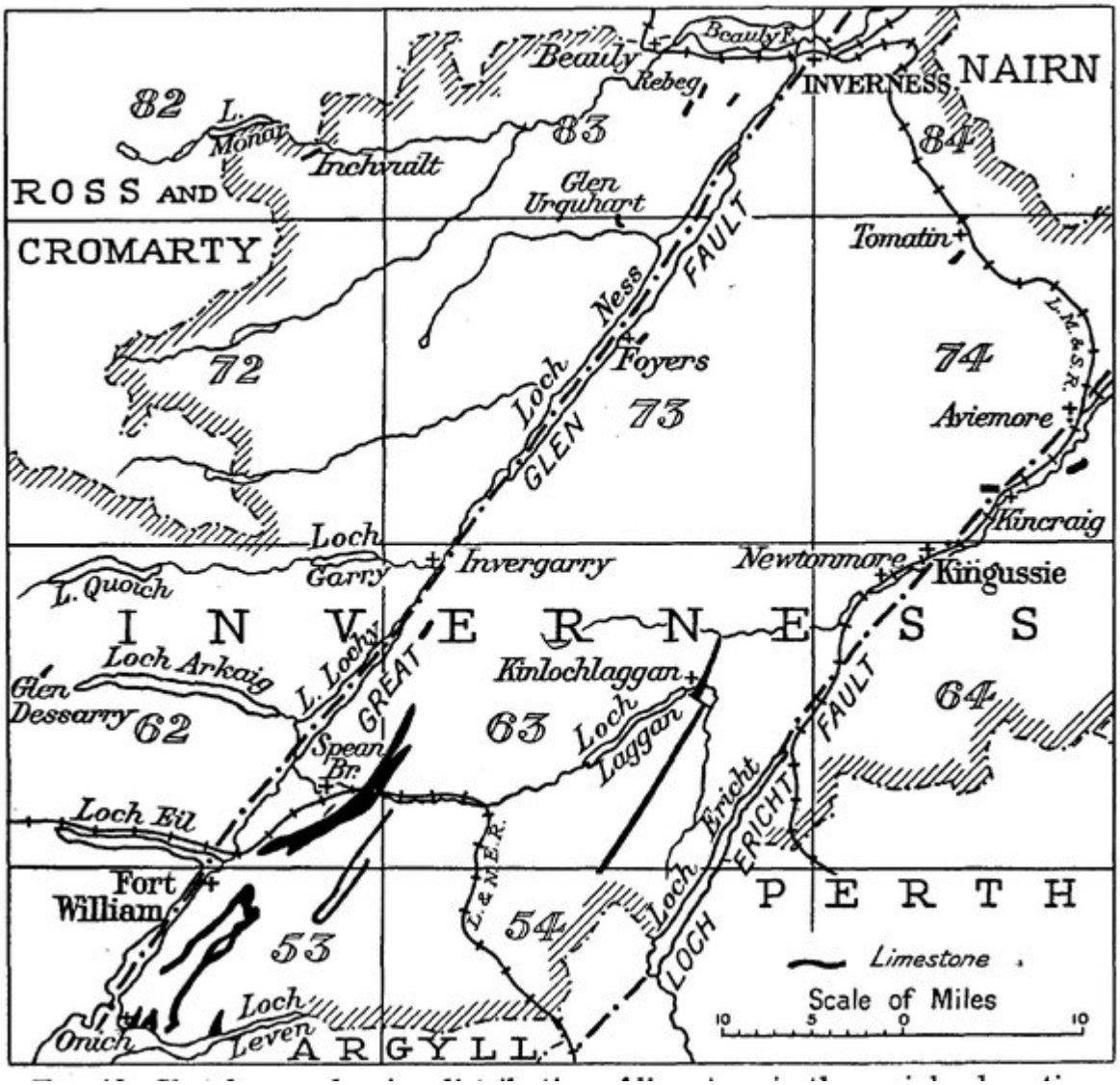

Figure 19 Sketch map showing distribution of limestone in the mainland portion of Inverness-shire.

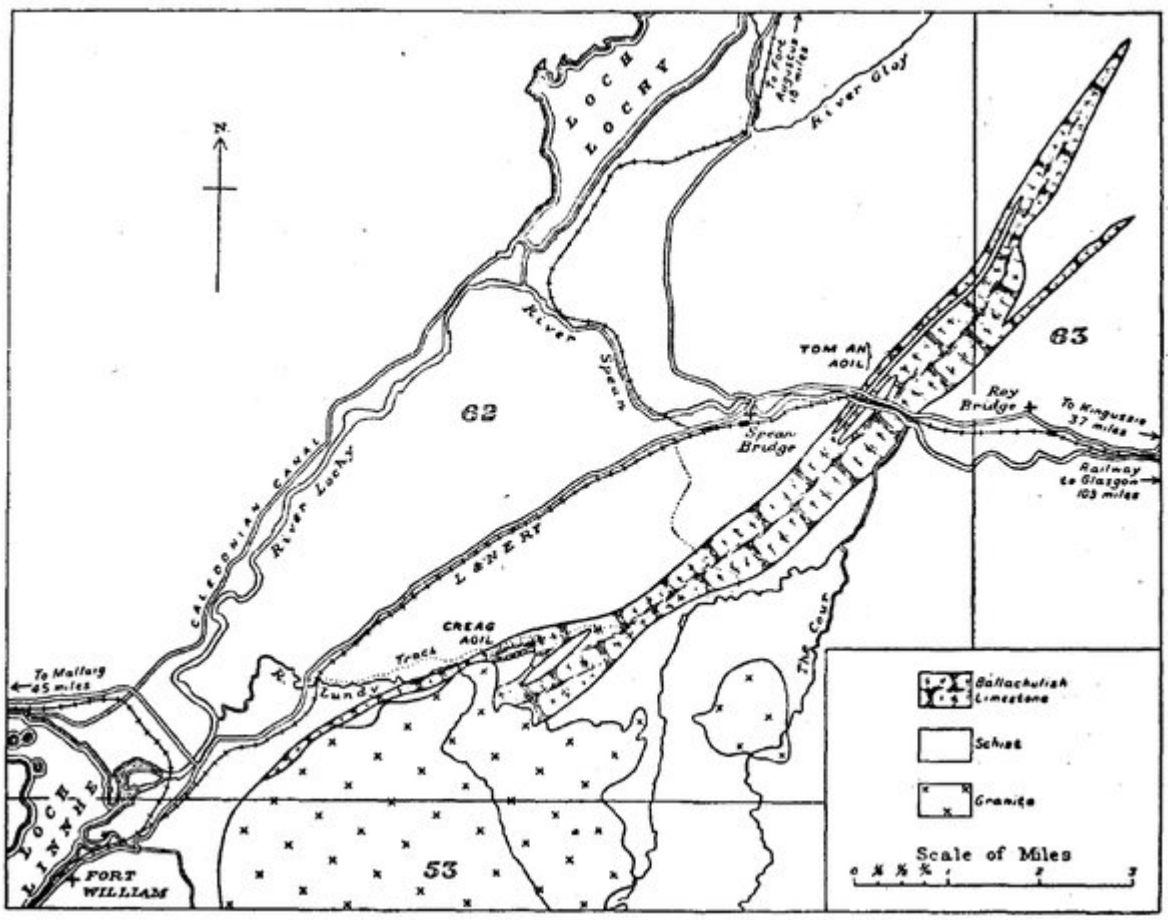

Figure 20 Sketch map of the Ballachulish Limestone in the Fort William–Spean Bridge district of Inverness-shire.

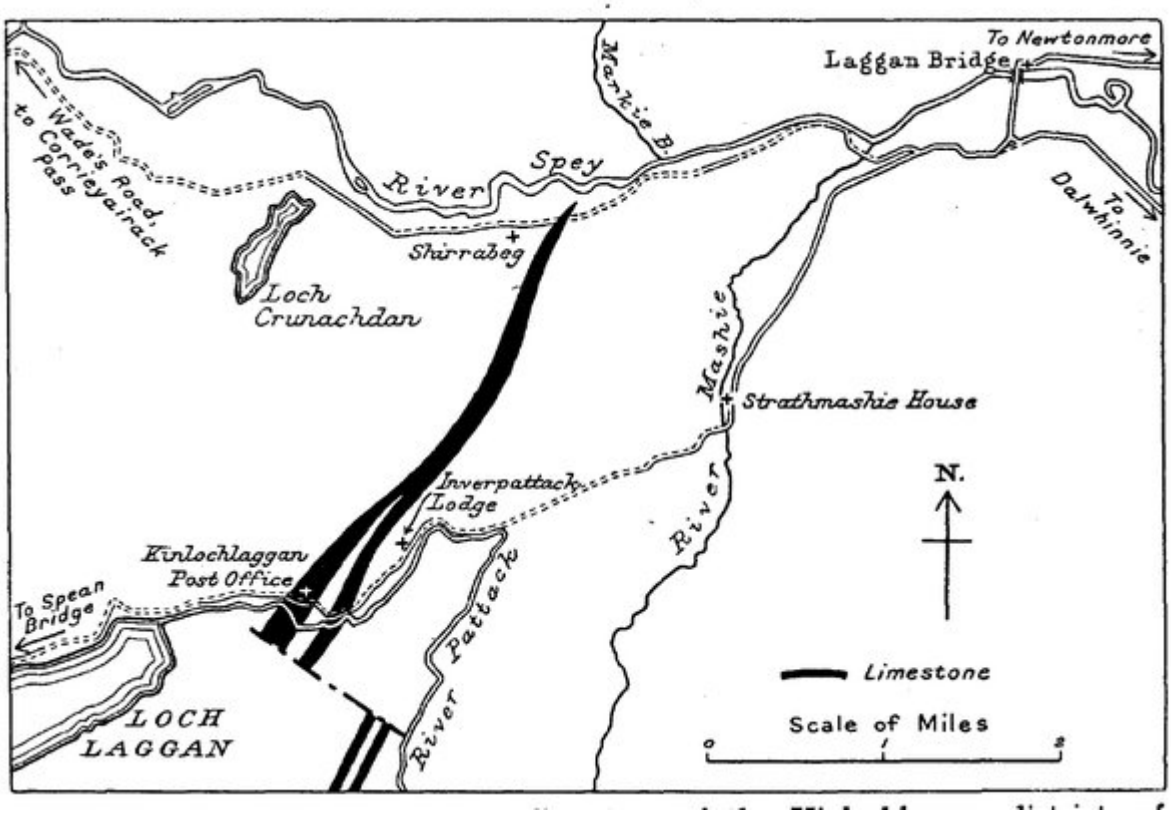

Figure 21 Sketch map showing the limestone of the Kinlochlaggan district of Inverness-shire.

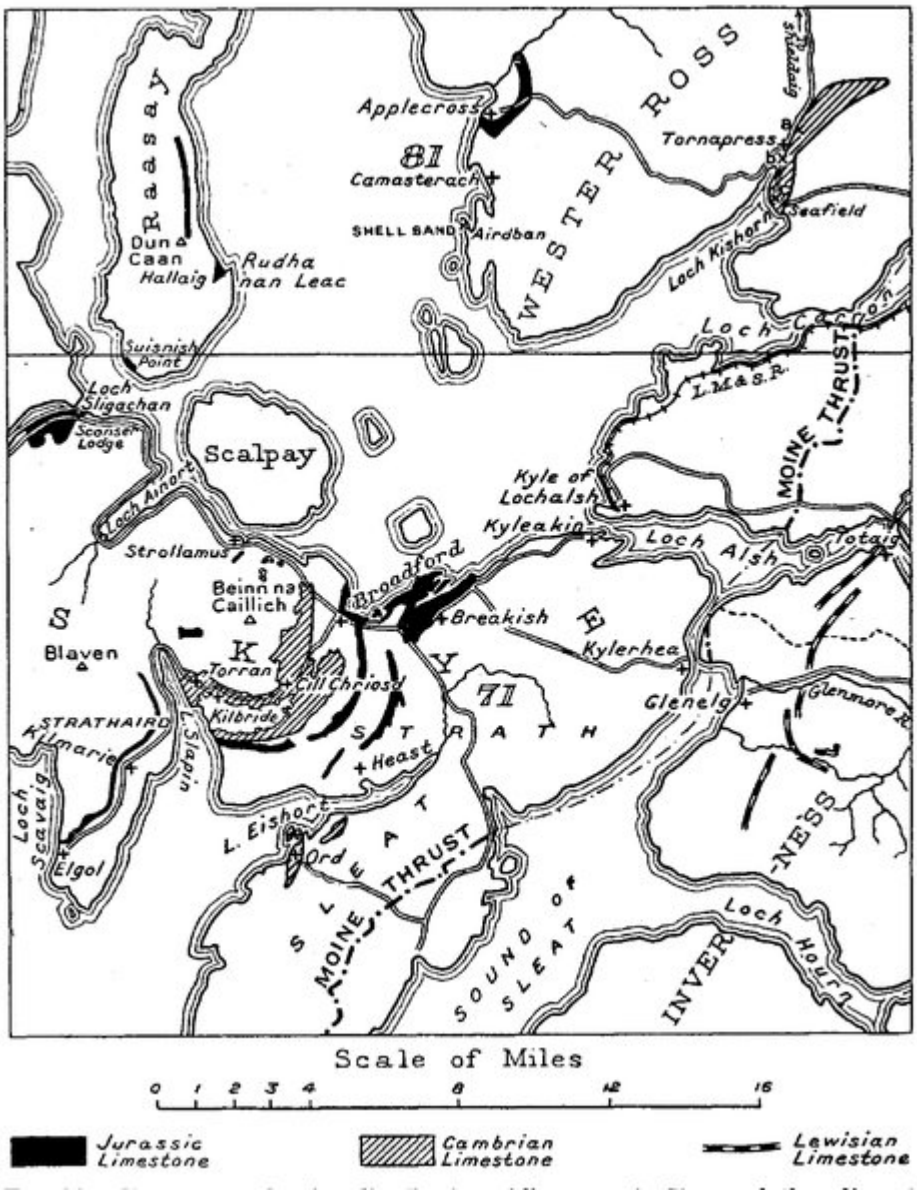

Figure 22 Sketch map showing distribution of limestone in Skye and the adjacent mainland.

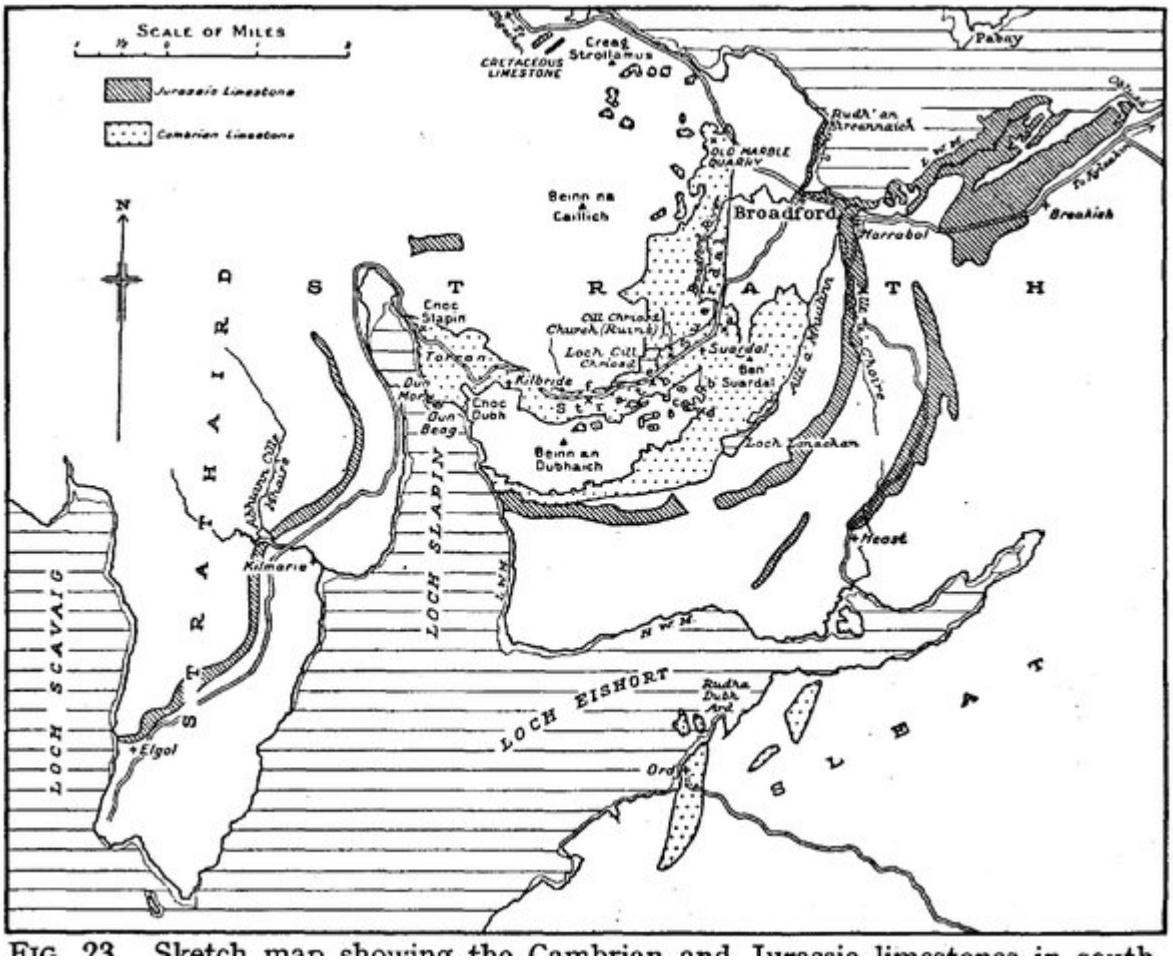

FIG. 23 Sketch map showing the Cambrian and Jurassic limestones in south-eastern Skye.

Figure 23 Sketch map showing the Cambrian and Jurassic limestones in south-eastern Skye.

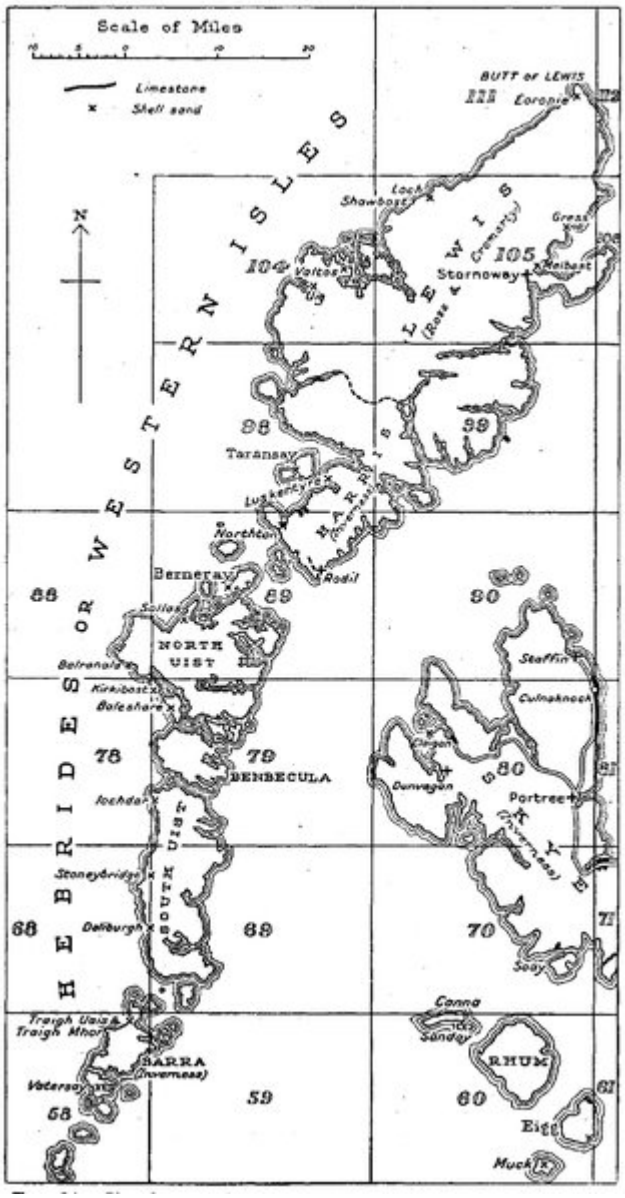

Figure 24 Sketch map showing calcareous deposits in the Hebrides and north-western Skye.

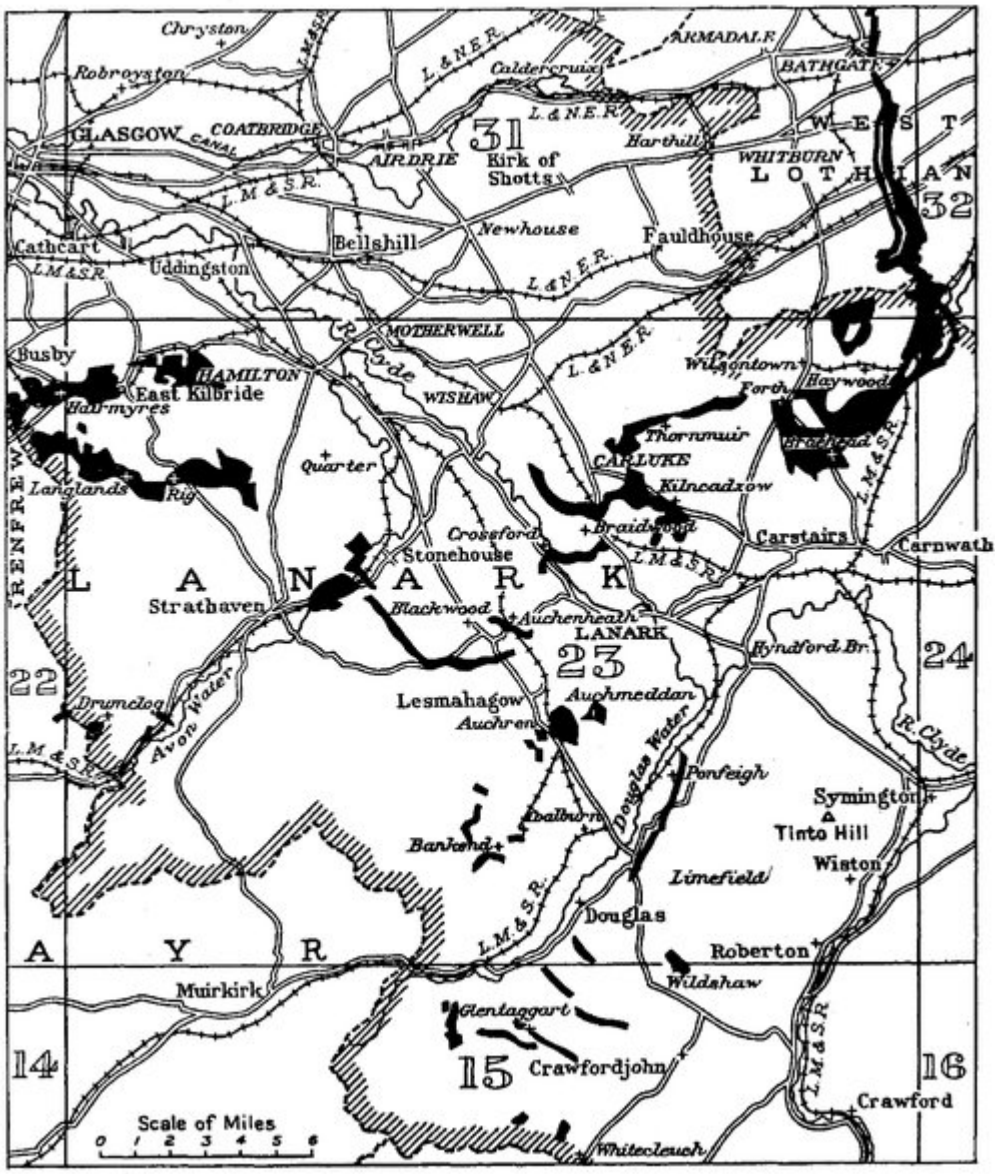

Figure 25 Sketch map showing main areas black of limestone in Lanarkshire.

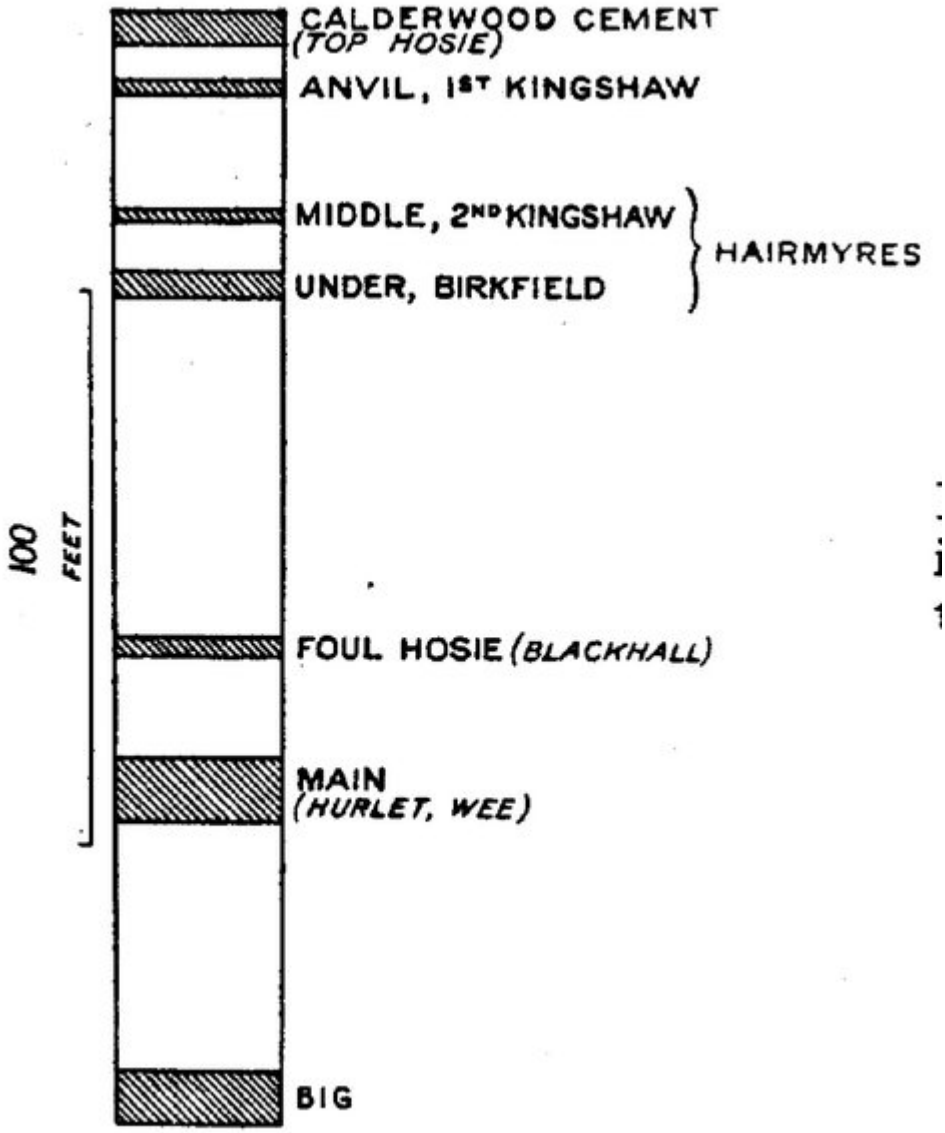

Figure 26 Vertical Section of the limestones in the Lower Limestone Group and at the top of the Calciferous Sandstone Series of Lanarkshire.

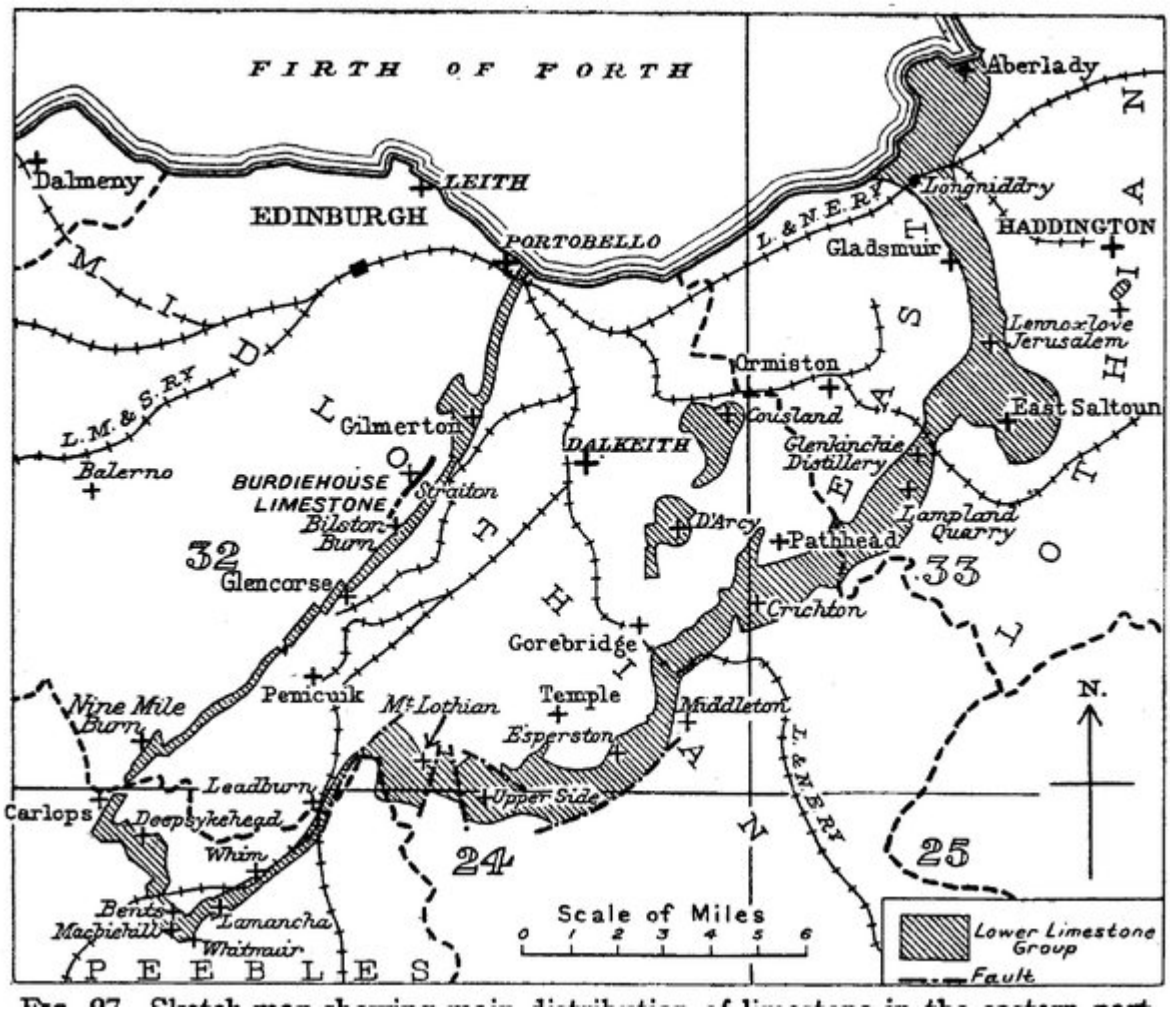

Figure 27 Sketch map showing main distribution of limestone in the eastern part of Midlothian and adjacent parts of Peebleshire and East Lothian.

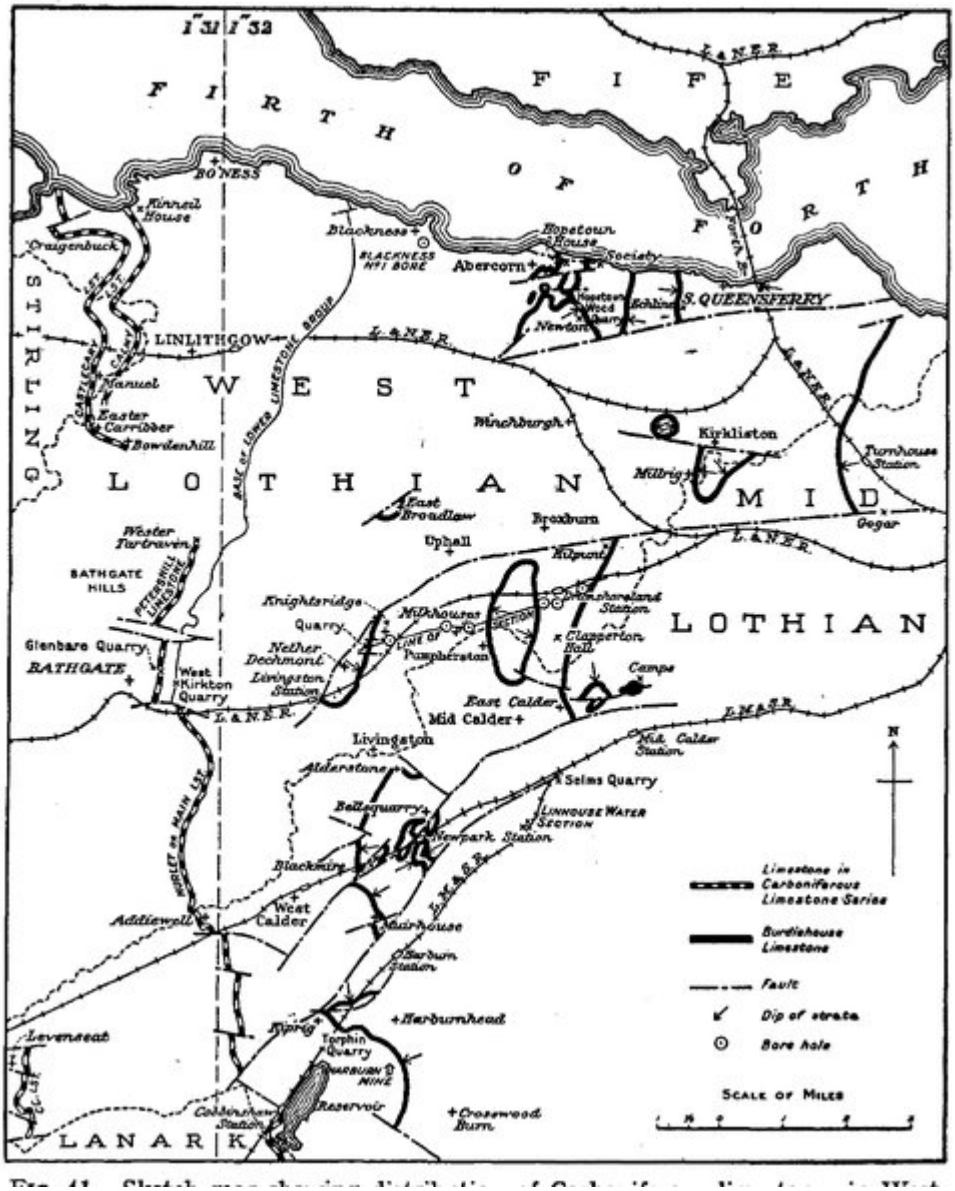

Figure 41 Sketch map showing distribution of Carboniferous limestones in West Lothian and the western part of Midlothian.

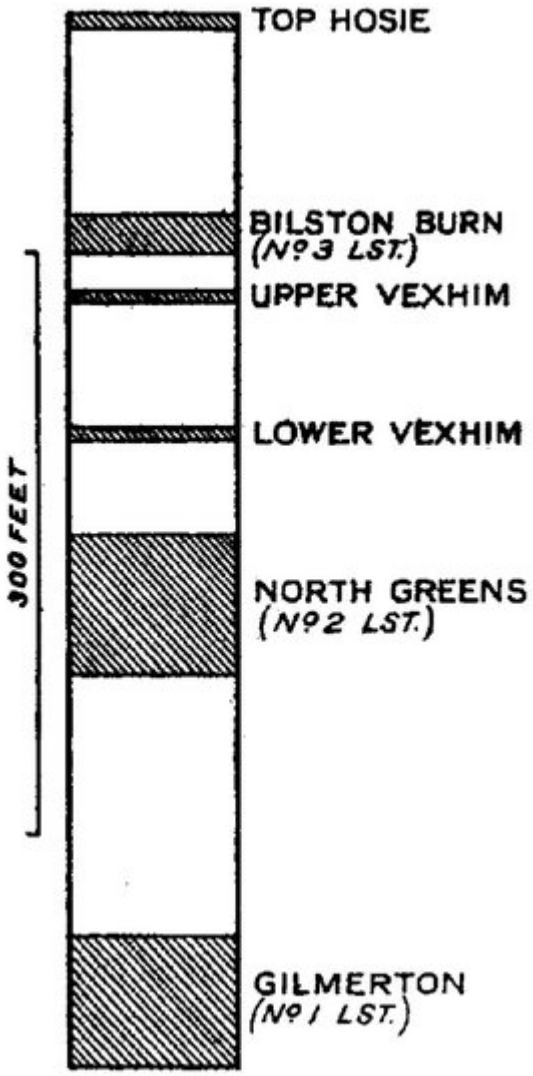

Figure 28 Vertical Section of the limestones of the Lower Limestone Group of Midlothian.

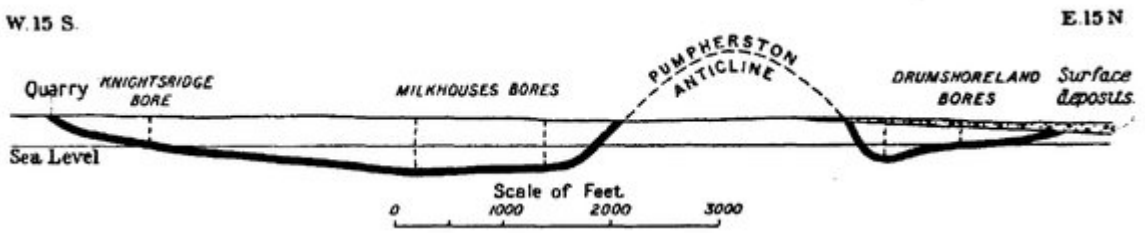

Figure 43 Section of the Burdiehouse Limestone in the Pumpherston area see line of section in Figure 41.

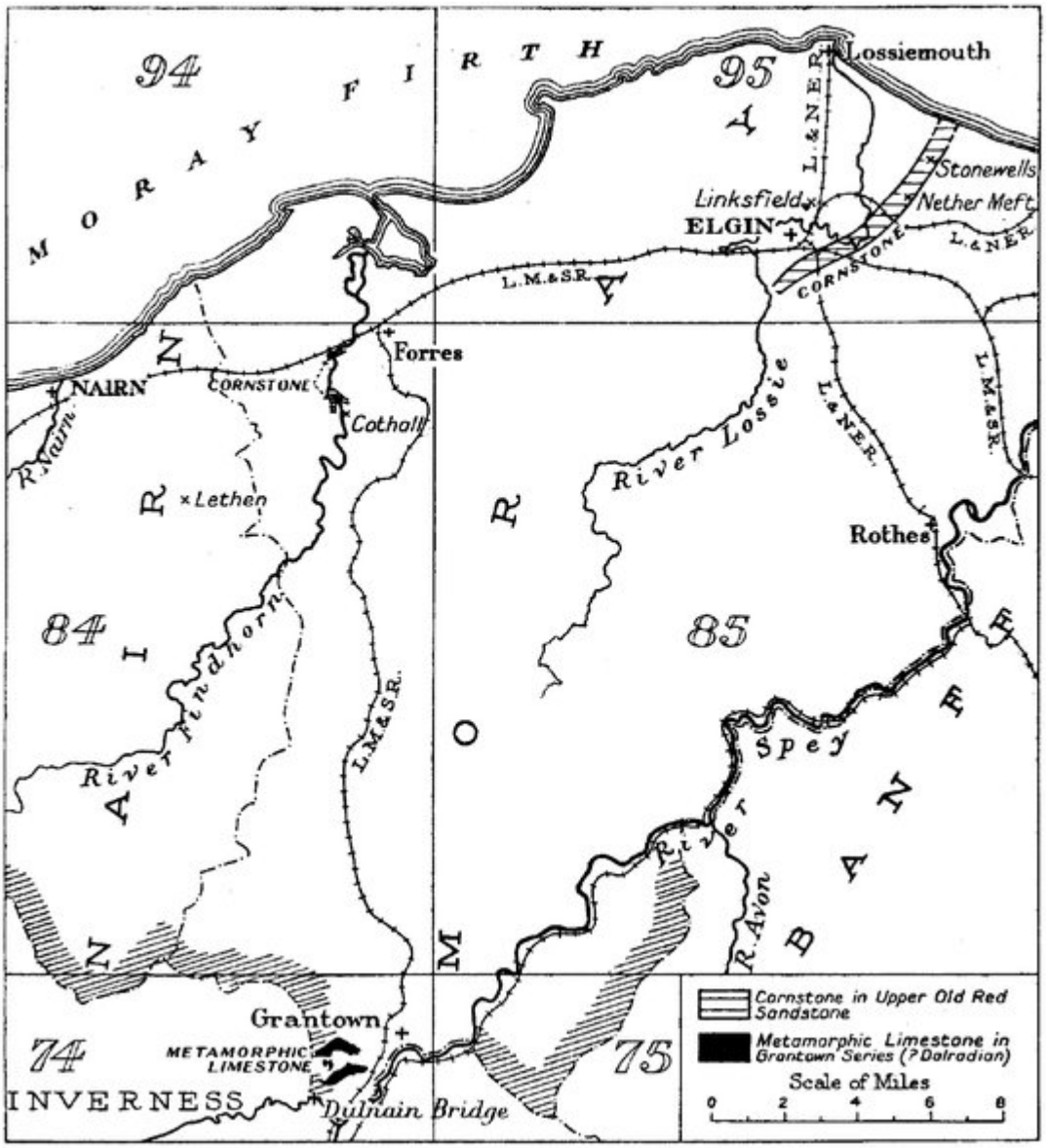

Figure 29 Sketch map showing distribution of limestone in the counties of Moray and Nairn.

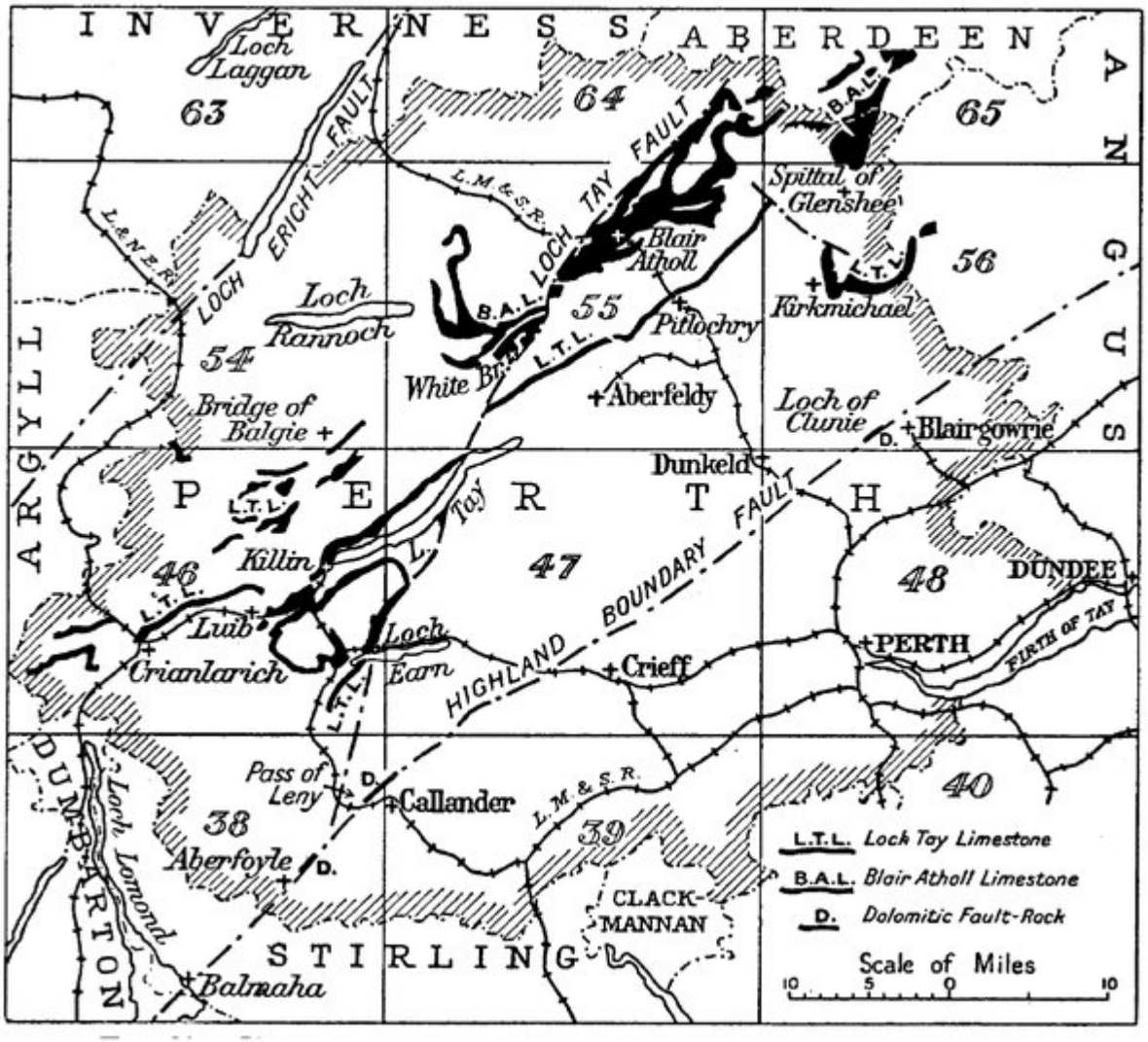

Figure 30 Sketch map showing distribution of limestone in Perthshire.

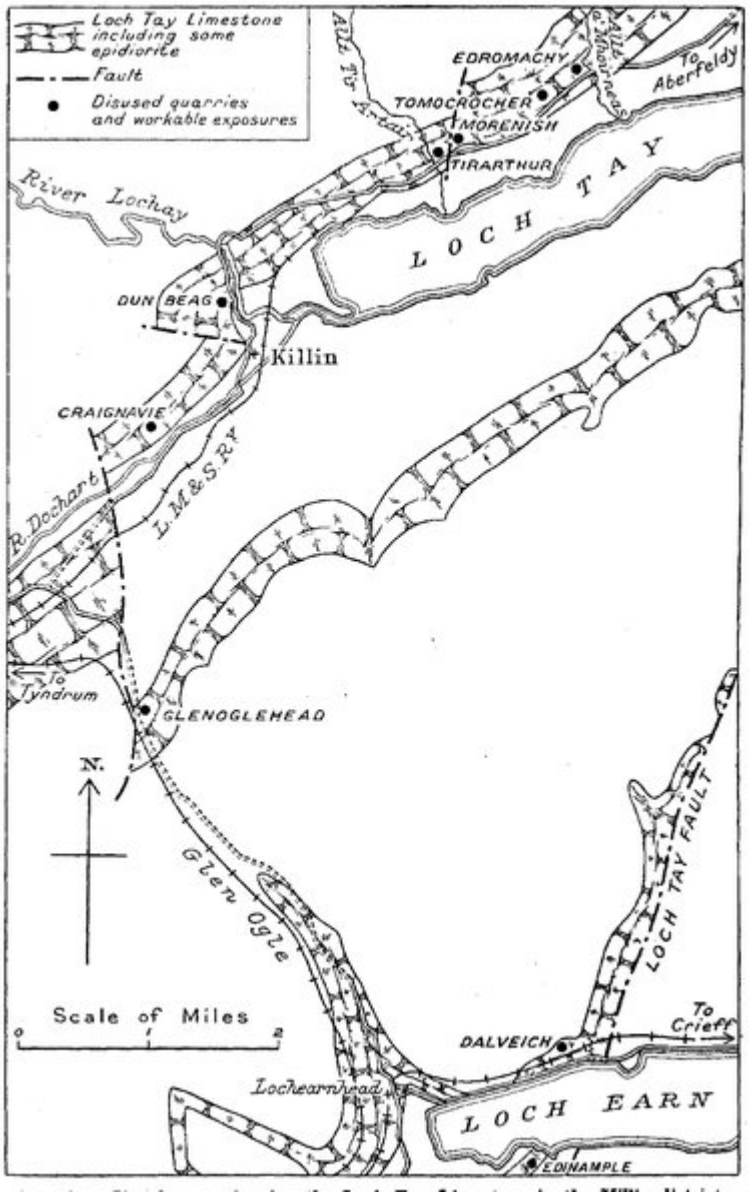

Figure 31 Sketch map showing the Loch Tay Limestone in the Killin district of Perthshire.

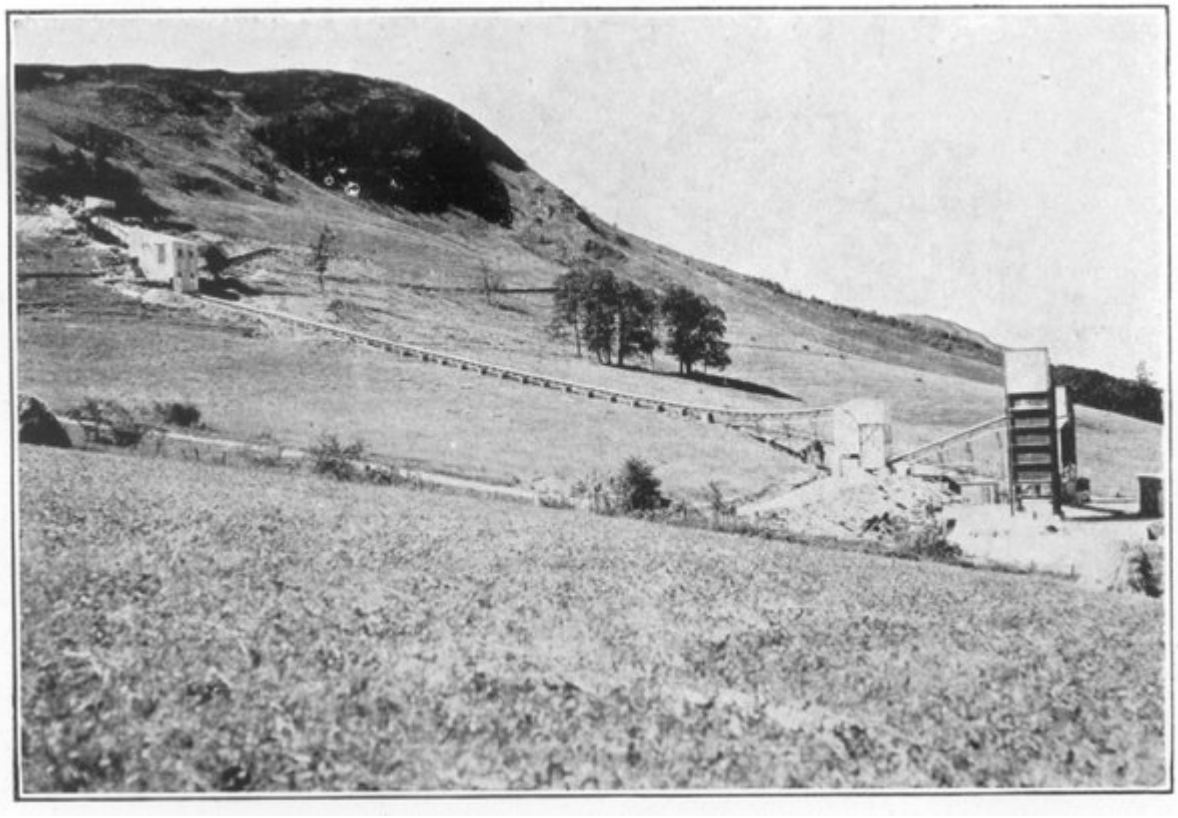

Plate 7B Creag Odhar, Shierglas, Blair Atholl, Perthshire. General view showing hill of limestone to left and crushing plant.

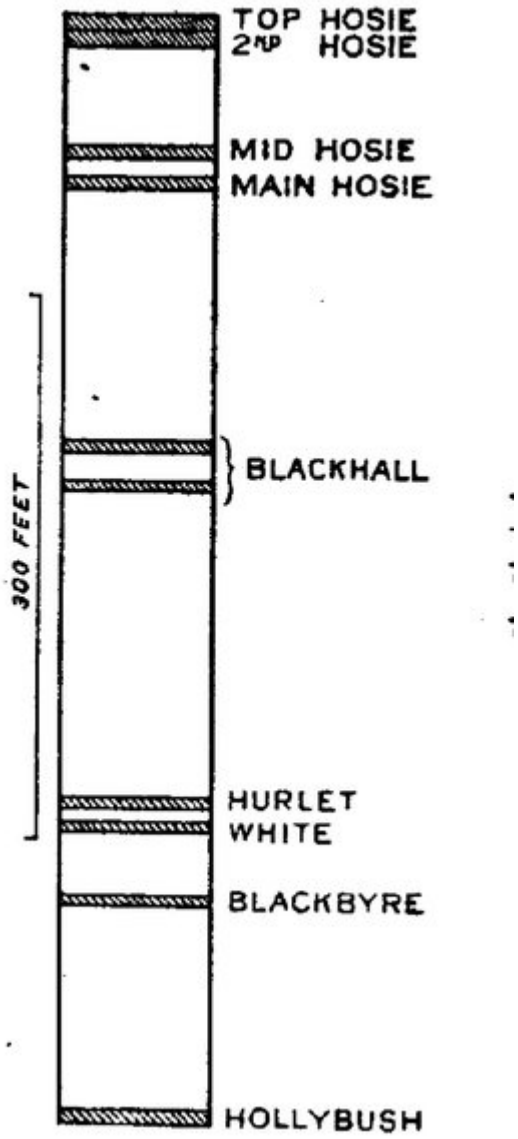

Figure 33 Vertical Section of the limestones in the Lower Limestone Group and at the top of the Calciferous Sandstone Series of Renfrewshire.

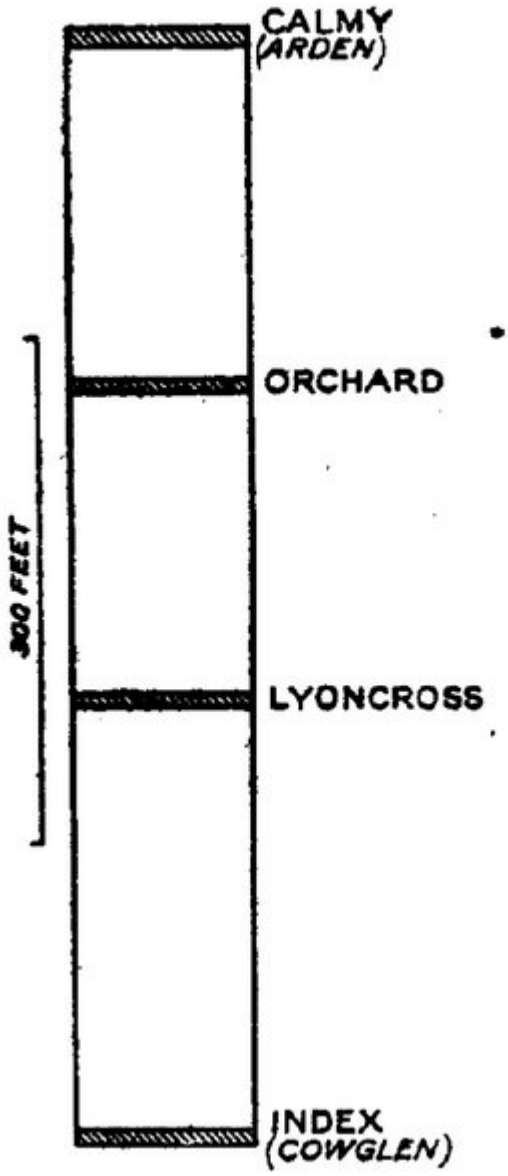

Figure 34 Vertical Section of the limestones in the Upper Limestone Group of Renfrewshire.

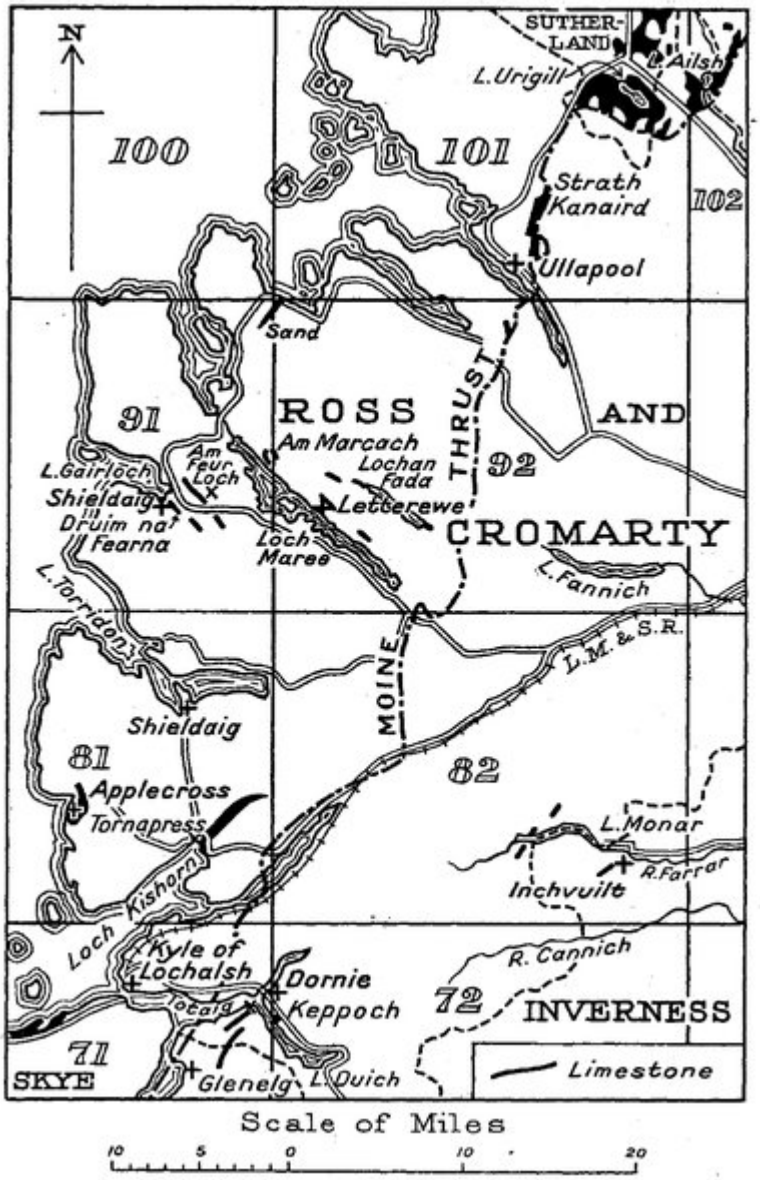

Figure 35 Sketch map showing distribution of limestone in Ross and Cromarty.

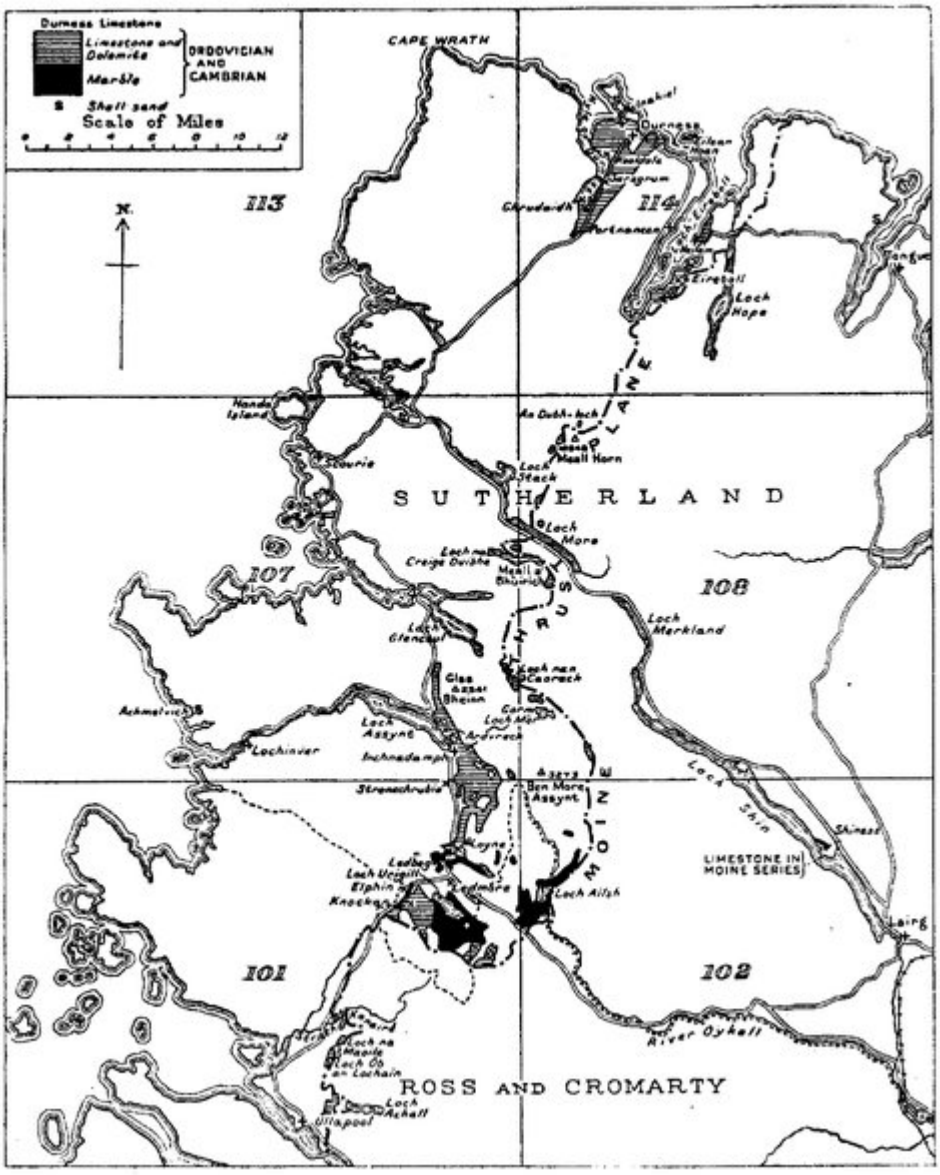

Figure 38 Sketch map showing distribution of limestone in Sutherland.

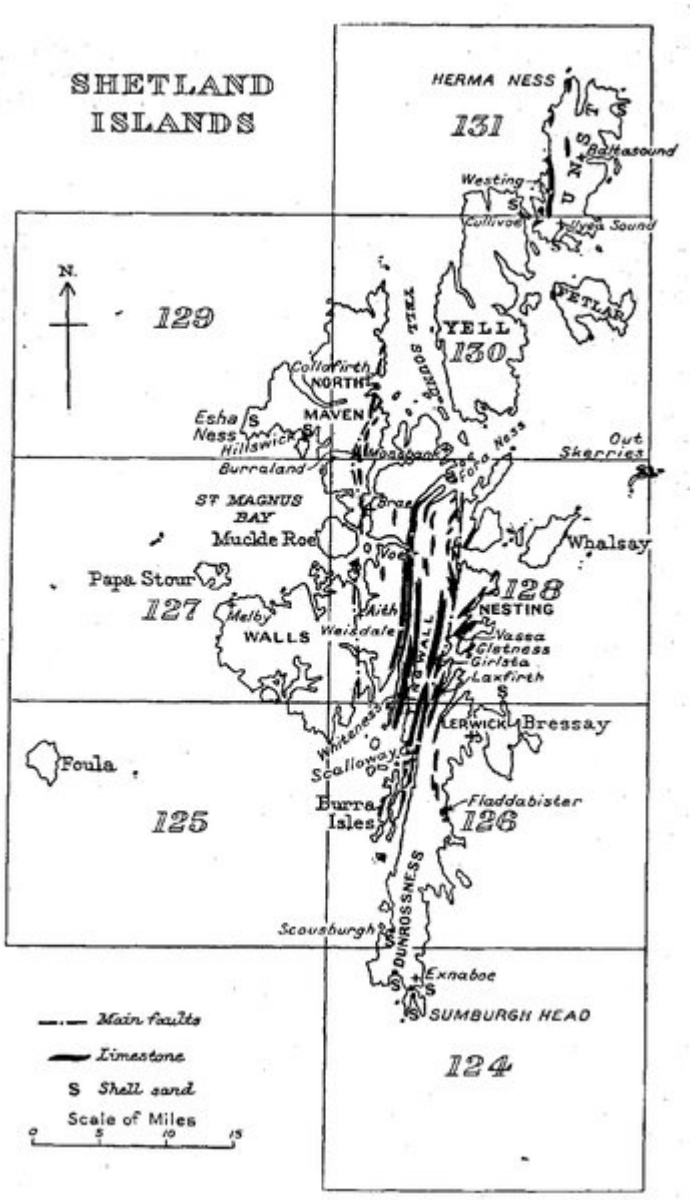

Figure 36 Sketch map showing distribution of limestone and shell sand in Shetland.

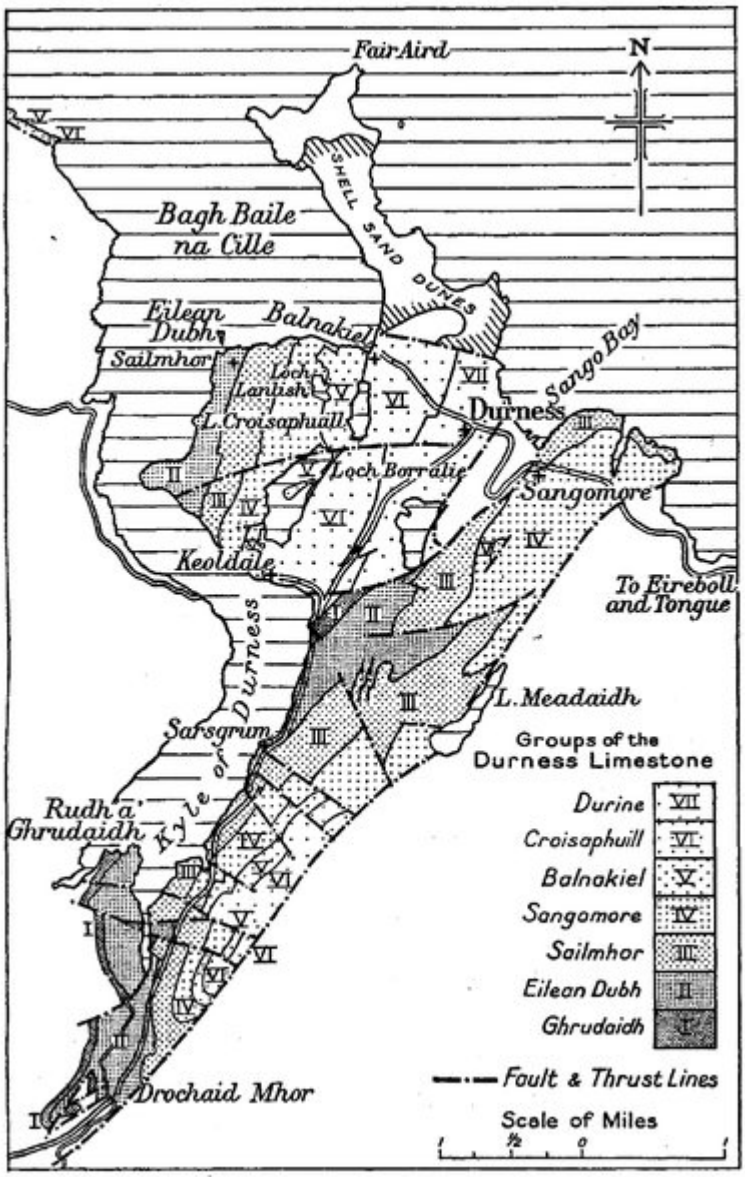

Figure 39 Sketch map showing distribution of limestone in the Durness district of Sutherland.

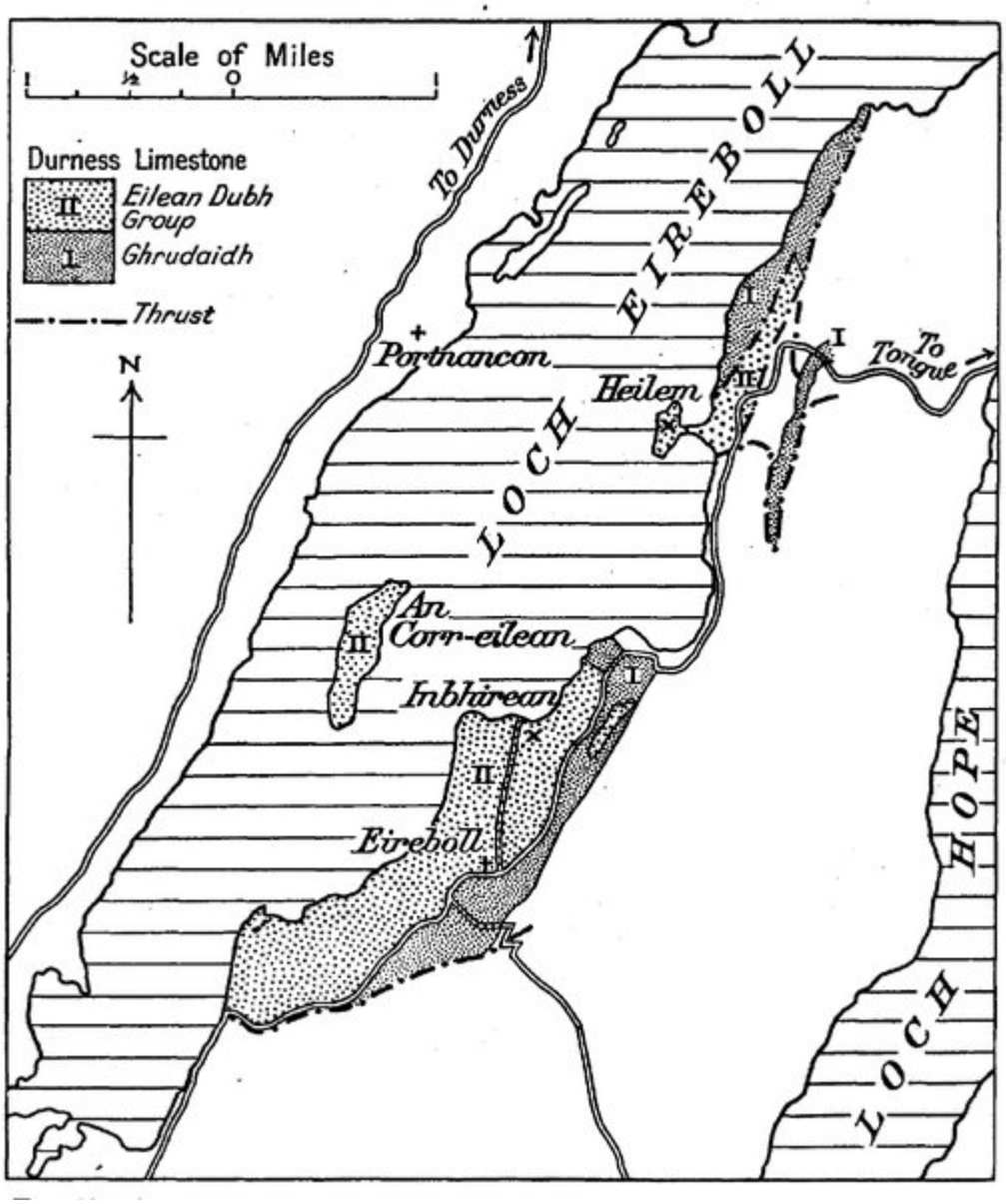

Figure 40 Sketch map showing distribution of limestone in the Loch Eireboll district of Sutherland.

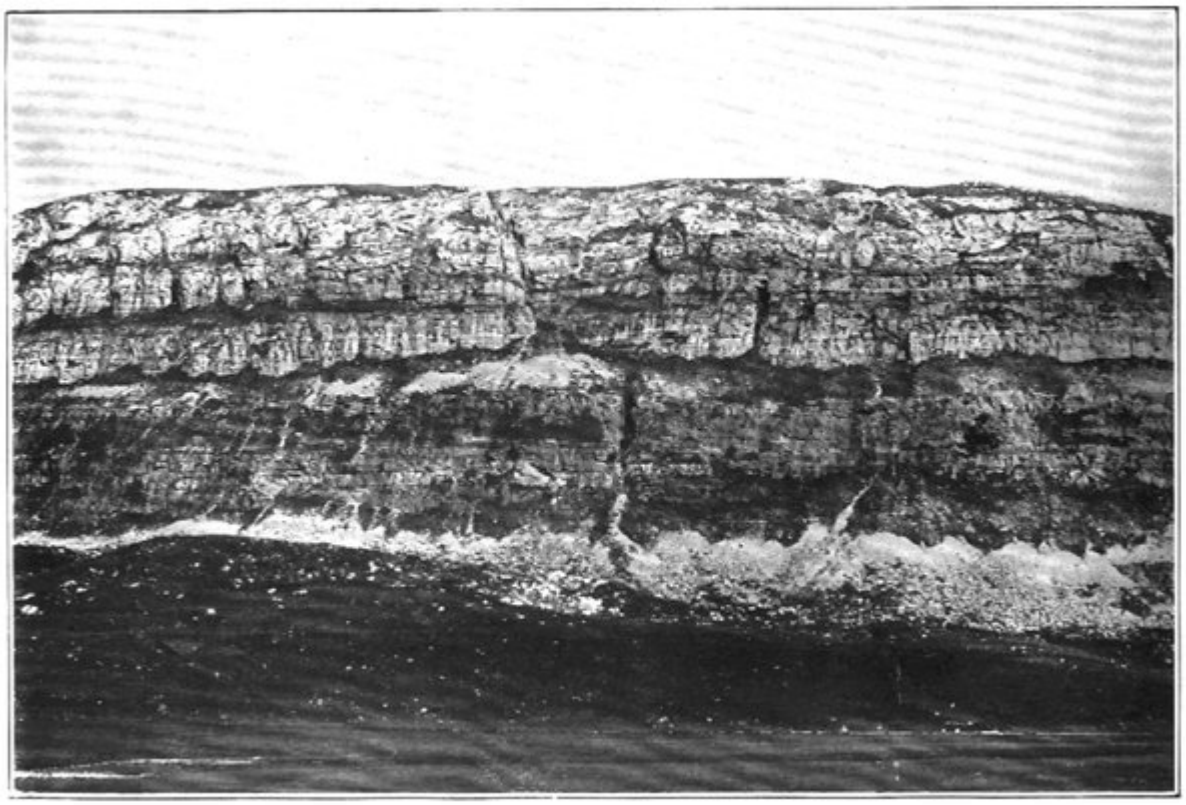

Plate 1 Stronechrubie Cliff, Inchnadamph, Sutherlandshire. Thrust mass of Durness dolomite and limestone. Frontispiece.

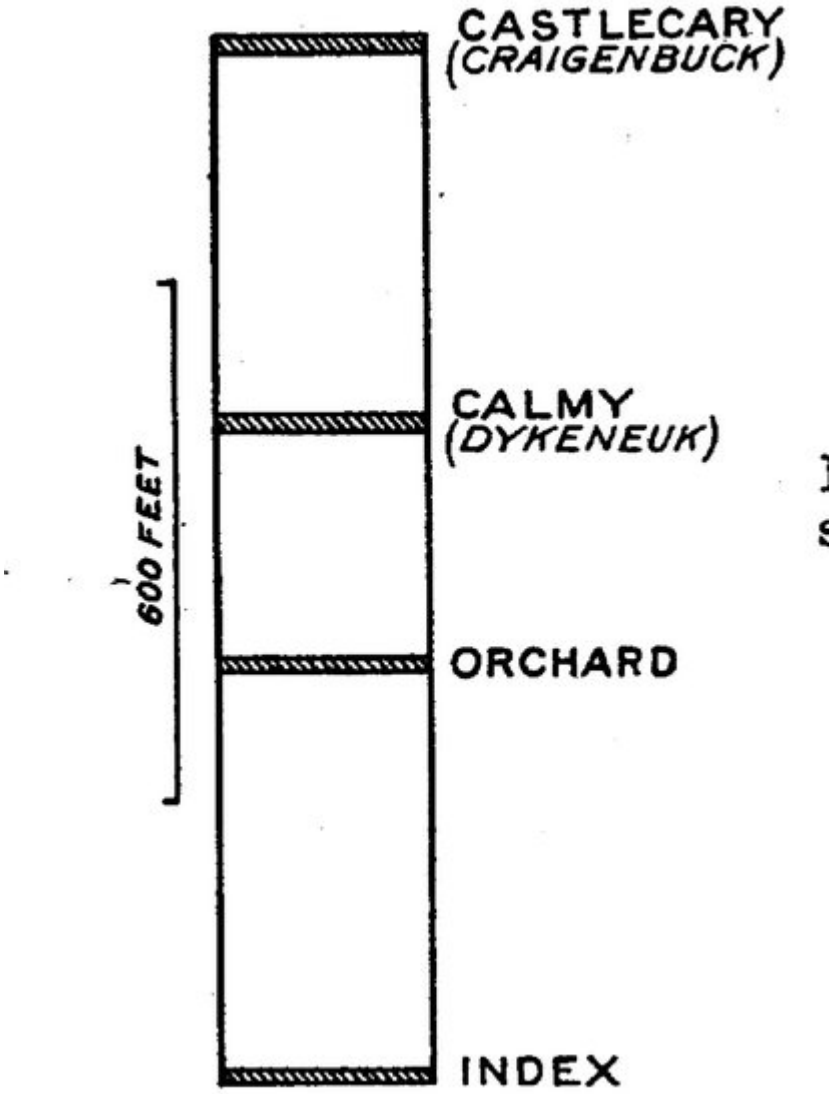

Figure 42 Vertical Section of the limestones in the UpperLimestone Group of West Lothian.