All these specimens are more or less like *Hydradendrium spinosum*; but on one of them (no. 14. 6. 61. 2, without name), which appears to have undergone better preservation than the rest, there is a thick light-brown sarcodic theca, which is uniformly inflated at short intervals over the branches, so as to present a succession of fusiform swellings averaging about 1-415th inch in their shortest diameter. When a bit of the branch bearing one of these swellings, after having been softened by soaking in spirit and water for twenty-four hours, is placed under the microscope and examined with a 1-inch object-glass, it may be observed to consist of a transparent sarcodic base densely charged with opaque white granular matter arranged in reticulated lines, which, on being further magnified, viz. under $\frac{1}{4}$-inch object-glass, presents a variety of cellular forms in great plurality and of different sizes, among which the most noticeable are:—1, a discoid body with crenulated margin and central circular area, about 5-6000ths inch in diameter; 2, a pyriform body about 6-6000ths inch long; and, 3, ovoid thread-cells about 3-6000ths inch in their greatest diameter, together with other minute forms which may or may not belong to a *Penicillium* with which the sarcode is permeated. But it is the fusiform inflations themselves on the branches which command our attention most; for they appear to have contained the full-grown polyp, of which, however, nothing now can be seen but a slight depression on the most prominent part here and there, bearing no resemblance whatever to the radiated actinozoic form of the polyp in the theca of a *Gorgonia*; nor, as above stated, are we likely to find any thing more, unless the specimen be seen in its active living state in its own element, or after having been properly preserved in spirit and water, in the manner of that of *Hydractinia echinata* above mentioned. Dana's figures *apud* Milne-Edwards (*op. cit.* Atlas, pl. C. 2. figs. 5, 6) show nothing more than Ellis's, viz. that the polyp's *head* has six tentacles.

XXXVII.—*The Chalk Bluffs of Trimmingham.* By A. J. Jukes-Browne, B.A., F.G.S.

The existence of certain isolated masses or bluffs of chalk on the shore near Trimmingham, in Norfolk, has long been known to geologists. They are partially buried under the deposits of the Lower Glacial series, which here form cliffs of considerable height, and founder down from time to time in great landslips, so that a clear section from top to bottom is rarely exhibited. Many writers have described these masses of chalk and the appearances presented by them under the successive disclosures caused by the wasting of the cliffs; but notwithstanding the attention they have attracted, the question of how they came to occupy their present position has always remained a moot point.

It was also well known that the Trimmingham chalk contained peculiar nodules of flint; but these had never been carefully examined until the locality was visited by Mr. W. J. Sollas and myself in 1875, when, finding that the hollow flints disclosed very distinct traces of sponge-structure, my friend undertook the study and description of these remains. As the results of his examination are likely to excite further interest in the chalk which contains these curious nodules, I am led to offer a brief review of the known facts and opinions regarding the Trimmingham bluffs; and the present paper may form a kind of introduction to Mr. Sollas's descriptions, which will shortly appear in the pages of this magazine.

The earliest notice of the Trimmingham Chalk is from the pen of Mr. R. C. Taylor in 1823 *; and some passages of this are worth quoting. He says, "The most easterly point at which chalk has been traced is on the coast between Mundesley and Cromer, where we find two detached masses of soft chalk, with numerous layers of flint, forming insulated cliffs of chalk. Several circumstances lead me to consider these masses as the remnants of a stratum which once extended further to the north-east, in the space now occupied by the sea, constituting a higher part of the series than the chalk of Norwich . . . . These masses are continuous with a solid bed of chalk, discernible at low water, reaching nearly a mile in length from Trimmingham to Sidestrand, and forming a level platform extending into the sea. . . . . That which particularly distinguishes this stratum is the vast abundance of a small curved oyster called *Ostrea canaliculata* †. Almost every part of the chalk is crowded with these shells; and many of the flints have from twenty to thirty of them adhering, which, in that case, being hardened by the silex, afford the best specimens."

It will be observed that Mr. Taylor notices only two chalk bluffs; and in Woodward's 'Geology of Norfolk' (1833) the chalk is mentioned as occurring in "two isolated disrupted masses." But in the section accompanying this book *three* separate masses are shown; and Sir Charles Lyell, whose first observations were apparently made in 1829 ‡, also mentions

* Trans. Geol. Soc. ser. 2, vol. i. p. 375.

† This is not the *O. canaliculata* of Sowerby. Dr. Barrois has lately identified it with the *O. lunata* of Goldfuss.

‡ 'Principles of Geology,' 4th edit. (1835), vol. iv. p. 90.

three protuberances of chalk on the coast. It would seem therefore that about this time a third mass made its appearance, brought into view probably by the gradual recession of the cliff-line. The site of this third bluff of chalk was a little distance to the south of the two now remaining; but as no traces of its existence are now to be found, I have endeavoured to collect the records of its brief history and gradual destruction.

A description of it is given in the first edition of the 'Principles of Geology' (1830, p. 180), with an illustration showing the side view of the promontory which it formed, and the relations of the chalk to the glacial beds above. This was repeated in several succeeding editions.

In 1840 Sir Charles Lyell contributed a paper to the 'Philosophical Magazine,' in which the three chalk masses are thus described*:—"The most southern of the three protuberances occurs near the Beacon Hill, about halfway between Trimmingham and Mundesley; the mass of chalk is about 20 feet high, its extent along the beach about 100 feet, and its thickness from the beach inland a few yards only. It stands up like a narrow wall, which will ultimately be destroyed; and then the whole face of the cliff will consist of clay, sand, and gravel. . . . . When I visited this spot in 1839 I found the cliff nearly in the same state as it remained in 1829; and the description which I gave of it in the 'Principles of Geology' would still be appropriate."

Five years later Mr. Joshua Trimmer wrote a description of the Norfolk cliff, in which he thus refers to the Trimmingham chalk†:—"Of the protuberances of chalk near Trimmingham the northern and middle seem now little changed, but the southernmost has undergone some alteration. Its length is still the same as when visited by Mr. Lyell; but it is reduced to nearly half its height, and the waves have washed away a portion of the overlying gravel at one extremity. The next fall of the cliff will probably bury this end of the protuberance entirely."

Mr. Gunn mentions the existence of the three chalk masses in his 'Geology of Norfolk,' and observes that a question has arisen as to whether they are detached boulders or part of the solid bed below. He informs me that his remembrance of the third bluff is, that in height it was less than either of the others, that it gradually wasted away under the attacks of winter storms, and finally disappeared in the great storm of January 1863. It was therefore no longer in existence when

* Phil. Mag. vol. xvi. p. 356.
† Quart. Journ. Geol. Soc. vol. i. p. 218.

Mr. Searles Wood, Jun., examined the cliffs; and consequently it is not indicated in the coast-section which he published in 1865.

Of the two masses which still remain, the more southerly, or that which was the centremost, does not call for any lengthy description; it does not stand out so prominently from the cliff-line, and consequently there are not the same facilities for studying its mode of occurrence. Sir Charles Lyell thus describes it*:—"The second or middle protuberance is near that last described, its front along the shore, measured in 1839, 65 yards. Its height was between 15 and 20 feet." Since that time its length and height have certainly diminished; but it does not seem to have undergone so much alteration as the other two.

Greater interest has always attached to the most northerly mass; and it has frequently been visited and described. Mr. Taylor's description has already been quoted; and Sir Charles Lyell thus writes of it in 1840†:—"The third and most considerable mass extends along the beach for a distance of 106 yards; and its position deserves particular notice, for it forms, like the southernmost mass, a projecting promontory about 30 yards beyond the general line of cliff." Views from the side and front accompany the further description of this mass.

The following notes were taken in September 1875; and the sketch was made on the spot at the same time.

The mass of chalk is about 35 yards long and about 30 feet high‡, ending on each side with a nearly perpendicular face; the talus of the foundering cliff above is partly banked against the sides; but there is no evidence of any faulting, and it is clear that much chalk has been carried away from both ends; the front face stands out 8 or 9 yards from the base of this talus.

Viewed from the southern side the upper surface of the mass is seen to slope slightly and irregularly inward towards the cliff; it is surmounted by a thin bed of sand, which is succeeded immediately by a brown sandy boulder-clay without the intervention of any beds resembling the laminated series.

The chalk contains bands of flints at distances of from 2 to 3 feet apart; some of these are hard, black, and compact; but

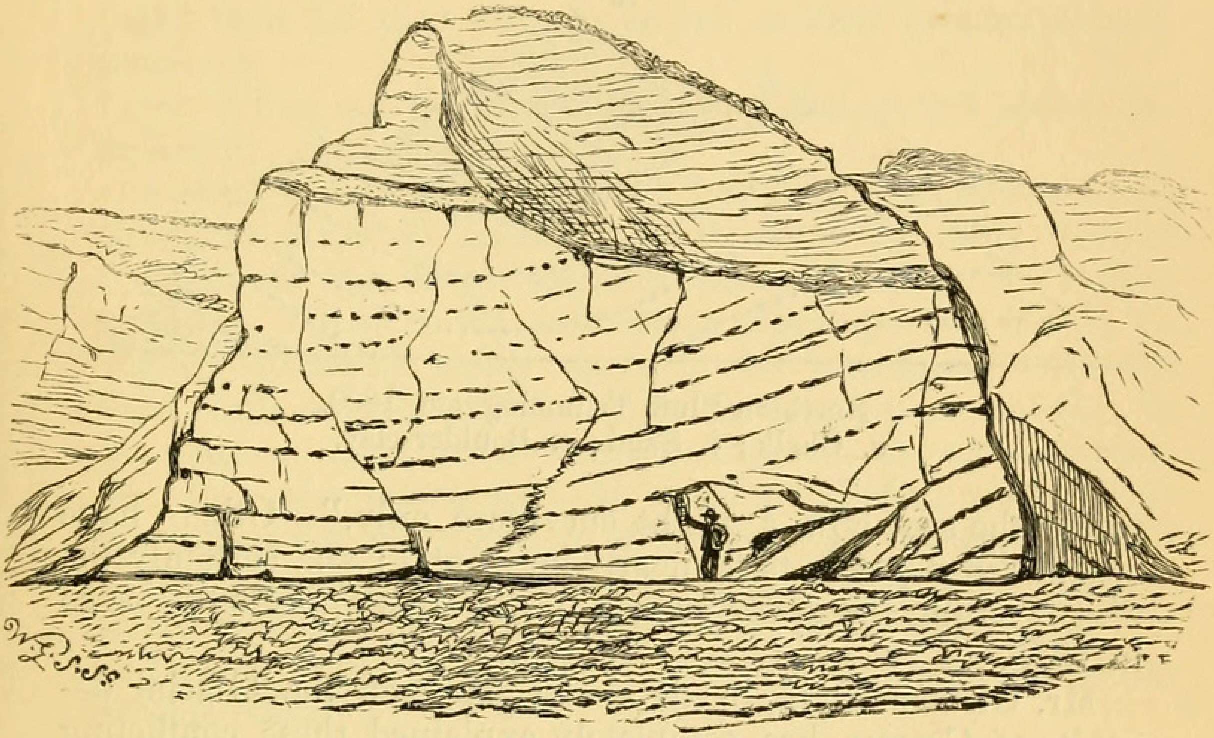
* Phil. Mag. vol. xvi. p. 356.

† Phil. Mag. vol. xvi. p. 356. See also Geol. Mag. vol. iii. p. 516, and vol. v. p. 544, and Lyell's 'Principles of Geology.'

‡ Mr. C. Reid, of the Geological Survey, has since informed me that his measurement gives 38 feet as its height from the present beach.

the majority are only half silicified, being hollow or partly filled with a grey chalky matter, which is gritty to the touch and is full of sponge-spicules and minute organisms. The flints are moreover surrounded with similar greyish chalk, which sometimes forms a band connecting two or more together;

Fig. 1.



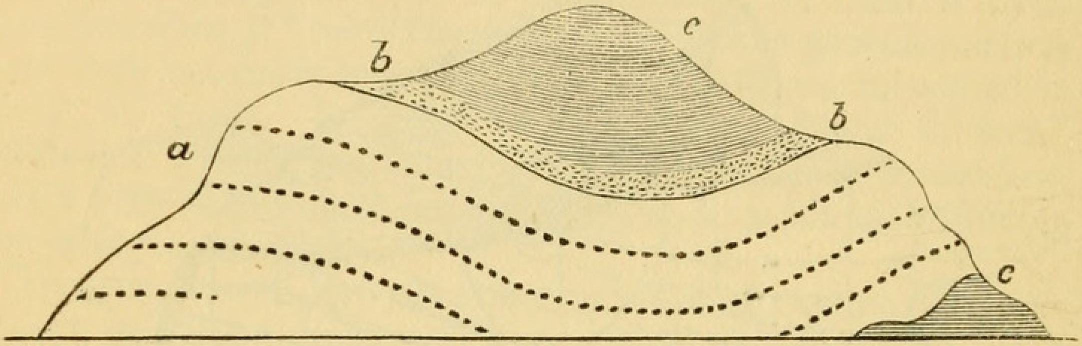
Northern Bluff, Trimmingham, 1875.

this greyish chalk also occurs in places without enclosing any flinty matter, and gives a mottled appearance to the mass. Between the layers of flint nodules the rock is full of a small curved species of oyster (since identified as *Ostrea lunata*, Nilss.); *Belemnitella mucronata* is also common; and there are many other fossils (see *posteà*); but the best specimens are adherent to the flints.

If the measurements above given be compared with those of Sir Charles Lyell, and the mass in its present state (fig. 1) be compared with the figure in the early editions of the 'Principles of Geology' (reproduced in fig. 2), it will be seen that it has now only one third of the length it possessed in 1839. Originally the front face seems to have exhibited a complete synclinal curve, with more than half of the corresponding anticlinal at the southern end; but now only the centre of the synclinal is left, the beds rising very slightly to the southern, and more decidedly towards the northern end.

With regard to the dip of the beds as viewed from the sides some difference of opinion has existed. It is seldom, indeed, that a clear section is presented by the side face; for the chalk breaks away along joint-planes, which are often discoloured, and still further obscured in summer time by the mud washed down from above. Sir Charles Lyell writes as follows* :— "A layer of chalk flints *in situ* shows that the stratification of the chalk is vertical, although the beds seen in a large cave

Fig. 2.

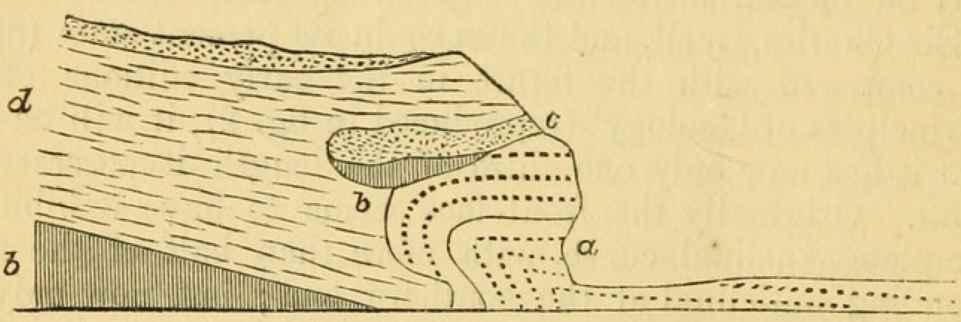


Northern Bluff, Trimmingham, 1839.
a. Chalk; *b.* Sand; *c.* Boulder-clay.

facing the sea show a slight curvature only." Others have considered the beds to be nearly horizontal; and certainly the flint layers in the upper portion of the mass appeared to be so in 1875.

Mr. Clement Reid, in his recent paper on the Glacial deposits of Cromer, has completely explained these conflicting appearances†. He had opportunities of visiting the spot after winter storms had cleared the section; and he discovered that the beds are bent into a sharp curve or loop, and are so contorted as to be horizontal in one place and nearly vertical in another. The diagram (fig. 3) is an enlargement of part of the cross section given by Mr. Reid.

Fig. 3.



Northern Bluff, side view.
a. Chalk; *b.* Boulder-clay; *c.* Sand; *d.* Contorted Drift.

* Phil. Mag. 1840, vol. xvi. p. 356.
† Geol. Mag. dec. 2, vol. vii. p. 55.

It will thus be seen that the disturbance of the chalk has resulted in the production of a double set of curves, the axes of which are at right angles to one another.

Several interesting questions are suggested by the position of these elevated outliers of chalk near Trimmingham.

(1) Are they connected with the chalk scar seen further out on the shore?

(2) How did they come to be left in their present isolated position?

(3) When was the chalk bent into the curves above described?

Although some have supposed that they were merely large fallen or detached masses, like those in the cliffs west of Cromer, yet the most competent observers are of a different opinion. Thus, in the description above quoted, Mr. R. C. Taylor distinctly states them to be continuous with the solid chalk below, as if he spoke from actual observation in the matter. Sir Charles Lyell inclined to the same opinion. Mr. Gunn also writes me word that he and Mr. Joshua Trimmer concurred in regarding the masses as fixtures and not boulders; and, finally, Mr. Fisher and Mr. Reid have observed that a particular layer of grey chalk is visible both in the cliff and on the foreshore opposite; so that little doubt can remain on this point.

With respect to the second question, several explanations have been put forward. Sir Charles Lyell seems to have regarded the masses of chalk as "protuberances" thrust upward into the overlying beds by the action of subterraneous forces; even in 1840 he speaks of being confirmed in his opinion, that both chalk and drift had been subjected to a common movement.

Mr. S. V. Wood, Jun., appears to have held a similar view, and even ventured to insert a fault at this point in his coast-section published in 1865. Whether he is still of the same opinion I am not aware; but it does not appear that he ever actually observed such a fault, and its existence can hardly now be maintained.

Mr. O. Fisher has suggested that the elevation and contortion of the chalk may have been due to a kind of "creep," like that in coal-mines, in consequence of the pressure exercised by the superimposed glacial beds*; but it seems unlikely that the weight of the overlying sands and clays could ever have been sufficient to affect the solid chalk to such an extent as this hypothesis demands. Moreover Mr. Fisher admits that there

* Geol. Mag. vol. v. p. 550.

are other features about the bluffs which are very puzzling. "One of these is the cavities they contain, filled with stratified alternations of calcareous sands and carbonaceous matter, evidently of ancient date. These cavities led me to suppose the masses might have formed needles or rocks in the glacial sea. But if so, it is difficult to conceive how the large flints, usually covering the chalk surface, could have been preserved upon their upper parts *in situ* as they are" (*loc. cit.* p. 551).

Mr. C. Reid has recently proposed another explanation*. He assumes the existence of a vast ice-sheet filling the North Sea in later glacial times, and supposes that the impact of this against the Norfolk shore was the cause of the contortions both in the Chalk and the Lower Glacial beds. This theory, however, seems open to the same kind of objection as that brought against Mr. Fisher's, viz. that physical considerations render it improbable : it is possible to conceive that the Lower Glacial beds may have been so doubled up ; but it is very doubtful whether the solid scar of chalk could have been squeezed up and contorted in the manner suggested.

Both these theories involve highly theoretical questions of physics ; and both assume that the contortions in the chalk were produced in Glacial times. It seems, indeed, more reasonable to suppose that this disturbance had a much more ancient origin, and that the beds of chalk were bent into the curves now visible before the commencement of the Glacial period. If this be assumed, there is then no necessity for calling in the aid of any special agencies, and the older and simpler view that the masses formed isolated stacks or pinnacles becomes the natural explanation ; moreover the existence of the contortions would then be the very cause which conduced to the preservation of the bluffs, by enabling them to resist the agencies which broke up the surrounding portions of the chalk.

There is another fact, mentioned by Lyell, which tends to confirm this view, viz. that glacial beds have been seen underlying one end of the more northerly mass (see fig. 1) ; and in the 'Philosophical Magazine' (*loc. cit.* p. 358) he thus speaks of it :—"I have stated in the 'Principles' that this mass of chalk at its northern edge actually overlies some beds of blue clay or drift. Now this remarkable superposition was still evident in June 1839, notwithstanding the unusual height of the sea-beach, the clay containing broken chalk-flints being traceable for 7 feet under the chalk. It is known to have extended much further in a seaward direction." Elsewhere

* Geol. Mag. dec. 2, vol. vii. p. 61.

he suggests that the mass must have been "undermined when the crag was deposited, unless the boulder hypothesis is to be preferred"*.

Mr. Fisher has recently described in greater detail the cavities he discovered in the chalk†; but he still hesitates to draw the inference which their existence seems naturally to suggest. If they were sea-formed caves, as their position, shape, and contents appear to indicate, and if (as he believes) "they were formed and filled in the interval between the formation of the bluff and its envelopment in Boulder-clay," surely this is almost sufficient to prove that the chalk mass existed as a cliff previous to the formation of the Lower Glacial series. I cannot think Mr. Reid is successful in explaining these caves away as expanded cracks‡. The cavity specially described by Mr. Fisher has a much greater resemblance to the termination of a water-worn cave; and since the chalk bluff is known to have suffered so much in late years from the attacks of the waves, it is quite possible that Mr. Reid has never seen any such cavities as were visible up to 1868. Certainly none were observable in 1875.

Mr. Fisher finds a difficulty in the beds which rest on the top of the bluffs, and which he thinks "were evidently lifted up along with it;" but he assumes that they belong to the basement beds, or so-called *Laminated* series, whereas Mr. Reid considers that they are a portion of the sands which overlie the Till. And if he is correct, the difficulty vanishes; for they are nearly on a level with the normal horizon of these beds (as shown in Mr. Reid's diagram, *loc. cit.* fig. 1).

The undermined edge described by Lyell and the existence of these ancient caves are, to my mind, strong arguments in favour of the view that the chalk bluffs were outlying rocks or needles, the remnants of a chalk zone which once formed a wide extent of land stretching far to the eastward, and that they owe their preservation to the local disturbance and arching of the strata, which gave them greater strength and enabled them to resist the action of the waves. Against their base were deposited the lowermost sands and clays of the fluvio-marine series; and as the area became gradually submerged their pinnacle tops were broken off and carried away; and upon the truncated surfaces thus left were laid down those later beds of clay and sand which are now seen in contact with the chalk.

It may also be pointed out that the Trimmingham bluffs

* Principles of Geology, ed. 5, vol. iv. p. 86.
† Geol. Mag. dec. 2, vol. vii. p. 149.
‡ *Loc. cit.* vol. vii. p. 238.

are by no means the only instances of contortions in the Norfolk chalk. Remarkable cases have been described by Mr. J. E. Taylor at Whitlingham * and at Swainsthorpe †. In the former case it is especially noted that the sands and gravels above do not participate in the disturbance of the beds on which they rest; hence, as Mr. Taylor says, it is evident that this disturbance took place before either the formation of the Norwich Crag or of the Drift deposits. If the section were equally clear at Trimmingham, I believe every one would be forced to accept the same conclusion regarding the chalk of that locality; but the foundering of the cliffs and the presence of the shingle beach combine to conceal the true relations of the beds, and allow scope for the free use of the scientific imagination. In this, however, as in most other cases, the simplest explanation is the most likely to prove correct.

This notice of the Trimmingham Chalk would not be complete without some reference to the interesting series of fossils it contains. The sponges will be described by Mr. Sollas; but the following list contains the names of the other fossils collected by ourselves and by Dr. Barrois ‡, who visited the locality in the same year:—

Belemnitella mucronata, *Schlot.*	Rhynchonella plicatilis, *Sby.*
—— vesicularis, *Sby.*, var.	—— limbata, *Dav.*
—— lunata, *Nilss.*	Ananchytes ovatus, *Lam.*
Pecten quinquecostatus, *Sby.*	Echinoconus Rœmeri ?, *D'Orb.* (or Galerites abbreviatus, *Lam.*).
—— sp.	Cyphosoma elongatum, *Cott.*
Terebratula carnea, *Sby.*	Cidaris serrata, *Desor* (spines).
Terebratulina striata, *Wahl.*	Trochosmilia cornucopiæ, *Dun.*
—— rigida, *Sby.*, var.	Serpula lumbricus, *Defr.*
Magas pumilus, *Sby.*	—— heptagona ?, *Von Hag.*
Crania parisiensis, *Defr.*	

To these may be added *Baculites magnus*, Sby., observed on Trimmingham beach by Samuel Woodward §.

Ostrea lunata is the species called *O. canaliculata* by Woodward and Rose. It is a Maestricht form, and was recognized by Dr. Barrois, who says (*op. cit.* p. 165), "I cannot distinguish my specimens from Trimmingham from the *O. lunata* (identical with the type figured by Goldfuss) which I have collected in the Upper Chalk of Ciply."

The variety of *Ostrea vesicularis* is very large and globose; it only occurs in the uppermost beds of the chalk, and ought to be distinguished from the smaller shells passing under the same name.

* Geol. Mag. vol. ii. p. 324. † *Op. cit.* vol. iii. p. 44.
‡ Recherches sur les terr. Crét. Supérieurs (Lille, 1876), p. 165.
§ Geology of Norfolk, p. 49.