3. *THE GLACIAL SECTIONS round SUDBURY (SUFFOLK).* By the
Rev. EDWIN HILL, M.A., F.G.S. (Read December 20th,
1911.)

THE sections round Sudbury are called in the Geological Survey Memoir of 1885 'perhaps about the finest in any inland spot in East Anglia.' They are described in the Survey Memoir on North-West Essex (1878); and there are further notes in that on Ipswich, Hadleigh, etc. (1885).

There is a paper by Dr. Marr in *Geol. Mag.* 1887 (p. 262); there have been excursions to the neighbourhood on the occasion of the Geological Society's Centenary in 1907, and by the Geologists' Association in 1898 and 1910, of which brief descriptions have been published. I know of nothing else. Since publication of the two Survey Memoirs some pits have been closed; some new ones opened; and many extended considerably. These changes have disclosed facts of considerable interest, which deserve to be put on record.

I. THE PRINCIPAL PITS.

I will name the position and contents of the principal pits, giving numbers to them for use in this paper and notes of references to them in the Survey Memoirs.

Beginning with those on the high road leading eastwards from the town, Green's Pit (1) has been filled in, but the singular contorted sands¹ are still visible. On the south side of the road two pits (2) called Victoria on the Ordnance Map and in the Geological Survey Memoirs,² now joined at the top, show Chalk, Thanet Sands, Crag, gravels, and a patch of Boulder Clay. Farther out along the road, on Gallows Hill,³ two brickworks (3), called California on the Ordnance Map, show bedded silts and upon these Boulder Clay.

The high road which runs out of the town south-east towards Newton, passes on its left (north-east) side, Whorlow's (4) Chalk-pit⁴ (Chalk, Thanet Sands, Crag, Glacial Gravels, and clay) and next, the entrance to the Alexandra Brickworks. Here are two pits⁵: the outer (5),⁶ nearest to the road, contains Thanet Sands, Crag, Glacial Gravels, Boulder Clay; the inner (6),⁷ half a mile from the road, very large, shows bedded silts and Boulder Clay, like those in the Gallows-Hill Pits (above, 3), which are indeed across

¹ *Geol. Mag.* dec. 3, vol. iv (1887) p. 262.

² 'Geology of N.W. Essex, &c.' *Mem. Geol. Surv.* 1878, fig. 15, p. 54; 'Geology of the Country around Ipswich, Hadleigh, &c.' *ibid.* 1885, pp. 132-33.

³ *Ibid.* 1878, p. 53: 'On the hill North-East of Sudbury'; see also *ibid.* 1885, p. 132.

⁴ *Ibid.* 1878, p. 55: 'Touching the eastern side of the cemetery'; see also *ibid.* 1885, p. 132.

⁵ Apparently opened since the publication of the Survey Memoirs.

⁶ *Mem. Geol. Surv.* 1878, p. 55: 'Eastward of the cemetery.'

⁷ Apparently opened since the publication of the Survey Memoirs.

a field barely 100 yards off. About a mile from the town, also on the left (north-east) side of the road, is a sandpit (7) which shows bedded sands and Glacial Gravel.

The high road running southwards from the town, to Great and Little Cornard, passes a large chalk-pit (8) near the railway-station,¹ with Chalk, Thanet Sands, Crag, Glacial Gravel, and clay. Farther on, a road to the left (Cat Lane on the Ordnance-Survey 6-inch Map) skirts the remains² of an extensive quarry (9). This is much overgrown, but Chalk can still be seen at its southern end, and beyond its northern end Crag is seen at the back of the Mauldon Gray Inn, not far from (5), but south-west of the high road.

In Great Cornard, a lane beside the church leads near to a pit (10) in a field about 300 yards east of the rifle-butt³; this shows a deep section in red sands, which I suppose to be Crag.

Leaving the town by way of Ballingdon Bridge, and taking a road southwards on the right bank of the Stour, we pass on the right the great Ballingdon Chalk-pit (11), described in the Survey Memoirs.⁴ Now, only Chalk and Thanet Sands are seen, with occasionally a trace of Woolwich and Reading Beds; over these is some late gravel. A little farther, on the left, is an entrance to the Ballingdon-Grove⁵ Brickworks (12). These contain Boulder Clay, gravels, and sands. The clay has been washed for brick-making, and in the residues some far-travelled rocks have been found. Much of the clay has now been dug away, and gravel is worked; below this Thanet Sands have been disclosed (also, a pit about 50 yards south of the western end is chiefly in these).

The high road leading south-westwards from Ballingdon Bridge, as it mounts Ballingdon Hill, passes on the left (east) the entrance to an extensive sand-pit (13) in the field.⁶ This shows a great thickness (perhaps over 40 feet) of false-bedded sands, with Boulder Clay lying upon them.

The Victoria Brickworks (14), north-west of Ballingdon Bridge,⁷ are chiefly in late gravels, but some Thanet Sands are visible at the south-western end, up towards the mill.

All the above-named pits are within a mile of Sudbury. About 2 miles south of the town, the brickworks (15) in Little Cornard contain Thanet Sands, a considerable thickness of false-bedded sands and gravels, some grey clay, and in this clay very large transported masses of Chalk. A few hundred yards up an adjacent lane (Chapel Lane, on the Ordnance 6-inch Map) a small excavation (16) affords the only section⁸ at present known to me of Woolwich and Reading Beds.

¹ Mem. Geol. Surv. 1878, p. 16, fig. 4?

² *Ibid.* 1878, p. 15: 'East of Sudbury is a line of Chalk-pit[s].'

³ Apparently opened since the publication of the Survey Memoirs.

⁴ Mem. Geol. Surv. 1878, p. 14, fig. 3.

⁵ *Ibid.* 1878, p. 37: 'At the great brickyard east of Balingdon.'

⁶ Apparently opened since the publication of the Survey Memoirs.

⁷ Mem. Geol. Surv. 1885, p. 132.

⁸ Apparently opened since the publication of the Survey Memoirs.

II. SANDS AND SILTS.

Since the date of publication of the Survey Memoirs additional aids have been furnished in the Ordnance Maps, by their larger scale, and by their contour-lines.

Six of the above-named pits lie on or near the 200-foot contour. In the two pits on Gallows Hill (3), and in the adjacent inner Alexandra Pit (6), is exposed a thick series of finely-bedded sandy silts, of which more than 30 feet can be seen. About half a mile east, at the same level, in the sand-pit on the Newton Road (7), is an exposure of at least 20 feet of bedded sands—chiefly pure sand, but in two or three beds a little clay is present.

Across the river, at the same level, in the sand-pit on Ballingdon Hill (13), are nearly 40 feet of somewhat current-bedded, stoneless sands, similar to the last, except that clayey sand occurs only at the top. Sands of similar character seem to occur not far off, in the parish of Middleton. In all these pits, except that on the Newton Road (7), Boulder Clay overlies the beds.

The sand-pit north of Great Cornard Church (10), east of the rifle-butt, is just below the 200-foot contour. It is in red sands, which are, I think, a remnant of Crag. Similar red sands can be traced at short intervals up to the pit (2) in which Mr. W. Whitaker recognized Crag.

There seems, then, to have been at Sudbury an extensive deposit of sediments, sands, and silts, reaching nearly up to 200 feet above Ordnance datum. They are all somewhat current-bedded. Do they not indicate deposition in water which was shallow, and affected by only moderate currents? This level of 200 feet O.D. is 120 feet above the alluvial meadows at the bottom of the valley.

III. BOULDER CLAY.

In the Gallows-Hill (3) and inner Alexandra (6) Pits, upon the bedded silts lies Boulder Clay. This forms a sheet which is exposed continuously for several hundred yards. The ground behind the pits rises gradually into the plateau of Boulder Clay, which attains an altitude of nearly 300 feet O.D., and covers several square miles. The clay is found in wells to have a thickness of sometimes over 100 feet. We may deduce that these sections show a true base of the clay.

Its junction with the silts can be scrutinized, touched, tested. The passage from silts into clay is seen to be continuous: there is no sudden break. There are coarser beds in the upper foot or so of the silts, finer bands in the lowest foot of the clay. Flints are not abundant in the lowest part of the clay; where they cease to occur, the bed can hardly be assigned definitely to either division. The chalk-pebbles in the clay are rounded: smaller rounded chalk-pebbles are found at several horizons in the silts. It seems that the process which produced the silts changed by a gradual transition into the process which produced the Boulder Clay.

It may be mentioned that bedded silts are also seen lying under

Boulder Clay in brickyards at Woolpit, about 8 miles east of Bury St. Edmunds (also at about 200 feet O.D.), and in the Culford Brickyards, about 4 miles north-north-west of Bury (here at only about 100 feet O.D.). Sands under Boulder Clay have been proved at various levels (generally under 200 feet O.D.) in various well-sinkings, as, for instance, Brettenham Park and Felsham.¹

Along an extensive visible transition-line the action which produced the clay has left the silts perfectly undisturbed: it exerted on them neither thrust nor drag. In the lower of the two Gallows-Hill Pits (3) and in the inner Alexandra Pit (6), at its south-western end, the silts are seen to bend down into hollows² 10 or 20 feet deep, occupied by the clay. The beds are neither thickened nor thinned, they lap over as sheets. I am inclined to look on them as deposited on the sides of pre-existing hollows; but the hollows may be due to subsequent subsidence below. Some tiny step-faults may be explained on either view, and I have found no evidence which is decisive.

IV. GRAVELS AND ISOLATED CLAY.

The Stour Valley seems to be pre-Glacial. Boulder Clay was found in its bed in a boring at Glemsford, about 4 miles above Sudbury.³ The boring appears to show that the ancient valley-bottom there lies 470 feet below the present floor. It may be conjectured that this indicates a buried channel, and that such channel lies buried all along the present valley. If so, the old valley about Sudbury was deep and, in places, remarkably narrow. However, all known sinkings have reached Chalk at moderate depths.

Whatever may have been the shape of the old valley, a great mass of Boulder Clay must have been removed after deposition. Thus we find the thickness of over 100 feet on the plateau reduced to a few feet about the 200-foot contour: and at lower levels find it sometimes absent altogether, as at the Ballingdon Chalk-pit (11), the Ballingdon Victoria Brickworks (14), and the Little Cornard Brickworks (15), each at about 100 O.D.

The bedded sands and silts described in § II (p. 25) are absent from all pits below the 200-foot contour. Those pits that are called in the Geological Survey Memoirs 'Victoria Pits east of the town' (2) lie at a level below that of the Gallows-Hill (3) and inner Alexandra (6) Pits. They show Chalk, presenting a horizontal upper surface; over it Thanet Sands, somewhat eroded at the top; upon these again Crag, with an extremely-eroded upper surface; and, finally, on this coarse gravels and sands, violently current-bedded. Though only a quarter of a mile from the higher-level pits mentioned above, with their 40 feet of silts, no silt is here seen. In the coarse gravels lies a sheet, about 10 feet thick

¹ 'The Water-Supply of Suffolk' Mem. Geol. Surv. 1906, pp. 32, 52.

² Mem. Geol. Surv. 1878, p. 53: 'At the southern end. . .'

³ *Ibid.* 1906, p. 58.

and several yards long, of Boulder Clay. It is banded for a foot or two at its base, but above is normal tough clay. This sheet terminates at its south-western end in a contorted mass of yellow and white sand, which is rolled up into the clay. Gravels lie round the whole.

These pits are situated on the south side of a lateral valley. At about the same level, on the north side, is Green's Pit (1) with the contorted mass of sand described and figured by Dr. Marr. Across the Stour, the Ballingdon-Grove Pits (12) are at their western end now chiefly sand, though, at one time, masses of clay and masses of sand were here intermingled confusedly. The clay has been mostly removed; but early in 1911 I found that a block of clay was being dug, some 20 feet broad and 10 or 12 deep, with sand on each side. A few weeks later all the clay had been removed, and the block was seen to have been embedded in fine sands, which dipped, not riverwards, but away from the valley.

At the eastern end of these same Grove Pits, in the digging of coarse gravel, two sheets of Boulder Clay have been cut through. One was 40 feet long, 4 to 8 feet thick, abruptly cut off at one end; the shape of the other end was hidden by a little talus.

In the outer Alexandra Pit (5) there is a sheet of the clay resting upon gravels. At first, appearances were not inconsistent with deposition *in situ*; but, as excavation progressed, the clay was seen to lie on a ridge of the gravels, and to bend down over this on each side. Further cutting has revealed it to be a sheet, 40 or 50 yards long by about 4 feet in thickness, ending abruptly against the gravels, which lie around it, above as well as below.

These isolated sheets and masses cannot have been formed *in situ*; they are as much boulders as any mass in the gravel; plainly they have been transported. All of them lie at levels below the base of the Boulder Clay, as seen in the Gallows-Hill (3) and inner Alexandra (6) Pits, and far below the higher parts of the plateau: their transport would be down hill. All of them lie on slopes of the present river-valley; and it will be remembered that clay can slip down very moderate slopes. At the brickyard near Ballycastle Railway-Station (Antrim), for instance, I saw Boulder Clay slipping down the hillside, though the slope was only 1 in 8. The excavation was shallow, but the turf for many yards above it was rent and fissured. The contorted sand and clay in the Victoria Pits (2) bend as they would be bent by a slip down a hillside. The jumble at the western end of the Ballingdon-Grove Pit (12) may be fallen masses, on a steeper slope, or down a cliff where the river had been undermining. Ice may have assisted in transporting the sheets. The coarse and strongly current-bedded gravels which lie around or adjacent indicate violent and varying water-action.

In the Railway-Station Chalk-pit (8) and Whorlow's Chalk-pit (11), which are about 300 yards apart, and each at about 150 feet above Ordnance-datum, clay is seen to rest upon irregular gravels. This, however, does not seem to be normal Chalky Boulder Clay; I think that it may be remanié. Such would naturally often be formed during the re-excavation of the valley.

V. ISOLATED MASSES OF CHALK.

The brick-pits in Little Cornard (15), about 2 miles south of Sudbury, lie on and above the 100-foot contour. They show at the entrance some Thanet Sands. Against these, on a slope which seems to be a bank of a former lateral channel of the ancient river, lies a mass of violently current-bedded sands and gravels. Against these gravels, still farther from the present valley, comes a stretch of grey stoneless clay, now mostly worked away. In this grey clay, at the farther side of the pit, lie several large masses of Chalk. They are very large: one, oval in shape, is not less than 30 feet long, by 10 feet in height. They contain no flints: they appear to be not original Chalk, but remanié Chalk, as are some of the Cromer masses. They lie embedded in the clay, which wraps round them and fills fissures. The clay itself looks as if it may be a mud washed from Boulder Clay.

The valley is wide and open above, but here is contracted by a spur of the plateau to about a third of its former breadth. These masses lie at the end of the spur. Were they stranded here? The gravels, against which their enwrapping clay rests, indicate powerful currents at levels 20 to 40 feet above the present valley-floor.

VI. GENERAL REMARKS.

This paper is the fruit of some words from Mr. Harmer, spoken when showing some Norfolk sections. He remarked on the light which might be thrown on the origin of Boulder Clay by the beds that immediately preceded it. I had almost relinquished Glacial studies, but the new idea roused me to a re-examination of West Suffolk sections.

The foregoing descriptions show that close to Sudbury, on each side of the existing Stour Valley, at or just below the level of 200 feet O.D., which is 120 feet above the present valley-floor, there are extensive deposits of sands and silts, such as appear to be aqueous deposits, laid down in shallow waters¹; and that these pass by a continuous transition into normal Chalky Boulder Clay: also that their undisturbed condition negatives the existence, during that transitional period, of any action such as thrust or drag.

Again, close to Sudbury, at levels of about 170 feet O.D. and below, on the sloping sides of the valley, are sands and gravels, often very coarse, generally presenting strong current-bedding, such as indicates torrential water-action. These gravels contain transported sheets and blocks of previously-formed Boulder Clay, some of which have shapes such as would be the consequence of slip down slopes. There has been some action able to deposit also, at the same level as some of these gravels, Chalk masses which weigh hundreds of tons.

It may be noticed that the foregoing deductions, made for the

¹ Compare the suggestion of an extra-Glacial lake, *Proc. Geol. Assoc.* vol. xv (1898) p. 454.

immediate neighbourhood of Sudbury, agree with the course of events probable if a submergence preceded the deposition of the Boulder Clay, and an emergence followed it.

DISCUSSION.

Mr. W. WHITAKER said that, when making the geological survey many years ago, he found no record of the fine sections at Sudbury, the finest inland sections of Drift in the Eastern Counties. These sections had been constantly changing, and luckily some years later the new developments were noticed by Dr. Marr. It was fortunate that the Author had continued the record.

He was disposed to look on the peculiar mass of Glacial Drift at the sides and bottom of the valley as belonging to a series of deposits older than the Boulder Clay of the plateau, and belonging rather to the 'Lower Glacial' of Searles V. Wood, an infilling of an early Glacial (or pre-Glacial) channel.

The thickness of the deposits in some of these channels was too great to allow of the explanation by land-slipping—it being greater than that of any other Drift deposits in the country, as much as 470 feet in the valley of the Stour some miles above Sudbury. Moreover, these deposits reached down to below sea-level, and obviously could not result from any process going on with the land at its present level. The Boulder Clay certainly was well adapted for land-slipping; but that could hardly be to the great extent pointed out. Besides, the Drift-channels contained various other materials as well as Boulder Clay.

The SECRETARY read the following remarks, received from Prof. T. G. BONNEY:—

'Unfortunately an engagement on Wednesday evening, made before I knew that this paper would then be read, prevents me from being present. That I very much regret, since, as the Author has taken me over all the sections (as I believe) described in his paper—in most cases two or three times at least—I should have liked to have expressed the opinions which I have independently formed. These are in full agreement with those set forth in his paper, so far as I can gather from the abstract. In the Sudbury sections at about 200 feet above O.D., a quite normal 'Chalky Boulder Clay' is seen overlying well-stratified silts and sands, with occasional false-bedding. These present every appearance of having been deposited under water, which was moving very gently and steadily. Their stratification shows no disturbance as it approaches the base of the Boulder Clay, and the latter does not in any way scoop or dig into it; but we find, not seldom, signs of a real, though rapid, transition from the one to the other.

'But, from about 180 to 100 feet O.D., that is more or less on the flanks of the Stour Valley (which the Glemsford boring has shown to be pre-Glacial)—sand, gravel, and Boulder Clay (normal) show great disturbance and strange associations,—masses of the last material occurring in the others, like large irregular erratics. Their mutual relations are not suggestive of a ploughing-up by the snout of a glacier (which, had it deposited the Boulder Clay, would by this time have retreated from the district), but a downslipping of the older materials and a mixture of them with coarser gravels of more local origin.

'I may add that, sometimes in the Author's company, sometimes with others, I have seen this orderly succession of silt, sand (more or less gravelly), and Boulder Clay, in other parts of the Eastern Counties, and not in them only.

Thus, while I am fully conscious of the difficulties presented by the hypothesis of the subaqueous deposition of Boulder Clay, that which regards it as the direct product of an ice-sheet seems to me to involve yet more serious difficulties, at any rate in our Eastern Counties.'

The AUTHOR, in reply, agreed with Mr. Whitaker as to the existence of Boulder Clays of more than one age. But the sheets described in these gravels were not contemporaneous lenticles; they had tolerably uniform thickness and abrupt ends. Without the aid afforded by the 6-inch maps and contour-lines, the paper could not have been composed. Photographs had been taken, but these materials do not readily give clear results.