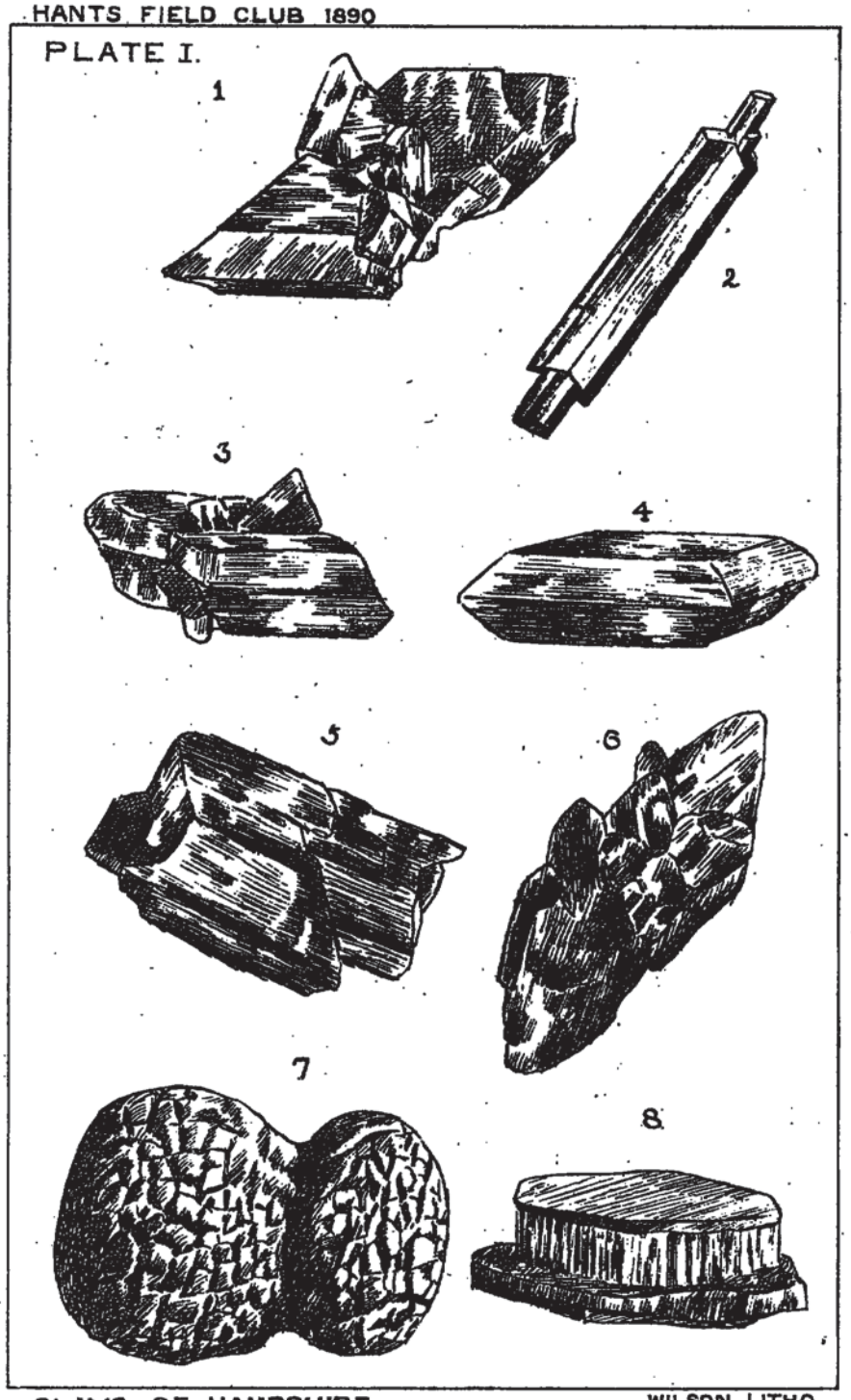
HANTS FIELD CLUB 1890

PLATE I.



CLAYS OF HAMPSHIRE

WILSON LITHO

FIGS: 1-6 SULPHATE OF LIME, CRYSTALS

FIG 7 CONCRETION OF CLAY IRONSTONE

FIG 8 VEINS OF GYPSUM

THE CLAYS OF HAMPSHIRE AND THEIR ECONOMIC USES.

By T. W. Shore, F.G.S., F.C.S.

Hampshire probably contains a greater variety of clays of different geological ages than any other English county. This arises mainly from the circumstance that it contains a greater variety of Tertiary beds than exists elsewhere in England. These Tertiary clays exhibit important differences, although some of them have points of resemblance. The Hampshire clays are not, however, confined to those of the Tertiary age, for the oldest that are found in this county and used for economic purposes are the Wealden shales, and the most recent are the deposits of clay alluvium which lie near the wide mouths of the estuaries or along the banks of the rivers.

The relative ages of these clays may be seen from the geological table which is given herewith, and which shows the sequence of beds as they occur in Hampshire, those beds from which clay is obtained for economic purposes being marked with an asterisk (*).

From this table it will be seen that clay is or has been worked in this county from deposits of more than twelve different geological periods. The Tertiary clays lie both in the north and south of the county with a broad extent of chalk between, separating the Hampshire basin from that part of the London basin which is included in the northern part of this county. The line of junction of the chalk with the Reading beds in the north of Hampshire runs from Crondall on the border of Surrey in an irregular W.N.W. line to East Woodhay. The Hampshire Tertiary clays of the London basin lie north of this irregular line. In the south of the county the northern limit of the Tertiaries is

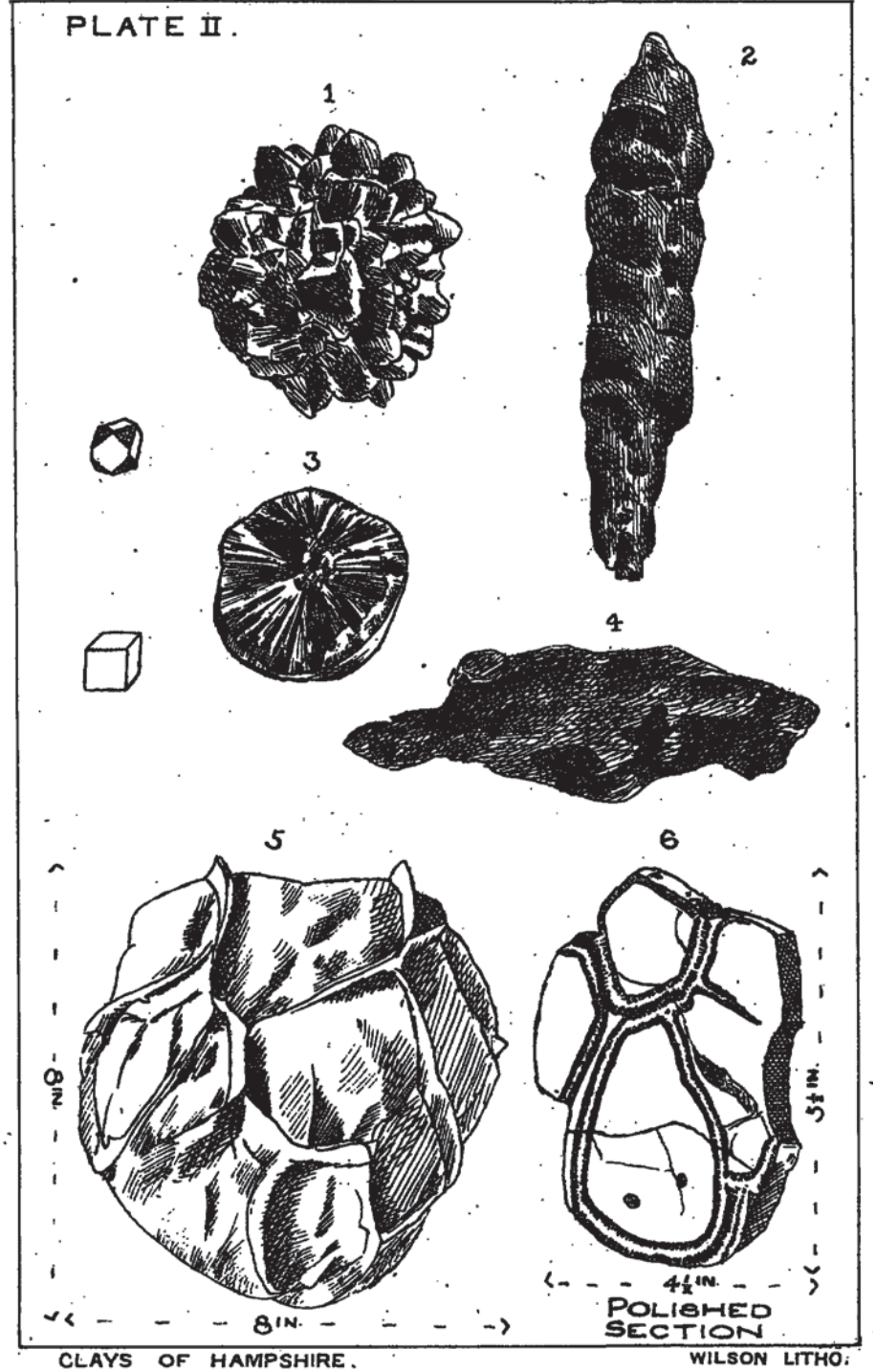
marked by an irregular west north west line, extending from near Rowlands Castle through what was formerly Bere Forest, past Otterbourn to Michelmersh and West Tytherley. Another upthrow of the chalk produced by the Portsdown anticlinal, and its westward prolongation, brings it again to the surface south of this line, and also brings the Reading beds and the London clay to the surface at Fareham, in the neighbourhood of Southampton, and also further westward. These Tertiary clay areas, alternating with the sandy areas of the Bagshot beds, produce a marked effect in Hampshire scenery. Between the sandy heath land of the Bagshot beds and the chalk, both in the north and south of Hampshire, there are broad belts of the London clay and Reading beds, which are marked by areas of rich woodlands. This is well seen near Burghclere and Odiham in the north, and in the south at North Baddesley and Ampfield. In the south-west also the belt of woodland in the neighbourhood of Fordingbridge, between the heaths of the western part of the New Forest and the chalk downs near Rockburn, is due to the same cause.

Hampshire contains no clay that approaches in composition to a pure Silicate of Alumina, like the Cornish china clay. One of the purest of the clays of this county is the pipe clay of the Lower Bagshot beds. I am not aware that any analysis has been made of the pipe clay found in this county; but an analysis of the light coloured pottery clay, a similar pipe clay from Dorsetshire, has been found by Dr. Percy to contain 48·99 per cent. of Silica, 32·11 per cent. of Alumina, ·43 per cent. of Lime, ·22 per cent. of Magnesia, 3·31 per cent. of Potash, 2·34 per cent. of protoxide and peroxide of iron, and 11·99 per cent. of water.

Sulphate of lime in the crystalline form of selenite, $Ca\,SO_4 + 2\,H_2O$ is a common ingredient in the clays of Hampshire. The crystalline forms it assumes are represented, Plate I, Fig. 1 to Fig. 6. Some of the crystals represented in these figures were obtained from the Bracklesham clay near the New Forest, and others from the London clay. Selenite occurs in some of the Hampshire clays in crystals of all sizes from small specks, to those of considerable size as represented on Plate I, which are drawn about half the size

HANTS FIELD CLUB 1890.

PLATE II.



CLAYS OF HAMPSHIRE.
FIGS: 1-4 IRON PYRITES OR MARCASITE
FIGS: 5-6 SEPTARIA

WILSON LITHO.

of the originals. Sulphate of lime is also sometimes met with in the form of veins of gypsum as shown in Plate I, Fig. 8.

Iron is contained in the clays in various forms. Nodules of clay ironstone rich in the metal, some samples containing as much as 50 per cent. of iron, occur in the Bracklesham clays near Hengistbury and along the shores of the Solent, and were formerly collected for the ironworks at Sowley, near Lymington, where some heaps of them still lie, or did lie a few years ago. Concretions of clay ironstone were also found in the Bracklesham beds of the Southampton Dock excavation. Some of these concretions often show remarkable lines of shrinkage, as shown on Plate I, Fig. 7. In some cases the concretions are pear or cone shaped and the shrinkage lines make the nodules to have an outward resemblance to fruits.

Iron also occurs in the clays in combination with sulphur in the form of iron pyrites, and that variety of iron sulphide known as marcasite, as shown on Plate II, Fig. 1 to Fig. 4. The radiating crystals of marcasite usually seen in these pyritic nodules when broken is shown on Plate II, Fig. 3. Occasionally iron sulphide is found which exhibits the typical cube crystal of pyrites, and one or more of the crystalline forms derived from it, as shown on Plate II.

Some of the clays which have been acted on by decomposing organic matter, also contain a small proportion of phosphate of iron in the form of vivianite. This is the case with the Bracklesham clay beneath the mud or peat of Southampton Water. Samples of this clay from the Netley shoal, showing thin bright blue veins of vivianite, may be seen in the Hartley Museum.

A common substance in the clays of Hampshire, often forming bands between the beds, is septaria, a hydraulic or argillaceous limestone, which contains also proportions of silica and iron. It occurs also in nodules. A lump of septaria, showing the septa or calcite lines of division in the mass, is shown on plate II, Fig 5, and a polished section on Plate II, Fig. 6. The specimen represented by Fig. 5 was obtained from the Lower Bagshot beds at the brickyard on the National Liberal Land Company's estate at Bittern.

In the sixteenth century alum was extracted in the Isle of Wight from the clays of Alum Bay, under a Crown monopoly, and the bay appears to have got its name from this alum clay. A well at Southbourne-on-Sea, near Bournemouth also shows that alum exists in the beds there, the water being highly charged with it.

Some of the clays also contain lignite, which is often found covered with small crystals of iron pyrites, and also in a more or less pyritised condition throughout, as may be seen in specimens of pyritised wood found in the Bracklesham clay of Southampton Dock excavation, and in specimen from the clay beds of Hordle and Barton.

Iron pyrites also occurs in Hampshire clays in an impure state forming small concretions consisting of minute crystals of pyrites intermixed with minute particles of earthy matter as shown on Plate II, Fig. 4.

The colour of the clays varies greatly. Some of the beds of the London clay, the Bracklesham clay, and the Gault are all locally known in Hampshire as the "blue clay." When so described it is of a dark dull blue colour, which appears in some instances to be due to the action of carbonaceous matter on the peroxide of iron in reducing it to the condition of the dark protoxide by deoxidising the iron. Where clay exists below beds of peat and below vegetation, even in localities where it is otherwise red, the carbonaceous matter by abstracting from the clay part of its oxygen, causes it to assume this blue colour.

On the other hand, when a newly cut section of blue clay is watched in a railway cutting or brickyard, it may often be observed after a time to change its colour to a reddish tinge, by the oxidising action of the air converting the protoxide of iron into peroxide. Colour alone therefore cannot be relied on as a test in identifying beds of clay.

The various colours of clay are mainly due to the presence of iron in various states of oxidation and also to organic matter, which latter, in some cases, colours it from light grey to black. Iron in the form of an hydrous peroxide imparts a deep red colour, which on becoming hydrated sometimes

changes to bright yellow, while shades of brown and purple are produced by intermediate conditions and concentration of the iron. A good example of yellow clay resting on dark brown clay was observed in the new railway cutting through the Barton clay near Hinton, in 1887.

Some of the green sandy loams of the Bracklesham and other clays of Hampshire owe their colour to the presence of green grains of glauconite, a hydrated silicate of iron, potash and alumina.

In other cases the colour is apparently due to the union of organic substances with the iron oxides in the clay. This was observed in the progress of the Southampton Dock excavation, where some of the newly cut loamy clay of the Bracklesham beds were observed to have pink, pale buff, mauve and other tints, but these, after a few days, disappeared, apparently by oxidation and the consequent destruction of the organic substances.

Those clays which contain only a small proportion of iron are necessarily paler in colour than others, for if the iron in such clays become completely changed into the peroxide, it is not sufficiently abundant to colour the mass. In the white and light grey clays iron, where it occurs, is principally in the form of carbonate of the protoxide.

Where the clay is bright red, as in some of the beds of the Osborne series, the presence of peroxide of iron is probably very abundant. Red and white or light grey appear to be the most permanent colours in clay, as may be observed in the Stamshaw red and mottled clays, and in the pipe clays of Hampshire.

The clays arrange themselves naturally under several classes:—1. Stiff or firm clays, like the typical London clay, which contain very little if any sand. 2. Loams which are sandy clays, such as those of the Lower Bagshot Beds. 3. Marls, which contain a considerable proportion of carbonate of lime, like those of the Bembridge series.

The following table shows the order of strata in Hampshire, the beds which contain clay used for economic purposes in this county, being marked with a * :—

TABLE OF STRATA IN HAMPSHIRE.

	BEDS.		LOCALITIES.
Pleistocene	*Recent Deposits *Drift Beds (Loam, Gravel, and Sand)		Many parts of the County
Upper Eocene	*Hamstead Beds *Bembridge Beds *Osborne Beds *Headon Beds	Oligocene or Fluvio-Marine Series	Isle of Wight only
Middle Eocene	Upper Bagshot Beds		[County Isle of Wight and S.W. of N.E. of the County, doubtful in the South
	*Barton Clay	Middle Bagshot	Hampshire Tertiary basin in the South of the County only.
	*Bracklesham Beds		Both Tertiary areas, viz.:—The London basin of North Hampshire and the Hampshire basin of the south of the county
	*Lower Bagshot Beds		
Lower Eocene	*London Clay		Both Tertiary areas, in the north and south of the county
	*Reading Beds		
Upper Cretaceous	Upper Chalk Middle Chalk Lower Chalk		Hampshire and the Isle of Wight
	Upper Greensand *Gault		Isle of Wight and East of Hampshire
Lower Cretaceous	*Lower Greensand (Atherfield Clay)		Isle of Wight and East of Hampshire
	*Wealden Shales		Isle of Wight

The Weald clay comes to the surface in the southern part of the Isle of Wight between Cowlease Chine and Compton Bay, and also further eastward near Sandown. The upper part of it consists of dark grey shales, and the lower part contains variegated marls. At Sandown bricks are made from the Wealden shales, and from the Atherfield clay of the Lower Greensand age which lies above it. The Atherfield clay of the Lower Greensand age takes its name from Atherfield, in the south of the Isle of Wight, and is essentially a clay formation, but contains in many places shelly and calcareous bands. It is sufficiently free from calcareous matter to be used for brick-making at Sandown.

The Gault is a stiff blue, or bluish grey clay, which is commonly slightly calcareous. It comes to the surface in the eastern part of Hampshire near Alton and Selborne, and underlies the greater part of the Crown forest land of Alice Holt, where it forms the heavy soil which is largely

found in that woodland area. In some places it contains calcareous nodules and small lumps of septaria, and also crystals of iron pyrites. It underlies the chalk at Alton, and a specimen of Gault clay from a depth of 360 feet at Alton is in the Hartley Museum. This sample effervesces slightly when treated with a dilute acid. The Gault in eastern Hampshire extends southwards from its outcrop near Alton to Blackmoor, at the west of Woolmer Forest, and it is used for brick-making at Bradshott, Oakwood, and Blackmoor. It also comes to the surface in the southern part of the Isle of Wight, where it has a thickness of 100 feet in Compton Bay, and it is worked for brick-making at Wroxall and at Bierlay, Niton. Where the Gault occurs under such conditions as exist in the Isle of Wight, its slippery nature occasionally causes the beds above it to slide over it, and so it has been the main cause of the landslips which have produced the scenery of the Undercliff. From this circumstance it is locally known in the Isle of Wight as the "blue slipper." These landslips have occurred from remote time to the present century, the most considerable slips at the Undercliff, within the last hundred years having been in 1799, in 1810, and 1818. In the eastern part of Hampshire similar slips of the overlying rocks over the Gault have occurred near Hartley Mauditt and at Hawkley.

The Reading beds in Hampshire consist of alternations of clay and sand. The clays are of many colours, some are sandy loams of a bright hue and some are red, mottled and plastic. These beds in Hampshire are of the typical Reading series. The plastic clay, which is one of the marked clay deposits of the lower Tertiaries, occurs at Alum Bay, where it is 84-ft. thick, and at Whitecliff Bay, where it is 163-ft. thick. It is also found near Portsmouth, where it is represented by the well-known Stamshaw clay, which is a red and mottled plastic clay found there and in other places in the Portsmouth district. Owing to its plasticity Stamshaw clay is much used for puddling purposes in dock engineering works and other similar operations. At Newport, I.W., the plastic clay has been used for making tiles and pottery.

An outlier of the Reading beds *in situ*, is found upon the chalk at East Stratton, near Micheldever. This is the most

important undisturbed outlier of Tertiary clay which exists in the chalk areas of Hampshire. Most of the other beds of clay on the chalk in this county consist of re-constructed material from the Tertiary and other beds, and contain generally fragments of angular flints, which are not found in the undisturbed beds. The Reading beds are, or have been used for brickmaking at the following places:—East Stratton, Whitway, Burghclere, Bishop's Waltham, Rowlands Castle, and near Fordingbridge. The basement bed of the London clay and the top of the Reading beds are, or have been used for bricks at Gosport, Bishop's Waltham, Otterbourn, near Titchfield, and in the north of the county. At Bishop's Waltham the clay from this bed is also used for making coarse pottery.

The London clay, as found in Hampshire, consists of beds of stiff tenacious clay, generally of a dark bluish colour, and separated from each other in some places by layers of hard calcareous rock, which is often fossiliferous, and in other places by bands of septaria. It is often found to contain much iron pyrites and selenite. It is 325-ft. thick at the South Camp, Aldershot, and 327-ft. feet thick at Gosport. [1] Beneath Southampton Common it has been found to be 304-ft. thick. Some of the chief railway cuttings which have been made through London clay in Hampshire are those at Newnham, near Basingstoke, one close to Fareham, on the main line, and another near Fareham, on the Netley line. The beds of the river Itchen, at St. Denys, and of the Hamble river, at Bursledon, rest on this formation. London clay is used for brickmaking at Fordingbridge, which is situated on its upper sandy bed. It is also worked for brickmaking at Ampfield near Romsey, at Crondall, and at Hollington, East Woodhay, at which place the upper sandy passage bed is used. This upper passage bed is also worked for brick and tile making at Fareham. The stiff London clay mixed with sand was used near Fareham for the manufacture of bricks by machinery, during the construction of the Netley railway. It was also dug at the Funtley brick and tile works which are now closed, and it has been used for brickmaking by convicts

[1] Hampshire Well-Sections, by W. Whitaker, F.R.S., Papers and Proceedings of the Hampshire Field Club, No. III, pp. 19-30.

in the dockyard excavations at Portsmouth. It occurs also at Rowlands Castle, where there are extensive brick and tile works. The stiff clay is of too strong an argillaceous nature to be used alone for brickmaking and requires some sand to be mixed with it to supply the requisite proportion of silica. It is used for the manufacture of drain pipes and other forms of coarse pottery at several of the places mentioned. The basement bed of this formation is used for brickmaking at Fareham, Braishfield, Otterbourn, and Crondall, and it has also been worked for the same purpose at Newport, I.W.

The Lower Bagshot beds in Hampshire consist of sand and loam, with occasional layers of pipe clay. The loam, which is generally of a pale yellow or buff colour when newly dug, is largely used as a brick earth, and in some places it is also made into coarse pottery. The pipe clay which is found in these beds at Bournemouth and Alum Bay contains many impressions and remains of leaves of land plants of sub-tropical and warm temperate growth, such as palms, aroids, maples, chestnuts, poplars, &c., as may be seen in the collections in the museum of the Hartley Institution. Pockets and thin layers of pipe clay are also sometimes met with in the loams of this series of beds. At West Wellow, on the border of Wilts and Hants, a deposit of pipe clay 6 feet thick occurs beneath about 10 or 12 feet of dark clay. This pipe clay appears to be almost identical with the Wareham pipe clay which is shipped at Poole for the manufacture of fine pottery. The bed of pipe clay at West Wellow extends over a considerable area, estimated at more than 40 acres, and probably much more extensive. This clay was formerly made into fine pottery, white glazed bricks, and other articles at Wellow. Tobacco pipes were also at one time made from it. It is now shipped at Eling, for the manufacture elsewhere of fine pottery, by Mr. G. W. Sandell, of Southampton. The pipe clay of the Lower Bagshot beds between Alum Bay and Freshwater Gate was formerly dug there for exportation, and the trenches still remain which mark the site of these old workings, which appear to have been abandoned owing to the bed being almost vertical, so that it could only be followed by mining. Pipe clay was also formerly dug near East Afton, I.W. Bricks are made from the loams of the Lower

Bagshot beds at Headley near Kingsclere, Tadley, Ramsdell, Cove, and other places in the north of the county. At Ramsdell near Basingstoke a bed of brown clay, known as Ramsdell clay, nearly 30 feet thick, occurs in the lower part of these Bagshot beds, and this appears to be a local deposit in the lower sands of these beds. At Cove, near Farnborough, the beds of this age appear to have been worked for the manufacture of coarse pottery for more than a century. The loams of the Lower Bagshot beds are used as brick earth at Bittern, on the National Liberal Land Company's estate, also at Old Portswood and other places in the southern part of the county.

The Bracklesham beds and the Barton clay have hitherto been taken as representing in south Hampshire the Middle Bagshot beds of the London basin. The Bracklesham beds consist of alternations of sand, sandy clay or loam, and in places stiff clay, the clay being more common in the upper, and the sandy loams in the lower part of the series. Some of the stiff clay which was met with in the Bracklesham beds in the new dock excavation at Southampton was apparently of as firm a nature as samples of stiff London clay. The Bracklesham clays and loams are largely used for brick-making in Hampshire. All the brick-yards at Chandler's Ford are in this formation. These beds are also used as brick earth all round Southampton. The series of brick-yards at Sholing, Bittern and Netley are all in these beds, as also are those at Coxford and Totton. Bricks were formerly made extensively from the Bracklesham clays and loams at Chilworth, where those used in building the South-Western Hotel, and the Lecture Hall and other parts of the Hartley Institution at Southampton, were made. During the building of Netley Hospital extensive brick-works were formed not far from its site, and the bricks for the building were made from the Bracklesham clays and loams on the spot.

The Barton beds are a deposit peculiar to the Hampshire basin, and consist of grey and bluish green clays, with sands particularly near the base, and bands of septaria. It has a total thickness of about 180 feet [1] in the cliffs between

[1] The Upper Eocene, by J. S. Gardner, H. Keeping, and H. W. Monckton, Q.J.G.S. Vol. xliv, p. 585.

Hordle and Barton. The lower Barton beds in the south of Hampshire are probably the geological equivalents of the upper Bagshot sands in the London basin, and the upper Barton beds are not represented in that basin. The Barton clay proper is a deposit of clay of about 50 feet in thickness at Barton. A cutting was made through the Barton clays in making the new railway from Brockenhurst to Christchurch, when the soft nature of the clay was observed to give it the same tendency to flow and slip, as may be seen at the cliffs. These clays are very fossiliferous, and so contain much carbonate of lime in the form of shelly matter. Where this is considerable, the clay is unsuited for brick-making. Bricks were however formerly made from the Barton clay in the old brick-yard at Gunville, near Newport, I.W., but this section is now overgrown, and in the new brick-yard there Pleistocene brick-earth is used. Septaria from the waste of the cliff near Barton has been collected and taken from the beach there for the manufacture of cement.

The Oligocene series are beds which are only found in England in the Hampshire basin, and these contain many clays. The Headon beds are about 147 feet thick at Headon Hill, and 212 feet at Whitecliff Bay. They consist of the Upper, Middle, and Lower series, the Upper and Lower being of fresh water or fluviatile origin, and the Middle beds of marine origin. These beds contain deposits of clay varying in thickness from 2 to 10 feet, and are separated by sands, layers of limestone, and fossiliferous bands. In the Isle of Wight the Headon beds are well developed at and near Headon Hill, and in the south-west of Hampshire they lie near the surface over a considerable area. The fine white sand about 7 feet thick, which lies at the bottom of the Headon beds at Alum Bay, was formerly worked extensively as a sand for making glass. In the south-west of Hampshire the Lower Headon marls have been much dug for marling land, and have had a marked effect in improving some of the sandy soils of that part of the county. The Headon beds were cut through at Sway in making the new railway from Brockenhurst to Christchurch. The sandy clay forms a compact hard mass when dry, as may be seen from specimens in the Hartley Museum, but it absorbs water, and thus

produced the mud streams down the slopes of the cuttings on this railway during its construction. This quality of the clay also caused the flow of the railway spoil, used in making the great embankment to the west of Sway. The clay from the Headon beds is largely used for making bricks at Beaulieu, Roydon, Exbury, Victoria brick and tile yard Brockenhurst, Pitt's Deep, and Lymington. At Victoria brickyard, Brockenhurst, it is largely made into coarse pottery, tiles, and drain pipes as well as bricks. At Freshwater the Headon clay is also made into pottery, and at the most important of the pottery works there large quantities of roofing tiles, finials, garden edging tiles, flower pots, and ornamental flower vases are manufactured from it.

The Osborne series consists of passage beds between the Headon and Bembridge beds and are from 100 feet thick. They contain several beds of clay and marl of various colours —red, mottled, blue, and green—and are exposed at Whitecliff Bay, Sea View, King's Quay, and other parts of the Isle of Wight. On the east side of Newtown River these red and green clays occur in the cliff and also in a brickyard there. At King's Quay near Ryde there are about 40 feet of bright red and mottled clays, but much obscured by slips. From the grey shaly band beneath this clay Mr. G. W. Colenutt discovered a few years ago a new fossil fish, the Clupea vectensis. The only locality in which these clays appear to have been used for brickmaking is near Newtown.

The Bembridge beds consist of marls in the upper part and limestone in the lower part of the series, separated by a bed which contains the fossil oyster, Ostrea vectensis. These marls attain a maximum thickness of 90 to 120 feet in the eastern part of the Isle of Wight, thinning out to about 70 feet towards their western limit. They extend from Hamstead round the northern part of the island to Whitecliff Bay. These marls comprise a series of variegated yellow and brown clays, lead coloured clays, variegated red and green marls and other thinner beds of clay. They are extensively worked for brickmaking near Ryde, in the brickyards at Ashey Road, Partlands path, Smallbrook, Oakfields, Stroudwood, and Haylands. Ryde may be said to be largely

built of brick made from these clays, which are also used for brickmaking at Wootton and Newtown.

The Hamstead beds lie upon the Bembridge marls, and consist of freshwater and estuarine marls and clays of various characters and colours, and marked by characteristic fossils. The series attains a total thickness of 250 feet, and these beds have lately been shown by a series of trial borings made under the direction of Mr. Clement Reid and Mr. A. Strahan, of the Geological Survey, to extend over a much larger area in the Isle of Wight than was formerly supposed, and to occupy the greater part of the Tertiary basin of the island from Yarmouth to Brading.[1] The Hamstead clay was formerly used for brickmaking at Lower Hamstead, but this brick-yard is now abandoned. It is used for tiles at Skinner's Grove tile works, and for bricks at Werror, at Wootton brick-yard, at Ashlake near Wootton, Staplers' brick-yard, south of Newport, and for bricks and tiles at Alverstone brick and tile-works.

Clay from the Oligocene beds is used with chalk in the manufacture of hydraulic cement at the West Medina Works, near Newport, and at Brading, cement is also made from the Bembridge limestone and marls.

Drift brick-earth, which is the loam from which bricks are made in a large number of places in Hampshire and the Isle of Wight, lies upon the surface of the chalk and Tertiary beds, associated with gravel at different levels in many parts of the county. In the island it may be seen in several places underlying the high level or plateau gravel, or intermingled and closely associated with it. Although its relative age has not been quite proved, some of the drift was perhaps deposited during the Glacial age, by the destruction of Tertiary and older beds, which existed in some instances at a considerable distance from where the debris has been redeposited, while in other instances the Tertiary beds destroyed could not have been far away, for in some sections in Hampshire the reconstructed beds do not differ greatly, except in containing fragments of flint, from the usual

[1] See Memoirs of the Geological Survey: The Geology of the Isle of Wight, by H. W. Bristow, F.R.S.; 2nd Edition, revised and enlarged by Clement Reid, F.L.S., F.G.S., and Aubrey Strahan, M.A., F.G.S., 1889.

character of Tertiary beds. The low-lying drift at Gosport, Portsmouth, and near Southampton is river drift of a later date. Drift brick-earth is one of the loams most largely used for making bricks in this county. In the Isle of Wight it is, or has been, worked at Downend, Little Lynn Common, Wootton, Parkhurst Forest, Place brick-yard near Northwood, West Cowes, Binstead, and other places. At Apse Heath, near Newport, the brick-earth is found lying upon the high level gravel. Drift brick-earth is, and has been, extensively worked for brick making on both sides of Portsmouth harbour, where it lies about four feet thick, and there are a number of brick-yards where it is now being used on the west side of Portsmouth, and north-east side of Gosport and Alverstoke. It has also been used for brick making at Northam, Hurstbourn Priors, Overton, Freefolk, Ropley, Rotherfield near Alton, Preston Candover, and other places. Drift brick-earth is the only clay which has been available for brick making over a great part of Hampshire, and it has been shown to exist in many parts of the county where disused brick-yards, now overgrown, may be seen. A disused yard of this kind exists at Ropley, where bricks were made at Swelling Hill for more than a century, and where part of the site of the old works is now a pond.

The great mud banks which exist in the estuaries of the Hampshire rivers may be regarded as clay beds in the process of formation. Mud from the Hamble river has been used for the manufacture of cement at the West Medina Works, near Newport. Deposits of clay alluvium formed by the rivers also exist in places along the courses of most of the streams.

On the Downs of Hampshire there is yet another kind of clay, which in many places lies on the chalk, and which is known to geologists as Clay with Flints. It is red in colour, and full of flints of considerable size, and is the origin of the red soils which exist at Medstead, Froxfield, Privett, and many other places. The origin of this clay is different from any other in this county, and is due to the gradual removal of the chalk in solution. Chalk contains from 94 to 96 per cent. of carbonate of lime mixed with from 2 to 6 per cent. of earthy matters, and it also contains flints imbedded in it. The rain as it falls sinks into the chalk free from carbonate

of lime, but as it issues from the chalk springs it is as highly charged with it as it can be. The small proportion of clay is insoluble, and so, as the surface chalk has gradually been dissolved, the flints and the clayey matter have been left. In the course of ages this accumulation has in some places formed a bed of clay with flints many feet thick, and such beds are silent evidences of the great extent to which the chalk has been insensibly dissolved away.

One of the most valuable silicates of alumina which has been found in Hampshire is Fuller's earth. It differs somewhat from ordinary clay, but its composition is such as to bring it within the scope of a paper on clays. The history of the working of Fuller's earth in Hampshire is curious. Dr. Kidd, who was Professor of Chemistry at Oxford, in his book entitled "Outlines of Mineralogy," published in 1809, vol. I, p. 176, says:—"A great proportion of the Fuller's earth of commerce comes from Hampshire," and he gives the following analysis of Hampshire Fuller's earth by Bergman:—

Silica	51·8
Alumina	23·0
Magnesia	7·0
Carbonate of Lime	3·3
Oxide of Iron	3·7
Water and other volatile substances ..	5·5
	94·3

This analysis, made about a century ago, must be considered according to the standard of chemical practice of that time.

Another writer on Mineralogy, James Sowerby, F.L.S., who published an elaborate work also in 1809, says in vol. III, p. 59 of his British Mineralogy, "Hampshire and Bedfordshire are the only two places mentioned by most authors where Fuller's earth is found," and he quotes Dr. Thomson, who says "I cannot find that any has been discovered in Hampshire, and indeed the analysis usually quoted from Bergman does not appear to me to indicate Fuller's earth." In this doubtful condition the question of Hampshire Fuller's earth appears to have remained, and as far as I know nothing has been written about it from 1809 to the present time. By the aid of the Rev. G. N. Godwin and Mr. J. M. Peake, of Liphook, I have been able to satisfy myself of the accuracy of Dr. Kidd's statement. At my suggestion Mr. Godwin

kindly made enquiries in the eastern part of Hampshire, where the Lower Greensand comes to the surface, and Mr. J. M. Peake, a member of this club, removed all doubt about the matter, by presenting to the Hartley Museum a sample of Fuller's earth he obtained some time ago from a depth of about 200 feet below Greyshott Down, while a well was being made there. About a mile from this down there is a locality near Headley, still known as Fuller's Bottom, marked on the six-inch Ordnance map. The height of Greyshott Down above Ordnance Datum is about 570 feet, and Fuller's Bottom lies between the 300 and 400 feet contours. It appears therefore that Fuller's earth was worked near Headley, probably in the first instance for the old local cloth trade formerly carried on at Alton and other parts of the county, and that the working ceased about the time when the cloth trade declined early in the present century.

The economic use of the clay used in the making of pottery, drain pipes, tiles, and bricks depends largely on its placticity, a quality which appears to arise from the diffused water in the material, and which probably causes the minute particles of the clay to slip over each other, as if they acted on each other like moist rollers.

The chemical changes which occur in the burning of clay are varied and interesting. The denser clays are difficult to burn completely, and where these contain carbonaceous matter the interior of the bricks is commonly of a different colour from the exterior burnt portion. When such bricks are afterwards subjected to the action of rain and the sun, they give out from the interior soluble compounds which show themselves on the surface.

The hygroscopic water in all clays is more or less driven off at a temperature of 212° F., and at a red heat the clay loses most of its combined water. At a little below white heat it bakes into pottery or brick. The colour which bricks assume after burning depends mainly on three conditions viz., 1—The proportion of iron in the clay ; 2—The proportion of air admitted to the combustion of the fuel in the kiln, for on this depends whether the bricks are finally burnt in an oxidising or a de-oxidising flame ; 3—Whether or not, and in what proportions, steam or water is present in the

brick, or is brought in a state of vapour into contact with it during the time the brick is at an elevated temperature.

If the clay is not freed from small lumps of calcareous matter, such as may exist in marls, the effect of the process of burning on these lumps is to reduce the carbonate of lime to quicklime, as expressed in the formula Ca CO_3 (calcareous matter) = Ca O (quicklime) & CO_2 (carbon dioxide), which latter passes off as a gas, leaving quicklime. When the brick is subsequently exposed to rain, this Ca O absorbs water and becomes slaked lime, thus—Ca O + H_2O = Ca H_2O_2, and as this swells it splits the brick.

If any iron pyrites, Fe S_2, remains in the clay, this compound is only partially decomposed in the process of burning, some of the sulphur being removed, while Fe S, sulphide of iron remains. When such bricks are afterwards exposed to air and moisture, oxidation takes place, and sulphate of iron is frequently produced, and as this forms crystals in the mass it also splits the brick. If selenite, or gypsum, Ca SO_4 + $2H_2O$, remains, and the clay contains also carbonaceous matter, the chemical action is somewhat similar, for the burning process first reduces this sulphate to sulphide of calcium, and then by subsequent absorption of water and oxygen crystals of selenite are again formed, which also destroy the brick. In the autumn of 1889 a Hampshire brickmaker, who occasionally used clay not free from selenite, and whose bricks in such cases crumbled, came to the Hartley Institution to ascertain its cause. From these illustrations the importance of freeing clay from iron pyrites and selenite will be apparent.

The commonest of all the chemical changes that occurs in the burning of clay is the change of colour in the brick itself from the natural colour of the clay to a red, which depends on the amount of protoxide of iron, Fe O, converted into peroxide, Fe_2 O_3. If the proportion of iron in the clay is very small the clay naturally assumes a pale colour after burning, like the Headon clay, which produces the light coloured bricks at Exbury, Pitt's Deep, and some places in the Isle of Wight. Most of the Hampshire clays and other brick earths, however, contain enough iron to form sufficient peroxide to give a red colour to the whole mass of the brick, and in some

cases, like that from the basement bed of the Lower Bagshot Beds at Fareham Hill, to give a very bright red colour.

The economic use of clay in Hampshire is as old as its history. Its chief economic use, that of brickmaking, is as old as the time of the Romans, by whom that art was introduced into England. Burnt clay of some sort has been found on every Roman inhabited site that has been discovered in this county. The Romans used it for making large tile-shaped bricks, as great as eighteen inches in length, one or more of which may be seen in the mediæval church of South Hayling, for the smaller bricks, like modern paving tiles, which have been found on the sites of our Roman villas, for the ridged tiles, something in shape like modern ridge tiles, which have been found abundantly at Fairthorn, near Botley, and on other Roman sites, and for the very small brick tesseræ of several colours for some of their pavements, such as that discovered at Bramdean. The tiles found at Fairthorn were evidently made from a stiff clay, for the material in many of these in a broken state is seen to have a flaky texture. It is not improbable that the London clay which occurs not far from this site was used for making such tiles. Some of the Roman bricks when broken may be observed to be of a blue colour inside, as if made from a blue clay and imperfectly burnt. I observed that this was the case in regard to the pieces of Roman brick which are still being ploughed up on the site of the Roman villa near Crondall. Small fragments of brick have also been found as an ingredient in Roman mortar in Hampshire. After Roman time, the art of brickmaking appears to have died out in England until some time in the middle ages, although tiles for arches and floors appear to have been made. The Roman form of these tiles was apparently used in arches, as may be seen in Britford Church, near Salisbury. The revival of brickmaking was probably due to the introduction of brickmakers from Holland, where the art was carried on continuously, and arrived at a high state of perfection. Most of the early brick buildings since the revival are in the eastern counties, but probably some of these were built of imported Dutch bricks. The remains of 15th century brickwork which still exist in the gateway at Basing probably mark the time

when the art of brickmaking was revived in Hampshire. After this time it appears to have spread in the north and south of the county, and in 1575 the town brickmaker with his kiln was a recognised institution on Southampton Common. The remains of the very fine brickwork which exist at Place House, Titchfield, a building now in ruins, but known to be of the time of Henry VIII, make it very probable that brickmaking was carried on near Fareham at that date. The fine Jacobean house of Bramshill begun by Lord Zouch, early in the 17th century, is a good example of the use of bricks in the north of the county. The bricks used for building the king's palace at Winchester in the time of Charles II are traditionally said to have been made from clay dug at Otterbourn. Avington House, another building erected by Charles II, appears to have been built of bricks made from old clay workings in the park. Some other important buildings in Hampshire appear to have been erected by utilizing the clay for brickmaking close to their sites, such as Lainston House, near Winchester, *temp.* Charles II, and Preston Candover House. Old clay pits also exist above the church in this last parish, where the bricks for the North and South Halls, Preston Candover, were made.

Tiles were made at Odiham in the 14th century, as appears by the accounts of Sir Bernard Brocas of the Vyne, who paid 40s. for 12,000 tiles in 1357, and also 6s. for fetching the tiles from Odiham.

In 1623 the town brickmaker at Southampton sold his bricks at 9s. 6d. per thousand, and a few years later at 10s. In 1704 it became necessary to remind him that the assize of bricks according to ancient custom was 10 inches long by $4\frac{3}{4}$ inches broad and $2\frac{1}{2}$ inches thick. This assize of bricks was first definitely fixed by an Order in Council of Charles I, in 1625. Previously, bricks were made of any size, and usually smaller. Some of the bricks in the Water Gate and wall still remaining at Southampton of Old Bugle Hall, built about the end of the 16th century, measure 9 in. by 4 in. and $2\frac{1}{4}$ in., while others are $7\frac{1}{2}$ in. by $4\frac{1}{2}$ in. by $2\frac{1}{4}$ in. The old size, as regulated by Charles I, is still the common size for English bricks, and it was adopted by Parliament in 1784 as the limit of size subject to the ordinary tax. The tax on bricks lasted

from 1784 to 1850, when it was repealed. In 1835 it was as much as 5s. 10d. per thousand bricks of the ordinary size, and if made of a larger size a higher duty was levied. A large number of brick buildings exist in Hampshire which were built under this heavy tax.

The use of Hampshire clay in the manufacture of pottery is older than its use in the manufacture of bricks, for the oldest pottery discovered in the county is a coarse and gritty ware found in barrows and other Celtic burial places. Specimens of this pottery may be seen in the museum of the Hartley Institution, where one of the largest urns found in the county, a burial urn from Dummer, is exhibited. Its probable date is about 200 B.C., and it appears to have been imperfectly baked and perhaps partly sun-dried.

In Roman time the manufacture of pottery in Hampshire was much improved, and a number of kilns of this date have been discovered in the New Forest at Crock Hill, Panshard Hill, Sloden, Anderwood and Oakley Enclosures, Island Thorn, and other places. Dr. Birch in his book on Ancient Pottery describes that made in the New Forest as a stoneware much resembling the Staffordshire, and supposed to have been made from clays of a similar composition, a heavier kind of pottery than commonly found, many vases being of a dark colour, or of a greyish colour, glazed like Caistor ware, and more like stoneware than any other Roman pottery. A collection of this pottery is exhibited in the Hartley Museum. The clay used by the Romano-British potters in the New Forest was probably derived from some bed of the Bagshot and Bracklesham series.

The remains of a potter's kiln of this date were also found in 1889 at Hall Court wood, near Shidfield, and a very fine specimen of a Romano-British vase previously dug up at Shidfield is shown in the same museum. The clay used near Shidfield was probably of the same age as in the New Forest. Romano-British potteries have also been discovered at Rock, near Brixton, in the Isle of Wight, specimens from which are exhibited in Newport Museum, also at Barnes, I.W. A pottery of Roman date also appears to have existed at Rowlands Castle, where the name potter's field still remains, and where remains of buildings (probably kilns)

plentifully strewn with charcoal, many vessels, and innumerable fragments of pottery have been found. Specimens of these vessels from the collection of the late Rev. E. Kell, F.S.A., are shown in the Hartley Museum.

The manufacture of clay into pottery in Hampshire can be traced during the middle ages better than the making of bricks or tiles. Specimens of pottery have been found in the county which have been described as being of Saxon and subsequent ages.

The supply of fuel for the kilns must always have been an important consideration in determining the site of any pottery or brickyard in Hampshire, previously to the introduction of railways. In former time the burning of clay depended chiefly on a sufficient supply of wood and charcoal, although peat was formerly used to some extent in this county for this purpose. This was the case at Cove about the beginning of this century, where a coarse kind of pottery was there burned with peat. It is probable that charcoal burning was formerly an industry preparatory to brick burning in Hampshire, as well as at an earlier period to iron smelting. Charcoal has more than twice the heat producing power than an equal weight of dry wood. The clay digging and brickmaking at Ropley and other places in the middle of the county appear to have ceased when wood became too dear to be used in firing the kilns towards the end of the 18th century. Four tons of coal are required to burn 8,000 bricks. Such places as Fareham and Lymington, which could get supplies of coal much cheaper than inland places, became at that time important seats of the brickmaking industry in the south of Hampshire. There are kilns still in use at Fareham which have been used for brickburning for more than a century, and in the yards at Fareham some of the best bricks in England have been made, those used for building St. Thomas's Hospital, London, having been made here. Another example of the use of Hampshire bricks in London is that of the Albert Hall, the outside bricks of which also came from this county.

The contraction of clay in burning is partly due to the loss of the water of combination, also to the loss of carbonic acid from the carbonates when they are present, to the ignition of

any carbonaceous matter, and to the drawing together of the particles in the formation of vitreous silicates. The amount of contraction depends on the clay. Pipe-clay used in pottery manufacture contracts from 11 to 13 per cent. In clamp brick-burning, where the clay is mixed with fine cinders and coke dust, the contraction and loss of weight must be very considerable. The best bricks lose about 14 per cent. of their weight in burning.

Hampshire possesses certain climatic advantages in tile making, and also to a less extent in brickmaking. For tiles, the clay is washed and afterwards left to consolidate. This washing is usually done in the autumn. The materials so used will consolidate in Hampshire where the early spring sun is stronger, a month or two earlier than in the northern counties, and so a longer season may be had for making and burning. The digging of clay and burning of bricks do not permanently injure the scenery of any locality, for many instances exist in Hampshire where nature, with a little aid, has again changed the site of old workings into level pastures or pleasant woods, and in some cases into picturesque dells. The traces of the operations of the town brickmaker on Southampton Common still exist in hillocks and hollows near its southern part, which mark the sites of the old diggings.

Formerly clay was much used in Hampshire for building purposes, and is still dug in some hamlets fringing the New Forest for the construction of dob cottages, the so-called "mud" houses, which are stated by some of those who live in them to be much more comfortable than the newer-fashioned brick cottages. The digging of clay for this purpose was an ancient common right, and where clay did not exist the old Hampshire peasantry used chalk reduced to a mud or dob, a practice which is also not yet extinct, as may be seen in the cottages at Mud Town, close to Andover. In ancient time, the mud stickers or clay plasterers were important artificers, described in old records as "luti appositores," who filled up the framework of timber houses with mud, clay, or dob. In Shakespeare's time this practice must still have been common for he draws an illustration from it in the well-known lines:—

> Imperial Cæsar dead and turned to clay
> Might stop a hole to keep the wind away.

Clay was also in former centuries used by brewers to make bungs for their barrels, with the aid perhaps of a piece of linen or leather. In 1567 the brewers of Southampton were ordered to cease digging clay in the saltmarsh, because it was public or town land, and were ordered to fill up the holes they had made. They used the clay to make bungs in this way, an ancient custom which also supplied Shakespeare with an illustration in Hamlet:—

> To what base uses we may return, Horatio!
> Why may not imagination trace
> The noble dust of Alexander,
> Till he find it stopping a bung hole?

In conclusion, I beg to tender my best thanks to those gentlemen who have assisted in the preparation of this paper, by kindly replying to the inquiries I have addressed to them, and also to Mr. S. J. Williams and Mr. H. B. Wren, students of the Hartley Institution, who have drawn the illustrations from specimens in the museum.