A Geological Sketch of Brean Down and its environs, with special reference to the Marsh Deposits of Somerset.

BY W. A. E. USSHER.

INTRODUCTION.

IT is to movements of the crust acting with more or less intensity, all through the Earth's geographical evolution, that we owe the diversity of age and arrangement of the rocks that compose the surface.

These movements have crumpled up the old sea beds of past epochs in the earth's story, and have allowed the sea, rain, and rivers to waste and grind them to gravel, sand, and clay, in time to form conglomerates, sandstones, limestones, slates and shales, to be in their turn upheaved, abraded, and in part reconstructed.

Most rocks, not of igneous origin, are derived from the waste of pre-existing rocks, but this is true in a less degree of limestones, such as those of Brean Down, into the composition of which the remains of the shells, crinoids, and corals, that lived in the seas of the time, entered more largely than the terrigenous mud, or silt, associated with them. Geologists distinguish the different ages of rocks by their relative positions and structures, which constitute the province of Stratigraphy, or Tectonic Geology—by the plants, animals, marine and fresh-water organisms contained in them; a study which reveals successive zoological epochs, and is called Palæontology.

THE OLDER ROCKS.

The rocks of Brean Down were originally deposited in more or less horizontal layers in the sea. They form the westerly continuation of the Carboniferous Limestone of the Mendips, and though now isolated at the surface, are connected beneath it with the limestones of Uphill, and of Worle Hill, Woodspring, Broadfield Down, and Clevedon.

The limestone beds of Brean Down partake of the northerly tilt, or dip, which is exhibited by the Mendip limestones along the northern side of the range, where we find them passing under the Millstone Grit beds, which in their turn dip northward under the Lower Coal Measures. Thus by tectonic geology we prove that the Carboniferous Limestone is older than the Coal Measures.

In a similar manner it is proved to be newer than the Old Red Sandstone, which rises from beneath the intervening Lower Limestone Shales, and comes to the surface near Winscombe, Priddy, Wells, and from Masbury Camp over Beacon Hill eastward to the vicinity of Whatley.

As the Old Red Sandstone belongs to the Devonian period, it is evident that the Carboniferous Limestone is newer than the Devonian rocks of the Quantocks and Exmoor.

Structure of Mendips. The upheaval and folding of the Mendip range is due to the "Armorican Movement," the same great north and south terrestrial shrinkage as that which produced the folding of the older rocks of West Somerset, Devon, Cornwall, South Wales, South Ireland, Brittany, and the Ardennes in post-Carboniferous and pre-Triassic times. On the south of the Old Red Sandstone outcrops we find the Lower Limestone Shales dipping southward under the Carboniferous Limestone, thus proving that the general structure of the Mendip range is an arch, or anticlinal fold.

This anticlinal folding is irregular, and the beds forming the crest undulate, dipping in places east and west, so that they present a series of anticlinal domes or periclines.

A pericline is the antithesis of a basin. That is to say, from an axis of any given length the beds of rock dip away on all sides in a pericline, whilst in a basin they dip from all sides toward the axis.

Denudation of Mendips. To the denudation of these periclines the exposure of the several masses of Old Red Sandstone on the Mendips is due.

The Somerset Coal Measures are preserved in basins in an undulating synclinal curve or trough, which is to a great extent concealed by the newer Secondary Rocks. This arrangement at and beneath the surface has been excellently shown by the late J. McMurtrie.[1]

Professor S. H. Reynolds has proved the existence of Silurian under the Old Red Sandstone in the Eastern Mendips,[2] so that when we contemplate the denudation of the irregular Mendip anticline, where Silurian rocks come to the surface, the removal of the whole of the Old Red Sandstone, as well as the overlying Lower Limestone Shales, Carboniferous Limestone, Millstone Grit, and Lower, Middle, and Upper Coal Measures must have taken place. This removal represents a vertical height of not less than 13,000 feet, or considerably over two miles, of which 3,000 feet has been assigned to the Carboniferous Limestone.

The Old Red Sandstone pericline west of Black Down is concealed at Shipham by Dolomitic Conglomerate, the beach deposit of the Keuper Marls, which entirely obscure the western end of the pericline, and break the superficial continuity of the Carboniferous Limestone at Loxton on the south, and at either end of Banwell Hill on the north.

These Marls, with their Dolomitic Conglomerate beach, encroach on the north and south flanks of the Mendips, concealing the Millstone Grit and Coal Measures, and flanking

1. *Trans. Instit. Mining Engineers*, vol. XX, Pl. XII, 1901.

2. *Quart. Journ. Geol. Soc.*, LXIII (1907), 217-238; and *Proc. Bristol Nat. Soc.*, Nov., 1912.

the Carboniferous Limestone of Broadfield Down, except between Barrow Gurney and Winford, where Rhætic and Lower Lias beds overlie them.

As we proceed eastward, owing to the general easterly tilt of the Secondary Rocks, newer formations come on.

Thus Rhætic and Lias beds rest directly on the Carboniferous Limestone, Lower Limestone Shales, and Old Red Sandstone indiscriminately, near Shepton Mallet, Priddy, and East Harptree, whilst further east, between Doulting and Mells, the Lias passes under Oolitic rocks which rest directly on the Carboniferous Limestone and older rocks, entirely concealing them on the summits toward Whatley.

Thus we prove by tectonic geology that the great removal of material from the Mendips took place before the deposition of the Secondary Rocks which surround them, and which break the superficial continuity of the various members of the Older Rocks in places.

This interval in time is partly bridged over on the south of the Mendips by Lower Trias and Permian rocks. In some parts of the world the gap is entirely filled by Permo-Carboniferous Rocks.

The diagram, Plate I, illustrating the removal of rocks from the Mendip anticline,[1] might without further explanation suggest the denudation of a mountain range over two miles in altitude, an assumption for which there is no warrant. On the contrary, as the Armorican movement progressed, the originally horizontal strata would be folded, and from the time when they emerged from the sea would be attacked by it as well as by subaerial agencies, and this ceaseless abrasion would go on possibly for long periods *pari passu* with the elevatory movement as the land rose.

1. The broken lines are designed to represent the general structure beneath the surface and their continuation above the surface denotes the mass of material denuded, without the complication of thrust faults, such as suggested by me in 1891 (*Proc. Som. Arch. & N. H. Soc.*, XXXVI, ii, 122), and by Prof. Reynolds in regard to the relation of the Old Red Sandstone to the Trap Rocks in 1907 (*Quart. Journ. Geol. Soc.*, LXIII, 234-5).

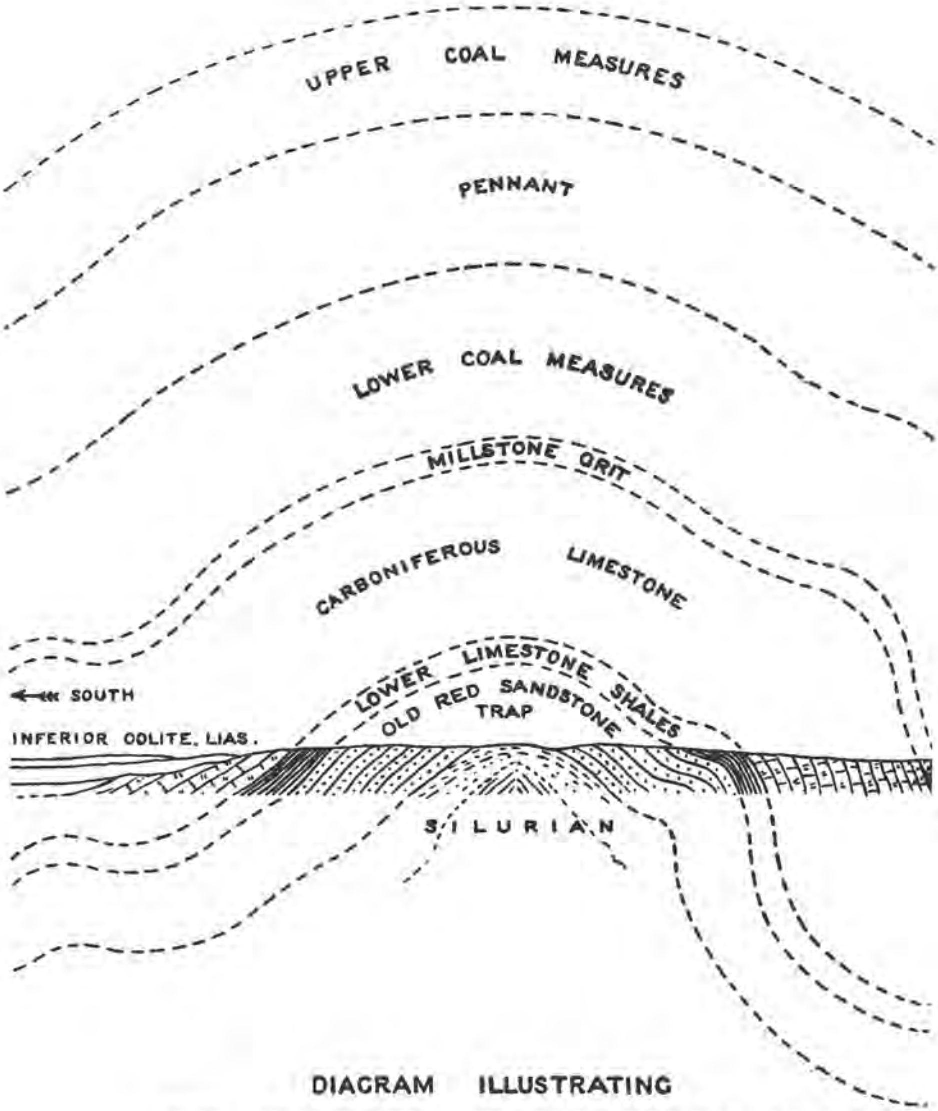
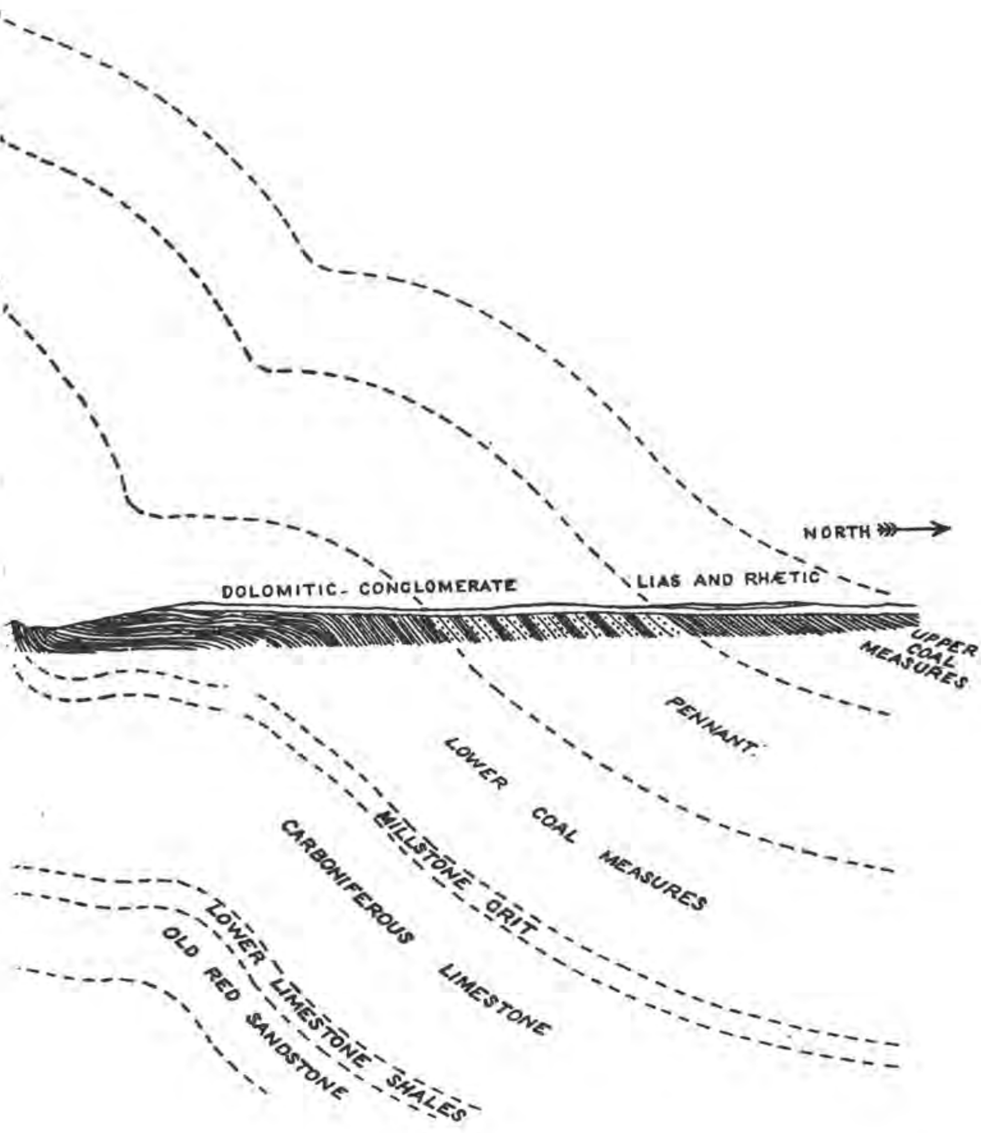


DIAGRAM ILLUSTRATING
THE DENUDATION OF THE MENDIP AREA
IN PRE-PERMIAN TIMES.

SCALE HORIZONTAL AND VERTICAL
2 INCHES = 1 MILE.

PLATE I



NORTH
DOLOMITIC CONGLOMERATE
LIAS AND RHÆTIC
UPPER COAL MEASURES
PENNANT
LOWER COAL MEASURES
MILLSTONE GRIT
CARBONIFEROUS LIMESTONE
LOWER LIMESTONE SHALES
OLD RED SANDSTONE

In this diagram section (drawn northwards from a point half-a-mile E. of Doulting Church), no attempt has been made to show the probable overfolding of the axis, and the reversed dips in the Coal Measures depicted by McMurtrie in treating of the isolated masses of Carboniferous Limestone overthrust on the Coal Measures at Luckington and Vobster.[1]

Palæontological Position of Brean Down Rocks.

To return to the Carboniferous Limestone beds of Brean Down. These beds form a small part of the Carboniferous Limestone, and their position in that series has been palæontologically determined by Dr. Sibly,[2] in accordance with the successive zones into which the Carboniferous Limestone has been divided by Dr. Vaughan.[3] Each zone is marked by certain leading forms, accompanied by an assemblage of fossils sufficiently distinctive to allow of the determination of the zone where the leading forms are scarce, or where, owing to local changes, the organisms have undergone modification, etc.

The zones in descending order are: *Dibunophyllum* zone, *Seminula* zone, *Syringothyris* zone, *Zaphrentis* zone, *Cleistopora* zone.

Dr. Sibly includes the rocks on the north side of Brean Down in the *Syringothyris* zone, and beds on the south side in Horizon γ—intermediate between the *Syringothyris* and *Zaphrentis* zones.

SECONDARY ROCKS IN RELATION TO THE MARSH LANDS.

We must now turn our attention from Brean Down to the extensive flat lands which stretch toward Congresbury and Clevedon on the one side, and to Glastonbury and the Polden Hills, and by Stretcholt to the Bridgwater levels, on the other.

1. Printed at the *Herald* Office, Northgate Street, Bath, 1876. See also *Trans. Instit. of Mining Engineers*, vol. XX, Plate XIII, 1900-1901.

2. *Quart. Journ. Geol. Soc.*, vol. LXII, 1906, p. 324.

3. *Ibid.*, vol. LXI, p. 181.

The marsh lands on the north are drained by the Yeo and Kenn ; on the south of the Mendips by the Axe and Brue in the Huntspill levels, and on the south of the Poldens by the Parret.

These flats encroach on the older Carboniferous and newer Secondary Rocks regardless of age, concealing their relations as well as the relations of the various members of the Secondary Rocks (such as the Keuper Marls of the Trias, the Rhætic Beds, and the Lower Lias) to one another as effectually as the Secondary Rocks conceal the relations of the various members of the Older Rocks.

The most conspicuous object in the marsh-lands, viewed from Brean Down, is Brent Knoll. This hill is composed of Middle Lias beds, capped by Upper Lias and Midford Sand. These are the newest Secondary Rocks between Crook Peak and the Poldens. They were originally connected with the rocks of Glastonbury and Glastonbury Tor, and in the intervening distance have been entirely removed by denudation. They owe their position to a shallow synclinal basin. The underlying Lower Lias beds, and the Rhætic beds beneath, are entirely concealed by the marsh deposits on the north, but emerge to the east in the Wedmore hills, and on the south in the Polden Hills, of which the Lower Lias Limestones form the dip slope. On the escarpment face of the Poldens the Rhætic Beds crop out, overlying the upper beds of the Keuper Marls, which are contemporary with the Marls and Dolomitic Conglomerate, which emerge from the marshes on the north and irregularly flank the south slope of the Mendips.

This basin-shaped disposition of the Secondary Rocks under the Huntspill levels is of peculiar significance, taken in connection with the occurrence of rock-salt in the Keuper Marls in the Puriton borings near Dunball. As the deepest part of the trough is under Brent Knoll, and therefore much nearer to the Mendips than the Poldens, the conditions point to the probability of the existence of an important salt field.

From the above remarks it will be seen that tectonic geology not only proves that the deposits of the flat lands are newer than the Secondary Rocks, but so much more recent that the movements which affected the lie of the Secondary Rocks had ceased, and a vast removal, or denudation, had taken place prior to their deposition.

THE MARSH DEPOSITS.

The marsh deposits consist of marine sands and shingle, alluvial clays and gravel, estuarine silt and beds of peat.

They fill extensive hollows cut out in the Secondary Rocks, and in such inliers of the Older Rocks as may occur in them, by rivers aided by incursions of the sea, when the land stood at a higher level.

Raised beaches. Before these hollows were excavated, when the land stood at 20 to 30 feet lower than now, the sea border was marked by an old beach at Birnbeck Cove, on the Carboniferous Limestone promontory of Worle Hill, near Weston-super-Mare, and on Woodspring Hill, composed of limestone pebbles, comminuted shells with small pieces of flint, according to R. C. Ravis,[1] who gives the following list of shells from the Woodspring beach :

Tellina balthica var. *solida.*	*Cardium edule.*
Littorina littorea.	*Murex erinaceus.*
,, *obtorta.*	*Pupa.*
,, *rudis.*	*Helix virgata.*
Nassa incrassata.	,, *campestris.*
,, *reticulata.*	
Ostrea edulis.	

When these beaches were formed, the sea, no doubt, cut back bays in the softer Secondary Rocks, which formed the cliff line between the harder promontories of Carboniferous Limestone at Brean Down, Worle Hill, and Woodspring, and their

1. *Proc. Bristol Naturalists' Soc.*, Vol. III, No. 7.

subsequent removal in the excavation of the hollows in which the marsh deposits rest, explains the absence of raised beaches elsewhere in the district.

GENERAL SEQUENCE OF EVENTS AFTER FORMATION OF RAISED BEACHES.[1]

The depression which permitted of the formation of the raised beaches is abundantly evidenced on the coast line of the South Western Counties.

1. *Elevation.* It was succeeded by a period of elevation, during which the old beach line was carried to a much greater height above the sea than its present position. This elevation was attended by glacial conditions, as evidenced by boulder clay in the South of Ireland, and by great surface waste forming "the Head," screes and talus fans shed from the higher ground above on the old beach platform in the South Western Counties.

During this period of more rigorous climatal conditions the force and volume of the rivers, and their consequent erosive and transporting power was greater than it is now, as shown in the Cornish stream-tin gravels.

In the earlier stages of the elevatory movement it is probable that there were pauses of sufficient duration to allow the sea to form lower shelves, such as is evidenced near Padstow, where the old beach in consolidated reefs projects through the present sand-beach. In this way the cutting back of the Secondary Rocks would determine the plane surface, deeply grooved by the ancestors of the Yeo, Axe, Brue, and Parret, as the elevation proceeded.

2. *Subsidence.* After the land had attained its maximum elevation (the study of the marsh deposits only supplies us with the minimum), it began to sink, and as the subsidence

1. The successive general movements are distinguished by the numbers 1, 2, 3, 4, to prevent confusion where referred to in the sequel.

proceeded and more genial conditions prevailed, wood growth flourished and extended over the low lands which stretched far beyond our present coasts. Gradually the sea circumscribed the forest lands, denuding peat beds and accompanying fluviatile deposits which, where partially spared, were buried beneath marine deposits on the low lands. That there were periods of pause and oscillation during which blown sands accumulated on the coast, and fluviatile or lacustrine conditions reasserted themselves for a time is highly probable, but they do not appear to have been of much importance.

3. *Elevation.* Later on, however, an upward movement took place, accompanied during its continuance by a considerable denudation of the precedent marine deposits. In process of time the low land area advanced toward Wales.

4. *Subsidence.* The forest growth readvanced over this extended coast line during the succeeding subsidence, in the earlier stages of which the underlying fluviatile and lacustrine clays were formed. This readvance of the forests may be termed the submerged forest era, as it has left its traces here and there along our coasts in peat, with roots and trunks of trees on blue clay, where exceptional gales have removed the overlying sand between high and low water-mark.

The submerged forest at Stolford, three miles west of the mouth of the Parret, and at Shurston Bars, three miles further west, where it was noticed for three-quarters of a mile, has been observed by Horner, amongst others. He mentions roots and trunks of oak and yew in brown peat on blue clay, visible at low water. The land must certainly have stood 40 feet higher when this part of the forest flourished, a minimum estimate based on the improbable supposition that the trees grew down to the actual sea margin. For all that we can tell, however, the forest may have extended to South Wales, interrupted only by the course of the Severn and its tributaries.

Borings in the Marsh Lands.

It is obviously of the greatest importance to obtain in the marsh deposits indications of the inland extension of this final period of forest growth. In the "Geological Survey Memoir on the Quantocks and Taunton and Bridgwater areas," p. 83, I have pointed to the probable connection of the submerged forest with peat beds encountered in the excavation of the canal at Huntworth, in 1826, and in borings at Dunwear Brickyard by the Parret, at Bason Bridge School House, and on Shapwick Turf Moor, without, however, going into particulars.

All these sections, with records of two additional borings at the Milk Factory, Bason Bridge, kindly furnished me by Dr. C. Balfour Stewart, are shown in tabular form with reference to the tide levels in the illustration, Plate II. The surface levels have been tested except as regards Dunwear and Huntworth Canal. Poole gives the surface at the latter as "below the level of high-water-mark in the river Parret."[1]

There is considerable doubt as to the description of the 43 feet underlying the peat bed in the published account of the Bason Bridge School House boring, as it does not agree with the Milk Factory borings, specimens from which have been inspected. Moreover, Dr. Stewart has been informed that the peat in the School House boring rests on blue clay, and not on fine calcareous silt, as stated in the published account. If the lower part of the 43 feet in question were silt it would account for the discrepancy, as each informant might have applied to the whole the description of that part of the thickness which he had specially noticed.

We will now see, firstly, what evidence these sections afford as to the contour on which the marsh deposits rest; secondly, how far these deposits bear out the sequence of movements of elevation and subsidence since the formation of the raised beaches already outlined.

1. *Proc. Bristol Naturalists' Soc.*, Vol. III, No. 6, p. 46. July, 1868.

Evidence as to Contour of the Marsh Hollows.

The first line of enquiry gives meagre results. The Bason Bridge borings, reaching Lias at depths of from 81 to 89 feet from the surface, are the deepest ; next, some five miles east of them, in the Shapwick Turf Moor boring, Lias was reached at a little over 61 feet from the surface, which is lower, the difference in the levels of the basement beds being between 18 and 26 feet.

In the Parret drainage Keuper Marl was met with at 29 feet from the surface in the canal at Huntworth, and at about 23 feet from the surface at Dunwear, so that the deeper parts of the Bridgwater levels lie to the east of these places.

As I am informed by the Great Western Engineer that in driving piles for piers in the Castle Cary and Langport Line on the flats, between Langport East and the Parret, the Keuper Marls were reached at about 45 feet from the surface under clay and peat, underlain, according to one account, by marine sand, the maximum depth of the marsh deposits in the Bridgwater levels is likely to be much more.

The borings are too few to give much information as to the contour of the bed of the marsh deposits, but the numerous inliers of Keuper Marl in the Bridgwater levels, and of Lias, etc., in the Huntspill levels, is in accordance with fluviatile denudation modified by marine action, as subsidence allowed the sea to plane the surface of the old river channels, its work being subsequently, to a considerable extent, obliterated by a resumption of fluviatile conditions during the succeeding elevation.

Evidence as to Sequence of Events.

As regards the second line of investigation, the borings furnish much more satisfactory evidence.

Elevation (1). The deepest boring, that of Bason Bridge School House, in which the Lias was reached at 89 feet from the surface, under a foot of sand and clay overlain by three feet of shingle, proves that the raised beaches were elevated at least 89 feet above their present level, giving a certain minimum elevation of about 114 feet. The shingle bed could only have been formed as a coast-fringing beach. At that time the site of the lowest bed in the Shapwick Turf Moor boring would have been 25 feet above spring tide high-water level. This bed of sharp and broken gravel is somewhat suggestive of the conditions which prevailed during the accumulation of the Head. It may have been formed long before the basement beds in the Bason Bridge School House boring, and when the land stood at a much higher level than when the shingle beach was made.

Forest growth before the Hollows were invaded by the Sea. Above the basement gravel in the Shapwick Turf Moor boring, we have evidence of the earlier peat and forest growth in a very compressed bed of peat, containing well preserved roots and rushes 3½ inches thick, at a depth of 57 feet 4 inches from the surface, and 60 feet 4 inches below spring tide high-water level, and in a 4 inch bed of very dense peat containing sticks and leaves about 7 feet higher up.

These peat bands, the intervening fluviatile sand gravel and blue clay, and the black earth underlying the lowest band, must have grown and been deposited on sites above high-water-mark, probably during subsidence (2).

If we compare their level with the deposits at the corresponding levels in the Bason Bridge borings which consist of marine sands, it will be apparent that they were already formed when the sea occupied the site of the Bason Bridge borings, and must therefore be older than the marine deposits at corresponding levels.

Subsidence (2). In the deposits overlying the shingle bed in the Bason Bridge boring, we seem to have some indication of a stationary condition, during or after the formation of the shingle bank, permitting of the accumulation of blown sand, and perhaps 2 feet of marsh deposits, but in the overlying sand with marine shells, and in the sands of the Milk Factory borings we have proof of the subsidence which led to the destruction of the old forest ground, on the site of these borings, by the sea. As the subsidence went on, the entombment of the peat beds and associated deposits on the site of the Shapwick Turf Moor boring is evidenced by the quicksand bed, over 14 feet in thickness, which overlies them. The incursion of the sea is marked in the Shapwick Turf Moor boring by a bed of clay with sand which overlies the 4 inch dense peat bed, and no doubt saved it from destruction. This clay was probably attacked by the sea and mixed with sand, an explanation possibly applicable to the basement 1 foot bed of sand and clay which underlies the shingle in the Bason Bridge School House boring. This latter boring, as already pointed out, gives a certain minimum estimate of the amount of the elevation which succeeded the formation of the raised beaches, but this estimate is based on the supposition that the basement deposit marks the change from an elevatory to a subsiding movement. There is, however, every reason to think that the incursion of the sea took place after the subsidence had already begun, and that this minimum estimate of the elevation of the raised beaches falls very far short of the height to which they were carried.

During the period of elevation (1) the maximum amount of fluviatile denudation would naturally take place. In the succeeding subsidence (2) the infilling and silting up of the channels would be accomplished, and the older extensions of the forest would have flourished over more extended low-lands, and marsh growths would cover the undrained area.

As the subsidence proceeded the sea would advance, denuding the earlier forest beds and associated fluviatile deposits, and planing the surface in the coastal districts. In this way I would account for the marine sands directly overlying the Lias in the Bason Bridge borings, and further east in the Shapwick Turf Moor boring, leaving the earlier marsh deposits undisturbed until later.

We now come to the question as to how far the borings enable us to estimate the extent of this period of subsidence.

As in the Bason Bridge borings and in Shapwick Turf Moor boring, the marine sands are overlain by fresh water deposits, upon which the peat beds correlated with the submerged forest rest, it is evident that the subsidence (2) was succeeded by an elevation (3) which, as previously stated, carried the land, at a minimum estimate, to 40 feet above its present level.

The change from marine to fresh water deposits is marked in the Milk Factory borings by beds (16½ feet in one boring and 6 feet in the other) of silty clay, described as loamy sand. These beds are overlain by clay at a level of between 10 and 12 feet below mean tide.

In the Shapwick Turf Moor boring the top of the quicksand is overlain by 5 feet of clay and sand, which gives place to clay at 6 feet above mean-tide level.

In the Milk Factory borings, which are not 50 yards apart, the upper surface of the sand varies from 47 feet to 34 feet below mean-tide level. The surface of the sand in the published account of the School House boring is nearly 47 feet below mean-tide level.

In the Shapwick Turf Moor boring, 5 miles east of the Bason Bridge borings, the surface of the sand is at about 17 feet below mean-tide level.

From these discrepancies it is evident that the correspondence in level of the deposits in the different borings does not denote contemporaneous deposition in the cases under consideration. If we are to take the change from marine beds to fresh-water deposits in the borings as evidence of the extent of the subsiding movement (2), it is obvious that we must take the highest limit of the marine sands which, in the borings we have been considering, is 17 feet below the level of mean-tide in the Shapwick Turf Moor boring.

To account for the replacement of marine sands by fluviatile deposits below the corresponding level in the Bason Bridge borings, merely postulates the denudation of the sands by fluviatile agencies during the succeeding elevation (3), involving the removal of 30 feet of sand from the site of the School House boring, and of from 17 to 30 feet from the site of the Milk Factory borings. If we can rely on the description of the Dunwear boring [where Keuper Marl was reached at a depth of 23 feet 3 inches from the surface under 3 feet of running sand under 4 feet of soft silt, on which the peat bed I have correlated with the submerged forest rests], the subsidence would appear to have gone on, and sand to have accumulated to the level of 4 feet below mean-tide. This would involve the removal of 47 feet of sand from the site of Bason Bridge School House boring. The soft silt which underlies the peat in the Dunwear boring evidently corresponds to the soft silt which occupies a similar position in the Huntworth Canal section, where it is 9 feet thick, and rests on a very interesting bed of gravel; but in this section, where Keuper Marl was reached at 29 feet from the surface, there is no mention of sand. It would appear that the sand, if it extended to this site, had been denuded, and the channel filled by silt. Upon the Keuper Marl in this section 2 feet of blue clay, penetrated by roots and rootlets of plants, was met with, and on it the gravel bed above mentioned which is 1 foot thick, and contains shells, coarse hand-made pottery, bones of ox, horse, deer, and according to Anstice (in a letter to Buckland, Nov., 1826), dog or fox, porpoise, and human bones.

These two beds may be older than the marine sands, and higher beds of the same series may have been denuded during the elevation (3) which led to the growth of the submerged forest: an alternative explanation is given further on.

The Burtle Beds. In the paper communicated to the Taunton Field Club on their excursion to Brean Down on June 4th, 1914, of which this is an amplification, I ascribed the origin of the Burtle beds to incursions of the sea within the historic period, and in the "Geological Survey Memoir on the Quantocks, etc.," I suggested the possibility of their belonging to the raised beach period. At that excursion I had the pleasure of meeting Dr. C. Balfour Stewart, of Huntspill, who has studied these beds, and I have since visited sections under his guidance which convinced me that they are older than the submerged forest bed which, with underlying clay, we saw abutting against them by the Brue at Highbridge.

The Burtle beds consist of marine sands largely composed of comminuted shells. They occur at the surface at Burtle (near Edington Station), whence the distinguishing name, at Huntspill, Stretcholt, Chedzoy, Westonzoyland, Middlezoy, and between Perry Court and Wembdon north of Bridgwater.

They contain recent marine shells, and are usually found on, or flanking, mounds of Lias and Keuper Marl, which form inliers in the marsh deposits. In places, as near Greylake Farm north of Othery, the sand forms a low mound about 10 feet above the surrounding marshes.

Dr. Stewart regards these sands as marking the upper limit of the marine sands met with in the borings, and if I am right as regards the running sand at Dunwear boring being a marine bed, as the Burtle beds have been proved to go down to below the level of the peat bed at Highbridge, I think his opinion may be justified.

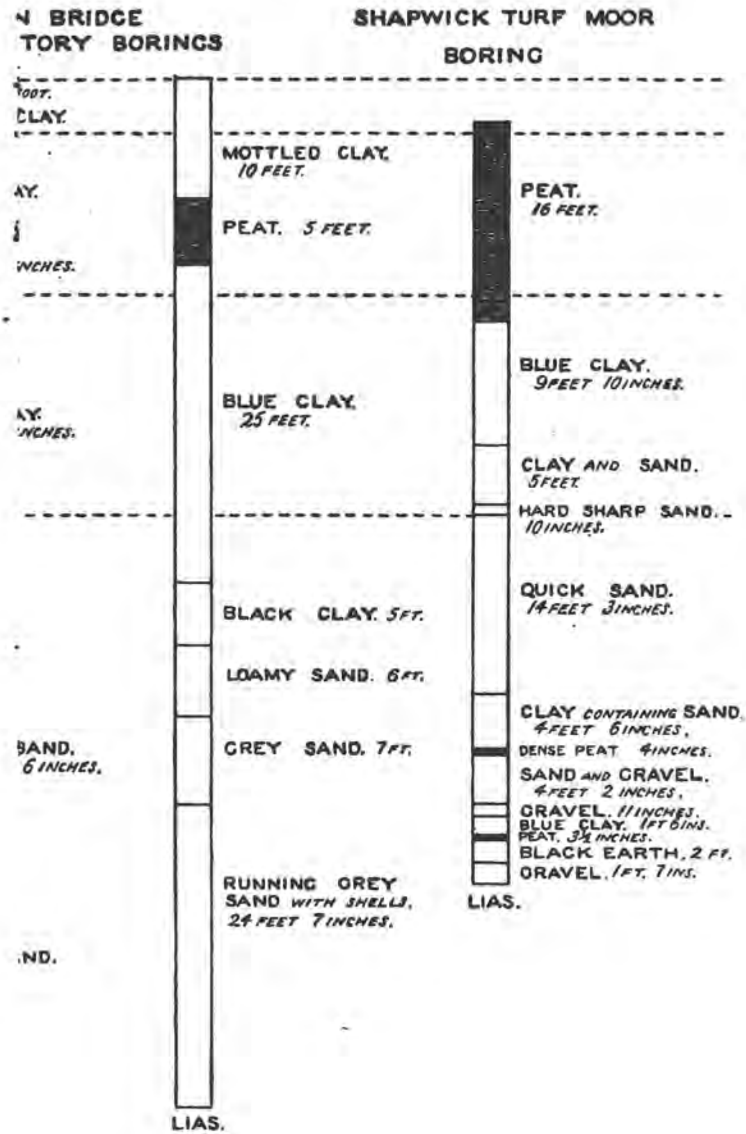
A few borings through the Burtle beds, and some more deep borings in the marsh deposits, would probably settle the question. If we assume his theory to be correct, we must admit that the subsidence (2) continued until the land stood at or a few feet below its present level.

We would explain the preservation of these sands at the surface, partly through their position on, or flanking mounds of Secondary Rocks, partly through their irregular consolidation, and partly through positions out of the way of direct fluviatile erosion during the succeeding elevation (3).

When the subsidence had attained its maximum, there would

TICAL SCALE — 1 INCH = 12 FEET.

PLATE II.



no doubt be a pause of sufficient duration to allow of the formation of sand dunes where the beaches margined low islands or spread over shoals of Secondary Rocks.

Elevation (3). We now come to the succeeding movement of elevation. In its earliest stages, with the retreat of the sea, the rivers and streams would advance, sweeping before them the unconsolidated sand and effecting a general lowering of the surface, and as the elevation progressed they would deepen their channels. The resultant deposits would be swept seaward as the elevation proceeded, and none are to be found in the borings, unless the soft silt in Dunwear boring and Huntworth Canal section are of this date. The deposits overlying the marine sands in the borings are the result of the succeeding subsidence (4), during which the submerged forests flourished, and as such prove the height to which the land had been raised.

Assuming that the Burtle beds mark the culmination of the subsidence (2) during which the marine sands in the borings were accumulated, we must take the lowest level of the fluviatile deposits in the borings as a minimum estimate of the extent of the succeeding elevation (3).

The criterion to be taken is therefore the base of the 16½ feet bed of loamy sand (silty clay) in one of the Milk Factory borings, which is 63½ feet from the surface. That is the minimum estimate of the elevation necessary to allow of the removal of the marine sand by a river cutting its channel downward through it. So we may give the minimum elevation in round numbers as 70 feet.

Subsidence (4). When the land had reached its maximum elevation, the beds overlying the marine sands in the deepest borings would be formed of an admixture of fluviatile mud and sand during the earlier stages of the ensuing subsidence, and subsequently the blue clays.

Submerged Forest Era. To formulate any theory as to when the advance of the forest growth took place would require more data than we possess. It must not, however, be supposed that the remains of the submerged forest on the foreshore and the beds of peat correlated with its latest stage in the borings mark the commencement of that era or afford any clue to its duration. The forests may have flourished in suitable sites during the subsidence before the growth on these sites.

It would appear more probable that the preservation of these relics of forest growth was due to a period of pause in the movement of depression, during which the forests were enabled to maintain their sites longer, and under conditions which largely restricted the extension of fluviatile and lacustrine sedimentation.

In the Bridgwater Brickyards a layer of peat 3 to 5 inches thick is generally found at about 11 feet from the surface, and in one case my informant, Mr. R. Y. Foley, mentioned the discovery of a 3 feet bed of peat at 16 feet from the surface. Both of these horizons are included in the submerged forest era, but which of them represents the submerged forest bed in the borings I am unable to say.

Again, I cannot say that the basement blue clay and overlying gravel bed in the Huntworth Canal section may not belong to the submerged forest era, in which case the marine sands forming the basement bed in the Dunwear section would either have been previously denuded or had not extended to this site.

If the soft silt underlying the submerged forest bed in this section and in the Dunwear boring is of the same nature as the beds overlying the marine sands in the other borings, it is natural to infer that they were formed in the denudation of the marine sands, in which case, as already suggested, the basement blue clay and overlying gravel bed would be necessarily of prior formation to the marine occupation of the marsh hollows.

Details of the composition of the peat beds correlated with the submerged forest are unfortunately wanting, with the exception of the Huntworth section. Here, though only 1 foot thick, the peat is said to consist of two irregular beds, and to contain branches of alder with silvery bark and bones and horns of deer.

The lower bed contains an abundance of fresh-water shells, whilst the upper bed contains marine as well as fresh-water shells.

The mention of marine shells in the upper bed suggests the invasion of the sea on the forest ground after its seaward extension had been submerged. Proofs of this are wanting in the borings, perhaps owing to the digging of the Canal section having been more minutely recorded.[1]

The subsidence which led to the destruction of the forest land on the foreshore would not have allowed access of the sea to its landward extension until the Stolford site had been submerged to a depth of from 18 to 20 feet.

The surface levels of the marsh lands are in many places below the level of Spring, and even Neap tide high-water, and the fact that the deposits overlying the submerged forest peat beds in the borings are estuarine, fluviatile, and lacustrine, prove the continuance of the subsidence after the submergence of the forests, and that the sea was kept out by natural and artificial embankments whilst estuarine conditions were normally confined to the actual river channels. It is obvious that as long as trees grew on foreshore sites no embankment would be necessary, but as soon as the level of the peat beds which mark its extension in the borings was reached by the sea the construction of embankments on all parts of the coast not naturally protected by sand dunes would have to be undertaken, when the land stood between 10 and 16 feet above its present level.

In the Shapwick Turf Moor boring it is only the lower part of the top peat bed that is taken as representing the inland

1. See Papers by Rev. W. A. Jones, *Proc. Som. Arch. Soc.*, vol. IV, and by Poole, *Quart. Journ. Geol. Soc.*, vol. XX, and *Proc. Bristol Naturalists' Soc.*, ser. 2, vol. III, No. 6.

extension of the submerged forest. In this case, instead of destruction and burial beneath fluviatile and lacustrine clays, the forest ground was converted into a morass which nourished marsh growths uninterrupted by drainage influxes, or overflows charged with sediments.

This is doubtless the history of the destruction and decay of the forest growth everywhere on the low lands, but the other borings are on sites where estuarine and fluviatile conditions and the ponding back of surface waters receiving influxes of mud speedily put a stop to the marsh growths, and in their earlier operation, no doubt, removed much of the decayed vegetation.

In the Shapwick Turf Moor boring the surface of the peat is a few feet below Spring tide high-water level, and the peat bed is said to be 16 feet in thickness.

Poole, in an address to the Bristol Naturalists on July 10th, 1868, gives the thickness of peat in the turf moors as from 15 to 25 feet, the upper beds being cut for fuel to a depth of from 7 to 8 feet. He describes the discovery of a road, 4 feet wide, made of split poles of birch and alder, leading across the peat between Burtle and Westbury (*sic*),[1] and at 7 feet from its surface. At this depth hazel bushes with leaves and half ripe nuts, and roots and stumps of birch and alder, were found standing in the peat. He comments on the rapidity of the peat growth, as the split poles would have been rotten if not covered up soon after the construction of the roadway.

Summary of Evidence as to Sequence of Events.

From the foregoing description of the marsh deposits as revealed by the borings it will be seen that they fully bear out the general statement as to the succession of movements of elevation and subsidence which have taken place since the raised beach period.

1. This is probably intended to be Westhay, in the parish of Meare, and not Westbury, 4 miles N.W. of Wells.—H. ST. G. G.

Firstly, they show that the raised beaches were carried up to a height of at least 114 feet above Spring tide high-water level.

Secondly, that a subsidence succeeded during which forests grew and fresh water deposits were formed until the sea entered and denuding the previously formed deposits filled the hollows with marine sands, perhaps up to the present level.

Thirdly, they prove that the subsiding movement was followed by an elevation of 70 feet or more, attended by the denudation of the marine sands and the deep grooving of river channels in them.

Fourthly, they show that this elevation gave place to a subsidence during which the river channels silted up and forests grew on a more extended coast line, their tenancy being finally marked by a pause in the subsidence attended by more restricted fluviatile action. That they were submerged on the foreshore, and when the subsidence reached their continuation within the limits of our present coast line, artificial embankments were constructed to keep out the sea where the coast was unprotected by natural barriers such as sand dunes, and that since then the land has gone down perhaps about 16 feet, and fluviatile deposits and marsh growths have accumulated.

Historic Period.

The changes that have taken place on the marsh lands since the submerged forest era have been greatly influenced by human agency, as we have seen, but it is a matter of conjecture as to when and by whom the embankments which formed so important a feature in these influences were first erected.

Horner[1] quotes De Luc as to the discovery of Roman pottery, moulds, and coins on peat [evidently the bed correlated with the submerged forest in the Bason Bridge borings] under 7 feet of silt, when the channel of the Brue was deepened. He also mentions the occurrence of relics of two Roman

1. *Trans. Geol. Soc.*, 2nd ser., vol. I.

potteries near Bason Bridge, under 12 feet of silt, and of a Roman road in the vicinity found under silt at nearly 6 feet below high-water level. If we can base anything on these discoveries they would seem to indicate a subsidence of about 10 feet during the Roman occupation and of about 6 feet since then. That is assuming that the moulds and coins on the peat bed were *in situ*, as it would then have been at the surface. But if, as I suppose, the submerged forest ground marks a stationary condition or oscillation in the subsiding movement the Britons may have witnessed its destruction on the foreshore, on the resumption of the subsidence, and may have constructed the first rude earthwork embankments to arrest the advance of the sea over the marsh lands, afterwards strengthened and completed by the Romans in a more durable fashion. This supposition would account for a local advance of the sea on the peat bed in the Huntworth Canal section.

From neglect in the upkeep of these ramparts against inroads of the sea, from gales and exceptional high tides and from inrushing waves propagated by earthquake shocks, there were doubtless many temporary incursions of the sea over parts of the marsh lands in Saxon and early Norman times.

In the *Saxon Chronicle* earthquakes are mentioned as taking place in 1048, 1049, 1060, 1089 (throughout England), 1119 (most felt in Gloucestershire and Worcestershire), 1122 (throughout Somersetshire and Gloucestershire). From the same source we have references to a great sea flood throughout the land in 1014; to a very high tide on St. Martin's day, 1099; to a great flood on St. Lawrence's day, 1125; but, excepting the earthquake in 1122, there is no mention of Somerset in connection with these disasters.

In later times, the most serious inundation of the sea on these marsh lands seems to have been in 1607. Mr. Sandford D. Cole, in his paper (privately printed, 1912) on "The Sea Walls of the Severn," quotes the black-letter tract, in which the 1607 disaster is described, and mentions later incursions of the sea. He gives valuable information respecting the artificial banks and their upkeep, and the gradual development of organized drainage and reclamation of the marshy lands, from the first establishment of Sewers Commissioners in Edward I's time to the present day.

The formation of the Burtle beds in historic times through inundations is quite out of the question. But before adopting Dr. Balfour Stewart's opinion and correlating them with the marine beds in the borings, it must be remembered that their actual connection has yet to be established. As far as the actual evidence of the mode of occurrence of the Burtle beds has been ascertained, the theory that they may mark a pause in the original elevation of the raised beaches, and thus be connected with the raised beach period as I suggested in the "Geological Survey Memoir," has not been disproved. As these two hypotheses are quite irreconcilable, this matter must be regarded as *sub-judice.*

CLASSIFICATION OF PLEISTOCENE DEPOSITS OF SOMERSET.

In the following table a general classification of the Pleistocene Deposits of Somerset has been attempted, in which each alternative as to the position of the Burtle beds is shown.

Deposits.	Conditions, Changes of Level, etc.
Raised beaches and contemporary river gravels.	Land at the close of a period of subsidence standing at 20 to 30 feet lower than now.
(Burtle beds possibly formed during an early pause in the elevatory movement). 'Head' shed on Raised Beach plane. River gravels with remains of Mammoth, Rhinoceros, etc., as at Taunton Gaol, and Tannery near Langport. Cavern deposits with extinct mammalia.	Elevation perhaps culminating in continental conditions. The marsh hollows eroded by rivers deepening their channels.

CLASSIFICATION OF PLEISTOCENE DEPOSITS OF SOMERSET (*continued*).

Deposits.	Conditions, Changes of Level, etc.
Cavern deposits with extinct mammalia. River gravels and clays with peat bands in lower part of Shapwick Turf Moor boring. Shingle bed and overlying sands in Bason Bridge School House boring, sands in Milk Factory borings, quicksand in Shapwick Turf Moor boring, running sand in Dunwear boring. (Burtle beds possibly formed during a pause at the termination of the subsiding movement).	Subsidence during which forests flourished on more extended coast line until circumscribed by the advance of the sea, which buried their traces together with associated river deposits under sea sand, where not denuded away. If Burtle beds can be assigned to this period they would mark the termination of subsidence when land stood at or a few feet below its present level.
The various levels of the top of the marine sands in the borings are accounted for by this period of denudation.	Elevation attended by much denudation of marine sands off the general surface and by rivers deepening their beds. Land advancing toward Wales permitting of re-advance of forest growth on low lands.
Clays with sand or loamy sand and overlying blue, etc., clays in Bason Bridge and Shapwick Turf Moor borings. Soft silt in Dunwear boring and Huntworth Canal section.	Subsidence accompanied by silting up of river channels, formation of alluvial and lacustrine clays.
Stolford and Shurston Bars submerged forest. Peat beds in Huntworth Canal section, in Dunwear and Bason Bridge borings and lower part of top peat in Shapwick Turf Moor boring.	Pause or oscillation marking the last stages of forest growth on the low lands.
Alluvial and lacustrine clays above the peat except, as in Shapwick Turf Moor boring, where marsh growth went on uninterruptedly. Roman coins, pottery, etc., found on peat bed and in overlying alluvial deposits.	Resumption of subsidence causing submergence of forest on foreshore sites while it lingered on in the low lands shut out from the sea by natural and artificial embankments, probably begun by the Britons and completed during the Roman occupation. Marsh fluviatile and lacustrine deposition.