XXX.—*Problems in the Glacial Geology of N.E. Scotland and some fresh Facts bearing on them.* By ALEX. BREMNER, M.A., D.Sc.

(Read 20th January, 1915.)

THE glacial geology of N.E. Scotland has been discussed in a long series of papers in the *Quarterly Journal of the Geological Society* (1858, 1860, 1865, 1874, 1882, 1906), by Dr T. F. Jamieson, and in the *Memoirs of the Geological Survey* (Explanation of Sheets 97 and 87 by Mr J. S. Grant Wilson). The succession of deposits given in the appendix to this paper has been established partly from these papers, partly from my own observations.

I. RELATION BETWEEN THE RED CLAY SERIES AND THE UPPER GREY BOULDER CLAY.

Dr T. F. Jamieson never seems to have been clear about the occurrence of the Upper Grey Boulder Clay though it is to be seen in several old sections to the south of Ellon.

The Upper can be distinguished from the Lower Grey Boulder Clay in the following ways :—

1. It is less compact, more sandy, more iron-stained, and less of a true "till."
2. It is seen at many points to plough into the underlying Red Clay Series.
3. It includes towards its margin a few erratics derived from the Red Clay, and is often tinged by admixture with Red Clay.
4. The moraines that fringe part of its outer border (where that border is not beneath the sea) contain a considerable number of Old Red Sandstone erratics and occasional chunks of Red Clay.

At first Dr Jamieson believed that the terminal moraines of the ice that "ploughed out" the Red Clay near Aberdeen extended in a crescent around the mouths of the Dee and Don from Millden Burn (five miles north of Aberdeen) to Tullos Hill (one mile south).¹ In his 1906 paper he extended too widely the limits of the last ice-sheet or stated his case too indefinitely. "The result of the last ice-sheet has generally been to form at the surface a thin covering of coarse mud charged more or less with stones. In the lower coast districts this lies on the top of the Red Clay and derives its colour partly from it, but

¹ The moraines on Tullos Hill are, but those further north are not, the outermost moraines laid down by the ice in question.

along the rivers and minor streams there is always more or less washed gravel formed by currents generated during the final melting of the ice.”¹ This is true only of the district along the lower Ythan: in other places an unmistakable boulder clay, with scatched stones, is found on top (Fig. 1).

Can the limits of this last ice-sheet be fixed? This is the first unsettled problem in the glacial geology of N.E. Scotland.

It was only in 1906 that Dr Jamieson clearly recognised²—or at least clearly stated—that the shelly sands and gravels near Ellon were part and parcel of the Red Clay Series, 2. They were previously regarded by him and by Mr Grant Wilson as interglacial and anterior to the Red Clay.

The Red Clay of 2 (see Appendix) in Sheet 87 is regarded by Mr Grant Wilson as boulder clay throughout. Dr Jamieson says that in the coast districts it is quite like a boulder clay, but that further inland it is a “deposit of deep or at any rate still water.”³ Throughout its whole extent there are sections where the Red Clay can be regarded as nothing but a boulder clay—an old ground moraine; in many places, however, nothing but a laminated brick clay is to be seen.

Dr Jamieson was uncertain whether to regard the laminated brick clays as laid down under marine conditions or as deposited in a glacial lake, but evidently intends to suggest that the sea had something to do with their formation. Can this question be definitely settled?

When the Strathmore ice invaded the coast districts of eastern Aberdeenshire was it or was it not in contact with the native ice? Jamieson’s statement implies that it was not. “The deposition of the Red Clay seems to have *followed close upon* the retreat of the ice that formed the Grey Boulder Clay.”⁴ Can this be determined?

These problems are more or less related and solutions to them will be suggested in what follows.

The ice-movement during what was, as far as the N.E. of Scotland is concerned, probably the maximum glaciation—the time of the Lower Grey Boulder Clay—may be described in the words of one of the latest writers on general glacial questions. “The ice which poured from the Highland Glens into the Central Valley of Scotland found itself opposed by that coming north from the Southern Uplands. It split as a consequence

¹ *Quart. Journ. Geol. Soc.*, vol. lxii., 1906, p. 27.

² *Quart. Journ. Geol. Soc.*, vol. lxii., 1906, p. 17. Section at Belscamphie. This relation is at present shown with equal clearness in a pit at Kippet Hills, where red clay is found above and below the shelly gravels (with Pliocene shells).

³ *Ibid.*

⁴ *Ibid.*

into two streams, one of which flowed south along the Firth of Clyde, and the other due east along the Firth of Forth into the North Sea. This latter stream found here a new element of opposition in the presence of the Scandinavian ice off the eastern shores of Scotland, and again divided into two. One-half passed south along the eastern coast of England and the other north by Aberdeen, merging on the one hand with the Scandinavian flow and on the other receiving tributary ice from the adjoining land. The united stream swept north-west over Caithness and the Orkneys in the direction of the open Atlantic" (W. B. Wright, "The Quaternary Ice Age," p. 48). This is the view illustrated in glaciation maps of Scotland. At this time the western margin of the Lowland ice (or Strathmore ice as we may call it) did not anywhere impinge upon the Aberdeenshire coast. The junction line between the N.E. ice and the Strathmore ice probably lay some five miles north of Stonehaven. South of this line the Lower Grey Boulder Clay is wanting, and Red Boulder Clay everywhere rests directly on the solid rock, in all probability not because the later movement which brought the Red Clay (2) to Aberdeenshire succeeded in entirely removing a previous grey clay, but *because no grey clay was ever there*.

Then came a time when the Aberdeenshire ice no longer had sufficient power to protect its territory, and the Strathmore ice was shouldered in upon the coast by the pressure of ice in the bed of the North Sea.¹

Not only so, but the native ice had retired so far as not to come in contact with that which moved northward along the coast; and in glacial lakes held up between the latter and the first rising ground the sands, gravels, and red clays were deposited.

The Sands and Gravels with bands of Red Clay were deposited in front of the Strathmore ice as it encroached upon the land; the Red Boulder Clay very frequently, in fact generally,² rests on this lowest member of the series, which to the north of Ellon contains many fragments of shells (Pliocene and Arctic); the Brick Clays associated with and overlying the Red Boulder Clay were formed during the slow retreat of the southern ice. The great inland extension of the Red Clay Series in the Ythan Valley (10 miles) and to the north of it (especially north of Stirling Hill), without any intermingling with Grey Boulder Clay, coupled with the fact that the Upper Grey Boulder Clay (with Old Red Sandstone erratics) invariably lies above the Red Clay Series,

¹ Probably this encroachment of the Strathmore ice was due not to any increased pressure by the Scandinavian ice—that was probably less than before—but to absence of resistance by native ice.

² e.g. at Blackdog Brickworks.

Fig. 1. Map showing the glacial deposits of the district between Stonehaven and Fraserburgh.

suggests—if it does not absolutely prove—that there was no contact between the Strathmore and the native ice.

The distribution of the Red Clay Series suggests the action of the lobate margin of an ice-sheet free to expand westward. On the north it encountered opposition from the Moray Firth ice-sheet; seaward it was restrained by Scandinavian ice; but on the low ground of the lower Ythan basin and northward to Stirling Hill and again about Peterhead it spread fanwise over the land (see map, Fig. 1).

How far the native ice retreated during the formation of the Red Clay Series one has no means of knowing, but the limits of its readvance can be determined with some precision (1) by ascertaining the limits to which the Upper Grey Boulder Clay extends, (2) by a study of the marginal channels associated with the Strathmore ice.

(1) *The Limits of the Upper Grey Boulder Clay* (see Appendix and map, Fig. 1).—It can hardly be that the Upper Grey Boulder Clay is absent north of Ellon because it has all been removed by denudation, for the post-glacial drainage system of this part of Buchan is essentially immature—the streams flow in steep-sided trenches. South of Ellon, on the other hand, every little burn has cut down to the Red Clay, even though the interstream spaces show a cover of Upper Grey Boulder Clay. Even holes for the planting of telegraph poles reach in some parts the underlying Red Clay.

(2) *Marginal Channels associated with the Strathmore Ice.*—Marginal channels can be formed only where the ice-margin abuts on land which is ice-free. The marginal channels shown on Fig. 1 do not mark the most westerly limit of the Strathmore ice. Most of them lie a mile or more within that limit, and are therefore phenomena of retreat.

Channels formed by marginal drainage along the edge of a land area are likely to be wholly obliterated by a readvance of ice from that area; they will be filled up with bottom moraine. It is extremely unlikely, moreover, that any of them will be re-excavated by meltwater during the retreat of the ice, since the direction of retreat and of the discharge of meltwater is now altogether different from that in consequence of which they were formed.

Between Stonehaven and Aberdeen—15 miles—there are six very pronounced marginal channels, and others less definite might be enumerated; between Aberdeen and Ellon—14 miles—none are found, though conditions must have been as favourable for their formation there as they were further south; north of Ellon they reappear. The inference is obvious. They are absent just where the Upper Grey Boulder Clay comes down to

the coast. They are absent or partially obliterated along a stretch of 5 to 6 miles between Aberdeen and Stonehaven, where the ice also reached the sea.

So by this second line of evidence we are enabled to fix approximately the outer limits of readvance of the native ice (see map, Fig. 1).

Overflow channels between Aldie and Dens and at Den of Boddam throw some light on the *extent of the ice-movement from the south*.

The *Den of Boddam* is a typical channel. It dies out northward at slightly under 200 feet. The intake and most of its floor are now covered by peat; its walls are of flint gravel (over 90% of rolled flints). The level of the intake is about 250 feet; the level of the north end is in all probability that of the margin of the ice after it rounded Stirling Hill.

The *Aldie-Dens Channel* (level of floor at intake 165 to 170 feet) was excavated by a direct overflow of meltwater across the Stirling Hill—Dudwick ridge. There are two intakes; one of which was temporary, the other more persistent. The original level of the col was probably nearer 300 feet than 200 feet. The effects of extraordinary erosion *die out northward at an elevation of only slightly over 100 feet*.

The material carried down this channel has contributed much to the great spread of alluvium around Longside, and the alluvial area is much more extensive than Sheet 87 indicates. The Strathmore ice which rounded Stirling Hill blocked the mouth of the Ugie and held up here a glacial lake. It is interesting to know that in a pit near Auchlee there is a considerable depth of red or brownish clay with quartzite pebbles (Old Red Sandstone). Probably this is part of the contribution made by the Aldie-Dens overflow to the alluvium of the district. A train of flints has also been carried down towards the Ugie from the flint-covered ridge to the south.

While this channel was in operation the Ugie Valley around Longside was ice-free and not submerged except to a very moderate depth by the waters of a glacial lake. This seems to me a point of great theoretical importance. If (as Dr Jamieson claims) the water in which the red clay beds and the blue clay beds (to be mentioned in the sequel) were deposited extended from Aberdeen by Peterhead to Inverness, and submerged the land about Ellon to a depth of 300 feet, and that near Inverness (*e.g.* at Clava) to a depth of 500 feet, it is very remarkable that no evidence of submergence to anything like these depths has been obtained from the wide valley of the Ugie.

Not a single Old Red erratic is to be found on the summit of

the ridge (mostly over 300 feet) between the Aldie-Dens and Den of Boddam channels; it is thickly covered with rolled flints. Stirling Hill (under 300 feet) has been swept bare. We can thus determine with some precision the elevation of the ice-margin in this district.

Dr Jamieson says: "In Buchan the Red Clay ranges up to a height of over 300 feet above the sea, but the bulk of it lies below the 200-feet contour."¹ From this he would deduce a submergence of over 300 feet. But the upper limit of the Red Clay² seems to be due to the height to which the Strathmore ice rose upon the land—300 feet or less near Aldie, 200 feet north of Stirling Hill, and 100 feet to the west of Peterhead.

That the bulk of the Red Clay lies below 200 feet may be explained otherwise than as a result of submergence, especially marine submergence. It would be strictly true to say that scarcely any red brick clay lies above 200 feet. But its horizontal distribution seems to me far more significant than its vertical range. The greater part of it lies around Port Erroll at a level of 100 feet more or less and to the S.W., S., and S.E. of Berry-slacks at a level of 200 feet and under, in association with the inlet and outlet of a great marginal channel.³

Between this channel and the sea lies a piece of ground which rises over 250 feet above O.D. When the Strathmore ice had retreated so far that its landward margin rested against the eastern flank of this rising ground (where there are moraines and small marginal channels), a glacial lake was held up against the south end of the col at Berryslacks (level then just over 200 feet). In the quiet waters of this lake the laminated red brick clay was deposited; its surplus water flowed across the col and cut the great trench which now connects the basin of the Forvie Burn with that of the Water of Cruden.

Sediment transported by this overflow was carried into a second glacial lake held up at a lower level by the ice-margin near Port Erroll. The brick clays of that locality (worked at a large brickwork) were probably derived in part directly from the ice that held up the lake, in part indirectly as described above. There is plenty of boulder clay about Port Erroll from sea-level up to and above 200 feet, but the brick clays seem to be restricted to levels of 100 feet and under.

Thus without calling in the aid of the sea we can account not

¹ "Book of Buchan," Peterhead, The Buchan Field Club, 1910.

² All the Red Clay, whether brick clay or boulder clay, is referred to by Dr Jamieson simply as "Red Clay."

³ Its absence or patchy distribution further W., S.W., and S. is due to its having been ploughed out by, or incorporated in, the bottom moraine of the ice that formed the Upper Grey Boulder Clay.

only for the vertical range but also for the horizontal distribution of the laminated red clay.

The scanty evidence afforded by shells, nearly all in fragments, was relied upon by Dr Jamieson to prove marine submergence, though in 1906 and before doubts had entered his mind. Nothing can be founded upon the shelly sands beneath the main mass of Red Clay north of the Ythan, for Pliocene as well as Arctic (glacial) shells are found, and found just where the Strathmore ice before it encroached upon the land must have passed over the bed of the sea. South of the Ythan and as far as Aberdeen and Stonehaven—where the ice was moving practically parallel with the coast—not a fragment of a shell has been found except at Blackdog. There they occur amongst the Brick Clays. Blackdog, indeed, is the only place within the Red Clay area where, from Dr Jamieson's account, one might judge the shells to be where the molluscs lived and died. They were found "in a black stratum in the midst of a bed of laminated clay and sand." But investigation shows that the dark stuff, with the included shell fragments and chalk boulders, occurs in the form of erratic masses.

Dr Jamieson must have been very fortunate to find in the one small pit open in his day the suite of shells he enumerates, thirteen in all. I have during the last ten years paid repeated visits to the large pit at the Blackdog Brickworks of the Seaton Brick and Tile Co., and have picked out shell fragments in plenty, but only a few were recognisable. These have all been found in what the workmen call "pockets" of dark sandy clay. The pockets are in general small and of infrequent occurrence; but recently a rather large one, the largest I have yet seen, has been displayed in the working face. It shows *no trace of lamination* and is choke-full of shell fragments (*some striated*) and bits of chalk (*practically all striated*).¹ Its relations to the surrounding clay show that it is an erratic dropped by ice in a frozen condition among the yielding clay beds. Though it is now easily dug with the spade, it is a bit of boulder clay, probably partly disintegrated by freezing of interstitial water.

Except just close to one of these pockets, not a single shell fragment is ever found in the Red Clay (here interbedded with grey clay and grey sand). Chalks and flints are fairly frequent in the Red Clay, and chalks especially so in the pockets of dark clay. Has the Red Clay derived them from the black stuff? The chalk boulders are usually striated whether they are found in the dark pockets or in the surrounding clay.

¹ There occur, also, not infrequently small pieces of dolomitic limestone exactly similar to the larger fragments found in the gravels (with Pliocene shells) at Kippit Hills.

Among shells found in these pockets I have identified *Cyprina islandica* (of particularly large size), *Pecten islandicus*, *Dentalium entalis*, a *Tellina*, an *Astarte*, and a fragment probably of *Saxicava sulcata*.

Other fragmentary organic remains have been found in the Red Clay—a skeleton of a fish $4\frac{1}{2}$ in. long, some fish vertebrae, part of the skeleton of an eider duck, some ossicles of *Ophiura*, and at a point below H.W.M. a fragment of the skull of a seal, *Phoca vitulina* (probably in a raised beach deposit in the Ythan estuary). Seeing that gulls and eider ducks abound in far northern regions and feed on fish, surely our reputedly fixed and solid earth must be reckoned to stand on a very insecure foundation if these fragments are to be taken as indicating submergence beneath the sea “to a depth exceeding 300 feet.”

II. RELATIONS BETWEEN THE RED CLAY FROM STRATHMORE AND THE BLUE (BLACK) CLAY OF THE MORAY FIRTH AREA.

In the Peterhead Section (see Appendix) a granite boulder with a casing of Black Clay was found in Red Clay. At Ednie occurs a mottled clay, *i.e.* a Blue Clay caught up and surrounded by Red Clay (Explanation of Sheet 87). To the north of Ednie, quartzite pebbles (O.R.S.) are scattered over the surface of the Blue Clay, ? from Aberdour. (*op. cit.*). “There seems to be a commingling of the two boulder clays at this point [near Peterhead] and it is quite possible that the ice-movements were simultaneous and contemporaneous (*sic!*)” (*op. cit.*).

Sections at Brucklay, Fraserburgh, and elsewhere show that the Blue Clay, like the Red Clay, was not the product of the latest ice-sheet (or ice-movement).

From the south shore of the Moray Firth there have been recorded, so far as I know, only two boulder clays, of which the Blue is stated to be below. There is some evidence in favour of the view that there are more than two and that the Blue is not the oldest; but in small and ill-exposed sections one cannot always be certain whether a clay that seems to lie below the Blue Clay may not be simply the Upper Boulder Clay enclosing a displaced fragment of an earlier *moraine profonde*. At the same time the evidence in favour of the contemporaneity of the Blue and Red Clays lends support to this view. For if there is south of Peterhead a boulder clay older than the Red Clay, so north of Peterhead one may expect to find a boulder clay older than the contemporary Blue Clay.

At all events further investigation is necessary in order to determine more carefully than has hitherto been attempted (1) the position of the Black Clay in the glacial series, (2) its contents,

(3) its source, and (4) its distribution—vertical and horizontal. For various reasons it may be doubted whether its source is, as Dr Jamieson stated, “the slaty rocks of the Banffshire Hills.” Jamieson also states that it was “deposited under conditions very similar to those under which the Red Clay of Aberdeenshire was laid down,” and also “ranges up to a similar or even greater height, being found occasionally at full 300 feet above the present sea-level.”¹ At more than one point I have found it at an elevation of just under 600 feet above the sea, so that Jamieson’s statements require to be tested.

Dr Mackie (*Trans. Edin. Geol. Soc.*, vol. viii.) has noted great variations in the direction of ice movement in Eastern Moray, and something similar occurs in the Moray Firth coast district further east. On the map I have entered the striae² recorded on Sheets 96 and 97 of the Survey Maps; these show, between the Deveron and New Aberdour, two directions of movement almost at right angles to each other and not to be explained as due simply to deflection caused by the form of the ground. Can these variations in direction be associated with differences in the character and contents of the glacial deposits?

In this connection it may be noted that boulders of Inchbae augen gneiss have been found on the foreshore close to Gardentown and on the hills above Pennan;³ the largest boulder at Gardentown must weigh about a ton. At Pennan the Inchbae rock was found in gravels associated with the brownish boulder clay overlying the Blue Clay.

“INDIGO” BOULDER CLAY OF AUCHTERELLON (WELL),
BELSCAMPHE (RAILWAY CUTTING), AND SOUTH OF ELLON
(RAILWAY CUTTING).

This boulder clay was first mentioned by Dr Jamieson in 1906: no other geologist has examined it. It would appear to be the oldest glacial deposit in the Ellon district. At Auchterellon it is separated by (Lower) Grey Boulder Clay from the Red Clay and can hardly be contemporaneous with the Blue Clay which mingles with the Red Clay near Peterhead (*vid. sup.*). “I could also mention other localities in this quarter [? Ellon] where a very dark bluish boulder clay occurs beneath a boulder

¹ *Quart. Jour. Geol. Soc.*, vol. lxii., 1906, p. 38.

² Other instances of striation and ice-moulding have been noted, some so extraordinary that further investigation seems necessary before they are recorded.

³ Buckie is the most easterly point at which this easily recognisable erratic has hitherto been found (*Explanation of Sheet 93*, pp. 150–151, and references there given).

clay of greyer hue.”¹ It is a pity that Dr Jamieson did not mention these localities, since the sections he described are closed and no others of similar character are known.

ROLLED CHALK-FLINTS AND QUARTZITES.

Distribution.—Rolled flints are found in larger or smaller numbers in every parish of Buchan. They are present embedded in, and on the surface of, the Grey Boulder Clay on the north side of the ridge that runs S.W. from Stirling Hill to Dudwick. But along the top of that ridge and particularly in the Den of Boddam there is on the surface a remarkable concentration of flint pebbles.²

The flints are usually accompanied by rolled quartzites dissimilar to the quartzites on which the rolled material frequently rests. The local material mingled with the flints and quartzites is usually little water-worn.

At the extreme S.W. corner of the area in which they are found, the flints are very scarce, while the quartzites become very abundant (Windyhills, near Fyvie). At the extreme N.E. corner (Den of Boddam) the flints, here more uniform in size and more highly rolled than elsewhere, are extraordinarily abundant, other kinds of pebbles requiring to be carefully looked for.

At Windyhills the deposit, consisting mainly of pale-coloured quartzites and quartz sand, is covered by a reddish-brown drift from the O.R.S. area to the west. Dr Jamieson did not observe this. He states also that the quartzites here found are pebbly quartzites of local origin. This is not true of the vast majority of the pebbles. On two visits I have not detected a single pebbly quartzite of local origin in the pits except in the brown drift on the top.

Source.—Dr Jamieson says the Moray Firth area is the probable source of the flints, and refers to the flints found in the shelly boulder clay of Caithness. Mr Grant Wilson thought they had been brought from the west during “the first or great glaciation.” A writer in the *Transactions of the Buchan Field Club* (vol. ii., p. 191), a keen observer, suggests that they may have been carried into the district from the N.E.; others suggest that they, like the “Greensand” of Moreseat, may have been but little moved since the period of their formation. This

¹ *Quart. Jour. Geol. Soc.*, vol. lxii., 1906, p. 23.

² No chalk is ever found associated with these pebbles. Of the flints found in the red brick clay some are rolled, others unrolled; chalk is associated with them, and one lump of chalk, 10 in. by 12 in., was found to enclose a flint. *Black flints* are scarce in the rolled flint area; they are by no means so at Blackdog.

diversity of opinion shows the need of further investigation. A study of the quartzites is, in my opinion, most likely to lead to some definite result. Flints are pretty much alike whatever be their source, while quartzites vary greatly.

Age.—These flints were certainly in the district before the Red Clay, for they occur quite plentifully in several sections of the sands and gravels underlying the Red Clay at Auchenten and Nethermill of Cruden; in the Red Boulder Clay to the north of Stirling Hill they also occur. It is to be noted that in the sands and gravels towards the coast (*i.e.* in the districts most distant from the main area of distribution) the flints are scarce and mostly broken, and have suffered a second imperfect rolling.

The Windyhills deposit is, as has been pointed out, overlaid by a later deposit. The Dudwick region can hardly have suffered glaciation since the flints reached it.

The cost of illustrating this paper has been defrayed by a grant from the Carnegie Trust.

APPENDIX.

GLACIAL SUCCESSION IN N.E. SCOTLAND.

Cove Quarry.

1. Grey Boulder Clay.¹
2. Red Boulder Clay.
(Beautiful cross striation in parts of the quarry.)

Half a mile W.N.W. of Quarry.

1. Lower Grey Boulder Clay.
2. Coarse gravels with Old Red Sandstone boulders.
3. Upper Grey Boulder Clay and moraines.

Aberdeen and Belhelvie Districts.

1. Lower Grey Boulder Clay.
2. Red Clay Series—
Sands and Gravels with bands of Red Clay.
Red Clay { Boulder Clay.
 { Brick Clay.
3. Upper Grey Boulder Clay, moraines and gravels.

¹ The deposits are given in sequence 1, 2, 3, from below upwards.

Ellon District.

- 1a. "Indigo" Boulder Clay with striated Arctic shells at Auchterellon (*Quart. Jour. Geol. Soc.*, vol. lxii., 1906).
1. Lower Grey Boulder Clay.
2. Red Clay Series—
Sands and Gravels.
Red Clay { Boulder Clay
 { Brick Clay.
3. Heavy Gravels and patches of Upper Grey Boulder Clay.

Slains and Cruden.

1. Lower Grey Boulder Clay.
2. Red Clay Series—
Sands and Gravels with shells and rolled flints and bands of Red Clay.
Red Clay { Boulder Clay.
 { Brick Clay.

Peterhead (Quart. Jour. Geol. Soc., vol. lxii., 1906).

1. Lower Grey Boulder Clay.
2. Red Clay Series¹—
Sand and Clay with shells.
Red Boulder Clay.
3. Mottled Boulder Clay, "as if a red and a blue had been jumbled together."

Brucklay (Trans. Buchan Field Club, vol. ii.).

1. Blue Boulder Clay.
2. "Yellow" Boulder Clay.

Fraserburgh.

1. Blue Boulder Clay.
2. Brownish Boulder Clay.

The following is a list of places where open sections in glacial deposits may be examined (May 1915):—

Banks of Cowie Water, near Bridge of Finlayston.
Cliff tops from Garron Point northwards.
Cantlay Hills, near Muchalls.
Muchalls Station (three pits and cliff sections).
Railway cutting north of Muchalls Station.

¹ Near base of Red Clay Series a granite boulder, 2 feet in diameter, had a casing of bluish grey gritty mud, a quarter of an inch thick.

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Monduff Farm (small opening).
Burn of Elsie, near Newtonhill Station.
Portlethen Station and top of hill 1 mile to N.E.
Cove Quarries.
Pit close to L. of Loirston and another further N.E.
Railway cutting half a mile S. of Bay of Nigg, and cliff top
near by.
South side of Bay of Nigg.
Ridge of Tullos Hill.
Pit near Balnagask Golf Clubhouse.
[Sewer excavations in and near Aberdeen—records in Burgh
Surveyor's Office.
Bore on foreshore near base of North Pier (descends to 59 feet
below O.D.)—record in Harbour Engineer's office.]
North bank of Don at New Bridge of Don.
Blackdog Brickworks.¹
Banks of Millden Burn.
Hatterseat Farm, Foveran.
Drums of Foveran.
Tipperty Brickwork.
Cross-stones of Ellon.
Various pits near Ellon.
Kippit Hills (two large pits and several smaller openings).
Cliff sections (occasional) near Collieston.
Pits at Auchenten, Hatton, and Nethermill of Cruden.
Banks of Water of Cruden, particularly near mouth (in-
clusion of Blue Clay in Red Boulder Clay).
Port Errol Brickworks.
Various openings from Stirling Hill to Dudwick Hill.
Windyhills, Fyvie.

¹ This is an interesting but very variable section.