

of low and medium refractive index, which is very characteristic of silicification. Carbonates are almost wholly absent, and neither apatite nor pyrite have been detected. The pyroxenes and also the opaque minerals are largely replaced by brown limonitic material, but cores of the fresh minerals still remain, together with chloritic borders around the pyroxenes and cream-grey streaks of leucoxene traversing the opaque minerals. The interstitial matter, as before, remains unaltered.

Specimen No. 8 (surface of the dyke, near margin—Exposure II) exhibits the effect of weathering on material of the same type as No. 7. Calcite and dolomite have both been leached out almost completely, while limonite has been leached out in certain parts and concentrated in well-marked bands parallel to the exposed surface.

It is clear that the two processes of alteration are of the same character as those involved in the infilling of the amygdales found in the Whin Sill and the Hett dyke. They represent a late-magmatic (paulopost) and probably hydrothermal stage of the waning magmatic activities, and have nothing to do with weathering, as commonly supposed, although at the same time the material in question is deeply weathered.

The alteration to the margins is evidently a consequence of the contraction of the dyke. The residual liquors, wherever situated, would tend to become concentrated and to move upwards along the channels offering least resistance; that is to say, along the contraction fissures which developed along the margins.

EXPLANATION OF PLATE VIII.

Magnification = 22·5 diameters.

FIG.

- 1.—Typical field of the dolerite of the Wackerfield dyke. Specimen No. 6 from Exposure II. See p. 446 for description.
- 2.—Typical field of the dolerite of the Little Whin Sill, Stanhope. The minerals are identical with those of the Wackerfield dyke, except that the felspars are slightly turbid. In texture the only difference is that here the felspar laths are less uniformly dispersed.
- 3.—Corroded phenocryst of bytownite in the Wackerfield dyke. Specimen No. 1 from Exposure I. See p. 447 for description.

The Foraminifera of the Hartwell Clay and Subjacent Beds.

By E. NEAVERSON, M.Sc., F.G.S.

(PLATE IX.)

INTRODUCTION.

DURING a temporary cessation of work on the Ammonites of the Hartwell Clay, the writer was asked to identify a series of Foraminifera found by Mr. E. Hollis of the Bucks. County Museum, Aylesbury, in washing a sample of clay from Hartwell. Other samples were collected and examined from all the available

1



2



3



PHOTOMICROGRAPHS.

G. S. Sweeting, photo.

Magnification = 22.5 diameters.

exposures of Hartwell Clay, and the results are given below. A series of the Foraminifera has been deposited in the Aylesbury Museum.

Previously the Foraminifera of this interesting deposit had received scant attention. A short list is given in the Geol. Surv. Memoir by H. B. Woodward (*Middle and Upper Oolites*, 1895, p. 227), but on account of the terminology employed, some revision appears necessary. In 1897 F. Chapman recorded fifteen species from Hartwell (*Proc. Geol. Assoc.*, vol. xv, p. 97), remarking that they "present a facies comparable with that of the Neocomian (*sic*) and Gault". No other lists appear to have been published, and the forms have not yet been described.

Foraminifera from beds of approximately the same age have been described by :—

Chapman (Tithonian Foram. Stramberg; *Linn. Soc. Journ. Zool.*, vol. xxviii, 1900, p. 28);

Perner (Ueber Foram. Tithon, Stramberg: *Bull. Acad. Bohême*, 1898, p. 1); and

Haeusler (Die Astrorhiziden und Lituoliden des Bimammatus Zone; *N. Jahrb.*, 1883, vol. i, p. 55).

Other works consulted are indicated in the text, but the synonymy is reduced to a minimum, only a few of the more important references being given.

The writer is indebted to Mr. E. Hollis for help in the collection and preparation of material, to Mr. S. S. Buckman, Mr. C. P. Chatwin, and Dr. A. Morley Davies for kindly criticism and suggestions, to Professor P. G. H. Boswell for reading the manuscript; also to Dr. F. L. Kitchin for an opportunity recently of examining Chapman's specimens of Gault Foraminifera, now in the Museum of Practical Geology. For this assistance the writer wishes to express his gratitude.

NOTES ON STRATIGRAPHY OF THE BEDS.

A combination of circumstances renders the determination of the zonal sequence in the Hartwell Clay and underlying beds a matter of some difficulty. The number of exposures is limited, some of the brickfields have not been worked for a considerable time, the workings are shallow, and the ammonites usually in a fragmentary condition. The identification of the ammonites also is not yet complete; only a provisional indication of the horizons is therefore given.

The typical Hartwell Clay is exposed at Hartwell, Aylesbury, and Bierton, and contains ammonites usually identified as *Perisphinctes pallasianus* (d'Orb.). This clay is overlain by the Portland Pebble-bed, which has weathered down to a sandy consistency. The clay at Whitechurch (5 miles north of Aylesbury) is probably on the same horizon as that at Hartwell, because, though it differs from the latter in the presence of selenite, fragments of ammonites occur

which seem to be the typical Hartwell forms. The deposit at Long Crendon, near Thame, represents a lower horizon than that usually worked at Hartwell. It contains some of the characteristic Hartwell Clay fossils, but the ammonites present different characters, being large inflated Perisphinctids with fairly coarse ribs. Similar ammonites were found at Hartwell years ago when the workings were deeper. At Wheatley and Shotover Hill the clays contain nodules enclosing ammonites of a still different type—fine-ribbed Perisphinctids involute in youth becoming evolute later; coarse-ribbed species, however, occur at both localities. These clays have until recently been referred to the Kimmeridge Clay, but an examination of the residues has disclosed the presence of glauconite, a mineral which appears to be absent from the typical Kimmeridge Clay of the district.¹ This, and the occurrence of typical Hartwell Clay belemnites in the clay at Wheatley appear to indicate that these beds should be classified with the Hartwell Clay as Bononian.² The following is a summary of the beds under discussion:—

4. Typical Hartwell Clay of Hartwell, Aylesbury, Berton, and Whitchurch.

3. Hartwell Clay of Long Crendon—a lower horizon than that usually worked at Hartwell.

2. Highest "Kimmeridge Clay" of Wheatley and Shotover Hill—a sandy clay.

1. Blue Clay of Wheatley and Shotover Hill with nodule band as basement bed.

GENERAL CHARACTERS OF THE CLAYS AND OF THE MICROZOA.

The following notes give the general characters of the microzoa; and also of the sediments from the various localities, pending a complete petrographical description.

Hartwell.—Abundant quartz and glauconite grains occur, many of the latter being casts of Foraminifera; marcasite is common, sometimes filling tests of Foraminifera, more often as spherical concretions. Ostracods³ are common, and Foraminifera abundant; hooklets from the tentacles of a belemnoid, remains of echinoderms,⁴ fish-teeth, otoliths, and scales are also found.

Aylesbury and Berton.—Quartz and glauconite grains are abundant as at Hartwell; spherical concretions of marcasite also are common. Foraminifera and ostracods are common, but the number of species is relatively small.

Whitchurch.—Selenite is the commonest mineral in the residues, occurring often in well-formed crystals. Quartz and glauconite are common, whilst marcasite frequently occurs. Foraminifera

¹ See also A. M. Davies, *Q.J.G.S.*, vol. lxxviii, 1907, p. 36.

² See A. M. Davies, *Introd. to Palæontology*, 1920, p. 385.

³ Chapman, *Proc. Geol. Assoc.*, vol. xv, 1897, p. 97 (list of species).

⁴ Bather, *Geol. Mag.*, 1916, p. 302.

are relatively rare, probably owing to the abundance of selenite. Ossicles of *Isocrinus* were found here.

Long Crendon.—Abundant quartz and frequent grains of glauconite, but the latter is not so common here as at localities nearer Aylesbury. Ostracods rare, Foraminifera common.

Wheatley and Shotover Hill.—Highest "Kimmeridge Clay"—Quartz grains and small aggregates of marcasite are abundant; glauconite grains occur, but are not common. Foraminifera abundant, ostracods common. Blue clay above nodule band. Quartz grains and small concretions of marcasite are the commonest minerals, whilst glauconite is rare. Foraminifera and ostracods are common.

Speaking generally, the colour of the glauconite of the Hartwell Clay is a rich green, but many grains present a dull yellowish appearance. This yellow colour appears to be due to decomposition, as on boiling with dilute hydrochloric acid the grains become green. The size of the grains is variable, some glauconite being present in each grade-size separated by elutriation, but they do not occur in grades greater than 0.5 mm. diameter, which consist entirely of shell fragments. Exact determinations of the specific gravity of the glauconite have not yet been made, but it is certainly variable. While most of the glauconite has a specific gravity less than 2.8, many grains come down with the heavy detrital minerals separated in bromoform. The grains are usually rounded, but some are sub-angular; many are obviously casts of Foraminifera and occasionally broken specimens of *Cristellaria* have been seen to contain an infilling of glauconite.

This indicates that, although some of the glauconite may be detrital, much is indigenous to the deposit. Similar observations have been made on the glauconite in the Gault of Ford, near Aylesbury, mentioned on a later page. In some samples of the Hartwell Clay, marcasite is most abundant, glauconite being rare. The marcasite occurs as spherical concretions or irregular grains, and often as an infilling in tests of Foraminifera. It would seem that in these cases marcasite has been formed instead of glauconite. It is hoped that more detailed work will show whether these two minerals are connected in any way; for the present no generalization can be made.

THE FORAMINIFERA.

In the following notes the occurrence of the Foraminifera at the localities mentioned is indicated by letters, thus:—

v.r. = very rare.	. 1 to 2 specimens	} in 1 lb. of clay.
r. = rare .	. 3 to 5 "	
f. = frequent .	. 6 to 10 "	
c. = common .	. 10 to 20 "	
a. = abundant	. above 20 "	

Family LITUOLIDÆ.

SUBFAMILY LITUOLINÆ.

REOPHAX, MONTFORT, 1808.

Reophax scorpiurus, Montfort.

Reophax scorpiurus Montfort, 1808 ; *Conchyl. Système*, vol. i, p. 330, 83^e genre.
Reophax helvetica Hæusler, 1883 ; *Q.J.G.S.*, vol. xxxix, p. 27, pl. ii, figs. 8-10.
Reophax scorpiurus Sherlock, 1914 ; *Geol. Mag.*, p. 221, pl. xviii, fig. 1.

A few specimens appear to belong to this species, but they are small and ill-developed. *R. scorpiurus* has been recorded from the Swiss Jurassic (Hæusler), the Oolite of Fontoy, Moselle (Terquem), the Gault of Folkestone (Chapman), and the Speeton Clay of Yorkshire (Sherlock). At present it has a world-wide distribution at depths varying from 3 to 3,960 fathoms (Brady).

Localities : Hartwell (v.r.) ; Whitchurch (v.r.) ; Wheatley, bed 2 (r.) ; Shotover Hill, bed 1 (v.r.).

HAPLOPHRAGMIUM Reuss, 1860.

Haplophragmium acutidorsatum Hantken.

Haplophragmium acutidorsatum Hantken, 1868 ; *Magyar földt. tarsulat*, B. 4, S. 82, Taf. i, fig. 1.

H. acutidorsatum Chapman, 1892 ; *Journ. Roy. Micr. Soc.*, p. 4, pl. v, fig. 11.

This is probably the form recorded by H. B. Woodward from the Lower Portland of Bucks as *Lituola navtiloidea* Lam.¹ It resembles *H. emaciatum* Brady, which, however, is an evolute form, whilst *H. acutidorsatum* is involute. The latter is known from the Tertiaries of Hungary (Hantken) and the Gault of Folkestone (Chapman). *H. emaciatum* is a shallow-water form occurring in the West Indies (Brady).

Localities : Hartwell (c.) ; Long Crendon (v.r.) ; Wheatley, bed 2 (v.r.).

Haplophragmium æquale (Roemer).

Spirulina æqualis Roemer, 1840 ; *Verst. norddeusch. Kreidegeb.*, p. 98, pl. xv, fig. 27.

Haplophragmium æquale Reuss, 1862 ; *Sitz. k. Akad. Wiss. Wien*, xlv, p. 29, pl. i, figs. 1-7.

H. æquale Chapman, 1892 ; *Journ. Roy. Micr. Soc.*, p. 5, pl. vi, figs. 1-3.

One specimen is referred to this species which was first recorded by Roemer from the Chalk of North Germany. It has since been found in the Upper Hils and Speeton Clay of Germany (Reuss) and the Gault of Folkestone (Chapman).

Locality : Long Crendon (v.r.).

Subfamily TROCHAMMININÆ.

THURAMMINA Brady, 1879.

Thurammina albicans Brady. (Pl. IX, Fig. 11.)

Thurammina albicans Brady, 1879 ; *Q.J. Micr. Soc.*, vol. xix, n.s., p. 27.

T. albicans Brady, 1884 ; *Chall. Rep.*, vol. ix, p. 323, pl. xxxvii, figs. 2-7.

T. albicans Chapman, 1892 ; *Journ. Roy. Micr. Soc.*, p. 7, pl. vi, fig. 9.

¹ *Mem. Geol. Surv.*, M. and U. Oolite, 1895, appendix, p. 400.

A few specimens from Hartwell are referred to this species, which is recorded from Upper Jurassic strata of Switzerland (Haeusler) and the Gault of Folkestone (Chapman). At the present day it lives off the coast of South America, best developed at a depth of 1,900 fathoms (Brady).

Locality : Hartwell (r.).

Thurammia papillata Brady.

Thurammia papillata Brady, 1879; *Q.J. Micr. Soc.*, vol. xix, n.s., p. 26, pl. v, figs. 4-8.

T. papillata, Haeusler, 1883; *Ann. Mag. Nat. Hist.*, ser. v, vol. xi, p. 262, pl. viii.

T. papillata Brady, 1884; *Chall. Rep.*, vol. ix, p. 321, pl. xxxvi, figs. 7-18.

Several specimens from the Hartwell Clay seem to belong to this species rather than to *T. albicans*. Their colour is brown, their shape variable, and the surface bears irregularly disposed perforate papillæ: often two or more chambers are mutually adherent. *T. papillata* is recorded from the Upper Jurassic of Switzerland (Haeusler), and at the present day is a deep-water form with a world-wide distribution (Brady).

Localities : Hartwell (f.); Long Crendon (v.r.); Shotover Hill, bed 1 (v.r.).

Family TEXTULARIIDÆ.

Subfamily TEXTULARIINÆ.

TRITAXIA Reuss, 1860.

Tritaxia? variabilis (Brady).

Verneuilina variabilis Brady, 1884; *Chall. Rep.*, vol. ix, p. 385, pl. xlvii, figs. 21-24.

Chapman recorded this form from Hartwell in 1897, but the present writer has failed to obtain it.

Family LAGENIDÆ.

Subfamily LAGENINÆ.

LAGENA Walker & Boys, 1784.

Lagena hispida Reuss.

Lagena hispida Reuss, 1858; *Zeitschr. d. deutsch. geol. Ges.*, vol. x, p. 434.

L. hispida Reuss, 1862; *Sitz. k. Akad. Wiss. Wien*, xli, p. 335, pl. vi, figs. 77-79.

L. hispida Brady, 1884; *Chall. Rep.*, vol. ix, p. 459, pl. lvii, figs. 1-4, pl. lix, figs. 2, 5.

This species was originally described from the Oligocene Septaria-clay of Pietzpuhl (Reuss), and Chapman records it from the Gault of Folkestone. Ranging from Lias to Recent, it lives at depths varying from 129 to 1,900 fathoms in many parts of the existing seas (Brady).

Localities : Hartwell (f.); Birtton (v.r.).

Lagena lævis (Montague).

Vermiculum læve Montague, 1803; *Test. Brit.*, p. 524.

Lagena lævis Brady, 1884; *Chall. Rep.*, vol. ix, p. 455, pl. lvi, figs. 7-14, 30.

L. lævis Sherlock, 1914; *Geol. Mag.*, p. 256, pl. xviii, fig. 14.

Lagena clavata (d'Orb.).

Oolina clavata d'Orbigny, 1846; *For. Foss. Vien.*, p. 24, pl. i, figs. 2, 3.
Lagena clavata Reuss., 1862; *Sitz. k. Akad. Wiss. Wien.*, vol. xlv, p. 320,
 pl. i, figs. 13, 14.
L. clavata Brady, 1884; *Chall. Rep.*, vol. ix, p. 456.

Chapman records *Lagena lævis* from the Hartwell Clay. One specimen, now in the Aylesbury Museum, is referred to *L. clavata*, which is probably a variety of *L. lævis*. This, the only specimen found by the present writer, has a fusiform contour and a pointed base. *L. lævis* is one of the commonest of the *Lagena*, and has been recorded from the Woolhope beds (Brady). It occurs at the present day in all latitudes and at all depths down to 2,435 fathoms (Brady). *L. clavata* has a similar distribution (Brady).

Locality : Hartwell (v.r.).

Lagena apiculata (Reuss).

Oolina apiculata Reuss, 1862; *Sitz. k. Akad. Wiss. Wien.*, vol. xlv, p. 319,
 pl. i, figs. 4-8, 10, 11.
Lagena apiculata Brady, 1884; *Chall. Rep.*, vol. ix, p. 453, pl. lv, figs. 4, 15-18.
L. apiculata Sherlock, 1914; *Geol. Mag.*, p. 255, pl. xviii, fig. 12.

Ranging from the Lias to the present day, this form is found abundantly at all depths in existing seas (Brady).

Locality : Hartwell (v.r.).

Lagena sulcata (Walker & Jacob).

Serpula sulcata Walker & Jacob, 1798; *Adam's Essays*, p. 634, pl. xiv, fig. 5.
Lagena sulcata Brady, 1884; *Chall. Rep.*, vol. ix, p. 462, pl. lvii, figs. 23, 26,
 33, 34.

Found at the present day in all latitudes at depths down to 2,750 fathoms (Brady), this species is recorded from various strata and occurs as low as Silurian (Brady).

Locality : Hartwell (v.r.).

Subfamily NODOSARIINÆ.

NODOSARIA Lamarck, 1816.

Subgenera *Glandulina* and *Dentalina* d'Orbigny.

Nodosaria (*D.*) *fontannesii* Berthelin.

Dentalina fontannesii Berthelin, 1880; *Mém. Soc. géol. France*, ser. III, vol. i,
 No. 5, p. 42, pl. ii, fig. 14.
N. (D.) fontannesii Chapman, 1893; *Journ. Roy. Micr. Soc.*, p. 593, pl. ix,
 fig. 15.
N. (D.) fontannesii Sherlock, 1914; *Geol. Mag.*, p. 257, pl. xviii, fig. 7.

This species was originally described from the Gault of France (Berthelin), and has since been found in the Folkestone Gault (Chapman), and the Speeton Clay of Yorkshire (Sherlock).

Locality : Hartwell (v.r.).

Nodosaria raphanus (Linn.).

Nautilus raphanus Linné, 1767; *Syst. Nat.*, 12th ed., p. 1164, No. 283.
N. raphanus Linné, 1788; *Syst. Nat.*, 13th ed., p. 3372, No. 16.
Nodosaria raphanus Brady, 1884; *Chall. Rep.*, vol. ix, p. 513, pl. lxiv, figs. 6-10.

This is the most widely distributed species of *Nodosaria* in the Hartwell Clay, occurring at all the localities except Aylesbury. It is recorded by H. B. Woodward as *Nodosaria* cf. *raphanistrum* [Linn.], and the specimens in Aylesbury Museum from the collection of the late Dr. Lee, of Hartwell House, have this label. Chapman records the form as *N. raphanus* from Hartwell. It ranges from the Lias and occurs at the present day at depths down to 1,400 fathoms (Brady).

Localities : Hartwell (c.) ; Bierton (r.) ; Whitchurch (r.) ; Long Crendon (a.) ; Wheatley and Shotover Hill, bed 2 (a.), bed 1 (r.).

Nodosaria seminuda Reuss. (Pl. IX, Fig. 1.)

Dentalina seminuda Reuss, 1850 ; *Denkschr. Akad. Wiss. Wien.*, vol. i, p. 367, pl. xlv, fig. 9.

Nodosaria seminuda Baggs, 1912 ; *U.S. Geol. Surv.*, Bull. 513, p. 59, pl. xvi, fig. 3.

A single well-developed specimen shows similarity with *N. seminuda* Reuss. The lower portion of the test is costate, the later chambers smooth ; the early septa are hardly visible, but the later part of the test is more constricted, the last chamber being almost globular. The species is therefore a catagenetic form, showing loss of ornament (costate to smooth). It lives at present in the Caribbean Sea (Baggs), and does not appear to have been recorded below the Tertiary.

Locality : Hartwell (v.r.).

Nodosaria (Gl.) humilis Roemer. (Pl. IX, Figs. 2, 3.)

N. humilis Roemer, 1841 ; *Verst. norddeutsch. Kreide*, p. 95, pl. xv, fig. 6.

N. humilis Chapman, 1893 ; *Journ. Roy. Micr. Soc.*, p. 585, pl. viii, fig. 18.

This form is very variable in its distribution at different localities. All specimens from Hartwell preserve a regularly conical outline due to the feeble inflation of the segments ; in certain individuals which are much longer, a greater number of chambers is developed than in the type. *N. (Gl.) humilis* has been recorded from the Upper Hils Clay, the Speeton Clay, and Gault of North Germany (Roemer, Reuss), from the Gault of Folkestone (Chapman), and the Gault of France (Berthelin), as well as from later deposits.

Localities : Hartwell (c.) ; Long Crendon (c.) ; Wheatley, bed 2 (v.r.).

FRONDICULARIA DeFrance, 1824.

Frondicularia concinna Koch. (Pl. IX, Fig. 5.)

Frondicularia concinna Koch, 1851 ; *Palæontographica*, vol. i, p. 172, pl. xxiv, fig. 5.

F. concinna Reuss, 1862 ; *Sitz. k. Akad. Wiss. Wien.*, vol. xlv, p. 54, pl. iv, fig. 13.

The Hartwell Clay specimens differ from the previously figured specimens in that the greatest width is nearer the initial end, and the outline is more irregular. *F. concinna* is recorded from the Upper Hils and Speeton Clay of Germany (Reuss).

Localities : Wheatley, bed 2 (f.) ; Shotover Hill, bed 1 (r.) ; Bierton (v.r.).

Frondicularia granulata Terquem.

Frondicularia granulata Terquem, 1863 ; *Mém. Ac. Imp. Metz.*, vol. xlv, p. 379, pl. vi, fig. 20.

Only one specimen of this species was found in the beds under discussion. Previously *F. granulata* has only been recorded from the Lias (Terquem).

Locality : Shotover Hill, bed 1 (v.r.).

MARGINULINA d'Orbigny, 1826.

Marginulina Jonesi Reuss.

Marginulina Jonesi Reuss, 1862 ; *Sitz. k. Akad. Wiss. Wien.*, vol. xlv, p. 61, pl. v, fig. 19.

M. Jonesi Chapman, 1894 ; *Journ. Roy. Micr. Soc.*, p. 163, pl. iv, fig. 24.

M. Jonesi Sherlock, 1914 ; *GEOL. MAG.*, p. 259, pl. xviii, fig. 15.

The individuals of this form differ considerably with regard to the number of chambers, but on the whole agree well with the published figures. Sherlock regards *M. Jonesi* as "a mere variety of *M. costata* (Batsch) characterized by fewer and more marked ribs", but he retains the specific name. Originally described from the Upper Hils of Germany (Reuss), it has since been found in the Gault of Folkestone (Chapman), the Speeton Clay of Yorkshire (Sherlock), and the Hartwell Clay (Chapman).

Localities : Hartwell (a.) ; Bierton (r.) ; Long Crendon (v.r.) ; Wheatley and Shotover Hill, beds 1 and 2 (c.).

Marginulina linearis Reuss.

Marginulina linearis Reuss, 1862 ; *Sitz. k. Akad. Wiss. Wien.*, vol. xlv, p. 60, pl. v, fig. 15.

M. linearis Chapman, 1894 ; *Journ. Roy. Micr. Soc.*, p. 161, pl. vi, fig. 14.

This form has been recorded from the *Minimus*-clay of North Germany (Reuss), the French Gault (Berthelin), Gault of Folkestone (Chapman), and the Speeton Clay of Yorkshire (Sherlock). It occurs also in the Oxford Clay of Buckinghamshire (see later).

Localities : Hartwell (r.) ; Shotover Hill, bed 1 (v.r.).

VAGINULINA d'Orbigny, 1826.

Vaginulina discors Koch. (Pl. IX, Fig. 6.)

Vaginulina discors F. Koch, 1851 ; *Palæontographica*, vol. i, p. 172, pl. xxiv, figs. 1, 2.

V. discors Reuss, 1862 ; *Sitz. k. Akad. Wiss. Wien.*, vol. xlv, p. 50, pl. iii, figs. 10-12.

V. discors Chapman, 1894 ; *Journ. Roy. Micr. Soc.*, p. 426, pl. viii, fig. 13.

Chapman recorded *V. discors* from the Hartwell Clay in 1897. The specimens found by the present writer are characterized by depressed septal lines and striated segments, but they lack the strong longitudinal ribs which are shown in figures by Reuss and Chapman. They differ in this respect also from *V. sparsicostata* Reuss. For the present, however, it seems advisable to retain them under the name *V. discors*, as they agree well with Chapman's

figured specimen from the Gault of Folkestone, now in the Jermyn Street Museum. This species is recorded from the Speeton Clay of Germany (Reuss) and the Gault of Folkestone (Chapman).

Localities: Hartwell (c.), Aylesbury (v.r.), Wheatley, bed 2 (f.), Bierton (r.), Long Crendon (r.).

Vaginulina harpa Roemer. (Pl. IX, Fig. 7.)

Vaginulina harpa Roemer, 1841; *Verst. norddeutsch. Kreide*, p. 96, pl. xv, fig. 13. *V. harpa* Reuss, 1862; *Sitz. k. Akad. Wiss. Wien.*, vol. xlv, p. 51, pl. iv, figs. 5-7.

Specimens from the Hartwell Clay referred to this species are very variable in outline, but the type of ribbing is constant. *V. harpa* is recorded from the Upper Hills and Speeton Clay of Germany (Reuss), the Lower Portland of Bucks (H. B. Woodward), the Hartwell Clay (Chapman), and older Jurassic deposits (see later).

Localities: Hartwell (c.); Aylesbury (f.); Bierton (r.); Whitchurch (f.); Long Crendon (v.r.); Wheatley and Shotover Hill, bed 2 (c.), bed 1 (a.).

Vaginulina incompta Reuss. (Pl. IX, Fig. 4.)

Vaginulina incompta Reuss, 1862; *Sitz. k. Akad. Wiss. Wien.*, vol. xlv, p. 45, pl. iii, fig. 5.

V. incompta Sherlock, 1914; *Geol. Mag.*, p. 260, pl. xix, fig. 10.

One specimen from the Hartwell Clay is referred to this species, which is recorded from the Upper Hills of Germany (Reuss) and the Speeton Clay of Yorkshire (Sherlock).

Locality: Hartwell (v.r.).

Vaginulina legumen (Linn.).

Nautilus legumen Linné, 1758; *Syst. Nat.*, 10th ed., p. 711, No. 248; 1767, 12th ed., p. 1164, No. 288.

Vaginulina legumen Brady, 1884; *Chall. Rep.*, vol. ix, p. 530, pl. lxvi, figs. 13-15.

This species ranges from Triassic to Recent. It is common in existing seas in shallow water (to 2,000 fath.), and is occasionally found in deep water (Brady).

Locality: Hartwell (v.r.).

CRISTELLARIA Lamarck, 1816.

Cristellaria humilis Reuss.

Cristellaria humilis Reuss, 1862; *Sitz. k. Akad. Wiss. Wien.*, vol. xlv, p. 65, pl. iv, fig. 16, 17.

C. humilis Chapman, 1894; *Journ. Roy. Micr. Soc.*, p. 648, pl. ix, fig. 7.

This form was originally described from the Upper Hills of Germany, and has since been recorded from the Gault of Folkestone (Chapman) and the Hartwell Clay (Chapman).

Localities: Hartwell (c.); Long Crendon (v.r.); Wheatley, bed 2 (f.); Shotover Hill, bed 1 (a.).

Cristellaria italica (Defr.).

Saracenia italica Defrance, 1824; *Dict. Sci. Nat.*, xxxii, 177; xlvii, 334; *Atlas Conch.*, xiii, 6.

Cristellaria italica Brady, 1884; *Chall. Rep.*, vol. ix, p. 545, pl. lxviii, figs. 17, 20-23.

C. italica Chapman, 1894; *Journ. Roy. Micr. Soc.*, p. 653, pl. x, fig. 10.

Specimens of *C. italica* from the Hartwell Clay resemble those from the Gault of Folkestone in having sharp edges and a distinct keel. Some elongated specimens approach *C. bononiensis* Berth., but preserve the spiral commencement. Ranging from the Lias upwards, the species has already been recorded from the Hartwell Clay (Chapman). It also occurs in the Gault of Folkestone (Chapman), and the Aptian of Surrey (Chapman). At the present day it is found in shallow water at depths varying from 90 fathoms in the Mediterranean to 725 fathoms in the North Atlantic (Brady).

Localities : Hartwell (a.) ; Aylesbury (c.) ; Bierton (c.) ; Long Crendon (a.) ; Whitchurch (f.) ; Wheatley and Shotover Hill, bed 2 (a.), bed 1 (c.).

Cristellaria sulcifera Reuss.

Cristellaria sulcifera Reuss 1862 ; *Sitz. d. Akad. Wiss. Wien*, vol. xvi, pp. 74, 93, pl. viii, fig. 8.

C. sulcifera Chapman, 1894 ; *Journ. Roy. Micr. Soc.*, p. 650, pl. x, fig. 2.

This form often approaches *C. italica*, with which it appears to be connected by transition-forms, but typical specimens are easily distinguished by the grooved sutural lines. *C. sulcifera* has been recorded from the *Minimus*-clay of Germany (Reuss), Aptian of Surrey, Gault of Folkestone, and the Hartwell Clay (Chapman).

Localities : Hartwell (f.) ; Wheatley, bed 2 (r.).

Cristellaria navicula d'Orb.

Cristellaria navicula d'Orbigny, 1840 ; *Mém. Soc. Géol. Fr.*, ser. I, vol. iv, p. 27, pl. ii, figs. 19, 20.

C. navicula Reuss, 1845 ; *Verstein. böhm. Kreidef.*, pt. i, p. 34, pl. xii, fig. 27.

C. navicula Chapman, 1894 ; *Journ. Roy. Micr. Soc.*, p. 650, pl. x, fig. 1.

Recorded from the Hartwell Clay (Chapman), *C. navicula* occurs in the Gault of Monteley (Berthelin), the Gault of Folkestone (Chapman), and many Upper Cretaceous faunas.

Localities : Hartwell (f.) ; Long Crendon (v.r.) ; Wheatley, bed 2 (r.).

Cristellaria convergens Bornemann.

Cristellaria convergens Bornemann, 1855 ; *Zeitschr. deutsch. geol. Gesellsch.*, vol. vii, p. 327, pl. xiii, figs. 16, 17.

C. convergens Brady, 1884 ; *Chall. Rep.*, vol. ix, p. 546, pl. lxi, figs. 6, 7.

C. convergens Chapman, 1896 ; *Journ. Roy. Micr. Soc.*, p. 4, pl. i, fig. 6

Chapman has already noted this form from Hartwell. It is also recorded from the Tertiary of Hermsdorf (Bornemann), the Gault of Folkestone (Chapman), and the Aptian of Surrey (Chapman). At the present day it is characteristically a deep-water form.

Localities : Hartwell (f.) ; Aylesbury (v.r.) ; Long Crendon (f.).

Cristellaria complanata Reuss.

Cristellaria complanata Reuss, 1845 ; *Verstein. böhm. Kreidef.*, pt. i, p. 33, pl. xiii, fig. 54.

C. complanata Reuss, 1862 ; *Sitz. k. Akad. Wiss. Wien.*, vol. xvi, p. 92, pl. xii, fig. 13.

C. complanata Chapman, 1894 ; *Journ. Roy. Micr. Soc.*, p. 653, pl. x, fig. 12.

Originally described from the Plänermergel of Bohemia, this

species has been recorded from the Gault of Folkestone (Reuss, Chapman), and the Aptian beds of Surrey (Chapman).

Localities: Hartwell (v.r.); Whitchurch (v.r.); Long Crendon (v.r.).

Cristellaria fragraria (Gümbel). (Pl. IX, Figs. 9, 10.)

Marginulina fragraria Gümbel, 1868; *Abh. m.-ph. Cl. k.-bayer Ak. Wiss.*, vol. x, p. 635, pl. i, figs. 58a-c.

Cristellaria fragraria Burrows & Holland, 1897; *Proc. Geol. Assoc.*, vol. xv, p. 38, pl. iii.

Numerous specimens from Long Crendon agree with Gümbel's figure 58a, and with the series of figures given by Burrows & Holland. Specimens from Hartwell have a different development in the younger portions of the test which is more elongated and more constricted at the septa, the chambers being more globular (cf. Gümbel's figure 58c). The tubercles which ornamented the earlier septa are not seen in the later part of the test, whereas longitudinal striæ are here developed. Both forms, therefore, agree in showing catagenesis of ornament, from tuberculate to striate, but the later (Hartwell) form exhibits a more advanced degree of uncoiling. *C. fragraria*, which is abundant in the London Clay, has already been noted from the Hartwell Clay (Chapman). It also occurs in the Nummulitic Marl of the Bavarian Alps (Gümbel), and in the *Clavulina Szabó* beds of Hungary (Hantken). Recent specimens were obtained from Torres Str. (155 fath.) and off the coast of S. America (350 fath.) only (Brady).

Localities: Hartwell (a.); Birtton (v.r.); Long Crendon (a.); Wheatley, bed 2 (v.r.).

Cristellaria cultrata (Montfort).

Robulus cultrata Montfort, 1808; *Conchyl. Syst.*, vol. i, p. 214.

Cristellaria cultrata Brady, 1884; *Chall. Rep.*, vol. ix, p. 550, pl. lxx, figs. 4-6.

C. cultrata Sherlock, 1914; *Geol. Mag.*, p. 262, pl. xix, fig. 4.

This species, which ranges from the Lias to the present day, was noted from Hartwell by Chapman. It is a common form and has been recorded from most of the Jurassic and Cretaceous deposits. At the present day it has a world-wide distribution and is found at all depths (Brady).

Localities: Hartwell (a.); Aylesbury (a.); Birtton (a.); Whitchurch (c.); Long Crendon (v.r.); Wheatley (a.); Shotover Hill (r.).

Cristellaria Roemeri Reuss. (Pl. IX, Fig. 8.)

C. Roemeri Reuss, 1862; *Sitz. b. Akad. Wiss. Wien.*, vol. xvi, p. 75, pl. viii, fig. 9.

Numerous rotulate *Cristellarians* with limbate sutures are referred to this species which was found by Reuss in the Middle Hils, Speeton Clay, and *Minimus*-clay of Germany. It does not appear to have been recorded since.

Two specimens from Wheatley show a decided tendency towards uncoiling; these are referred to *C. Roemeri* for the present, until more material is available for study.

Localities: Hartwell (a.); Aylesbury (r.); Birtton (r.); Wheatley, bed 2 (a.).

Cristellaria gibba d'Orb.

- C. gibba* d'Orbigny, 1839; *Foram. Cuba*, p. 63, pl. vii, fig. 20.
C. gibba Brady, 1884; *Chall. Rep.*, vol. ix, p. 546, pl. lxix, figs. 8, 9.
C. gibba Chapman, 1896; *Journ. Roy. Micr. Soc.*, p. 4, pl. i, fig. 7.
C. gibba Sherlock, 1914; *GEOL. MAG.*, p. 261, pl. xix, fig. 9.

This species ranges from the Lias to the present day, and is recorded from many of the Lower Cretaceous deposits as well as from the Hartwell Clay (Chapman). It is recorded living from the North Atlantic and South Pacific at depths of less than 500 fathoms, "but this is probably only a small portion of the area it inhabits" (Brady).

Localities: Hartwell (c.); Long Crendon (f.).

Cristellaria crepidula (F. & M.).

- Nautilus crepidula* Fichtel & Moll, 1798; *Test. Micr.*, p. 107, pl. xix, figs. 9-i.
Cristellaria crepidula d'Orbigny, 1839; *Foram. Cuba*, p. 64, pl. viii, figs. 17-18.
C. crepidula Brady, 1884; *Chall. Rep.*, vol. ix, p. 542, pl. lxvii, figs. 17, 19, 20; pl. lxviii, figs. 1, 2.
C. crepidula Chapman, 1894; *Journ. Roy. Micr. Soc.*, p. 648, pl. ix, fig. 8.

Under this name are included the strongly compressed, non-carinate, elongate *Cristellarians*, with depressed septal lines and narrow, almost vertical septal face. The form shows considerable variation of outline, and this variation is so gradual that no strict identification of the numerous "species" can be made. Ranging from the Lias, *C. crepidula* is now found in all existing seas and at all depths, but is nowhere very abundant (Brady).

Localities: Hartwell (c.); Birtton (r.); Wheatley and Shotover Hill, bed 2 (c.), bed 1 (r.).

Subfamily POLYMORPHINÆ.

POLYMORPHINA d'Orbigny, 1826.

Polymorphina fusiformis Roemer.

- Polymorphina (Globulina) fusiformis* Roemer, 1838; *Neues Jahrb.*, p. 386, pl. iii, fig. 37.
P. fusiformis Chapman, 1896; *Journ. Roy. Micr. Soc.*, p. 11, pl. ii, fig. 9.
P. fusiformis Sherlock, 1914; *GEOL. MAG.*, p. 263, pl. xix, fig. 12.

The question of nomenclature of this variable form has been discussed by Chapman (1896, p. 11) and Sherlock (1914, p. 264). The species is recorded from the Upper Hils and *Minimus*-clay of Germany (Reuss), Gault of France (Berthelin), and the Gault of Folkestone (Chapman). It still lives at depths down to 2,400 fathoms (Brady).

Localities: Hartwell (v.r.); Wheatley, bed 2 (v.r.); Shotover Hill, bed 1 (v.r.).

Family GLOBIGERINIDÆ.

GLOBIGERINA d'Orbigny, 1826.

Globigerina marginata, Reuss.

Rosalina marginata Reuss, 1845 : *Verstein. böhm. Kreid.*, pt. i, p. 36, pl. xiii, fig. 47.

Globigerina marginata Reuss, 1874 ; In Geinitz, *Palæontographica*, xx (2), p. 112, No. 2.

G. marginata Brady, 1879 ; *Q.J.M.S.*, vol. xix, n.s., p. 74.

G. marginata Brady, 1884 ; *Chall. Rep.*, vol. ix, p. 597.

This form, which closely resembles its isomorph *Pulvinulina menardi* d'Orb., is recorded from Hartwell by Chapman. It was previously restricted to the Cretaceous as a fossil form, being found originally in the Chalk of Bohemia (Reuss). It is very rare in Recent deposits (Brady).

Localities : Hartwell (f.) ; Wheatley, bed 2 (a.).

Globigerina cretacea d'Orb.

Globigerina cretacea d'Orbigny, 1840 ; *Mém. Soc. Géol. Fr.*, ser. i, vol. iv, p. 34, pl. iii, figs. 12-14.

G. cretacea Chapman, 1896 ; *Journ. Roy. Micr. Soc.*, p. 588, pl. xiii, figs. 5, 6.

Several small specimens are placed in this species, which is a characteristic Cretaceous form. It is common in all zones of the Gault of Folkestone (Chapman), and ranges into modern times (Brady). This is the first record of the species below the Cretaceous.

Locality : Hartwell (f.).

Family ROTALIIDÆ.

Subfamily ROTALIINÆ.

PULVINULINA Parker & Jones, 1862.

One specimen from Long Crendon belongs to this genus, but it is so badly worn that specific determination is not possible. The rarity of *Pulvinulina* in the Hartwell Clay is in sharp contrast with the abundance of the genus in the Speeton Clay of Yorkshire.

COMPARISON WITH OTHER DEPOSITS OF THE DISTRICT.

For purposes of comparison various deposits near Aylesbury were examined for Foraminifera, and the results are given below :—

Lower Gault.—Ford, 4 miles S.W. of Aylesbury. Dark-blue clay with abundant grains of quartz, glauconite, and phosphatic material, formerly worked for "coprolites". Over 130 species of Foraminifera were found by the writer and Mr. Hollis, of Aylesbury.¹ There are minor differences in distribution as compared with the Gault Foraminifera from Folkestone. The following fourteen species occur in the Gault at Ford and also in the Hartwell Clay. *Reophax scoriurus* Montf. (v.r.) ; *Haplophragmium acutidorsatum* Hantken (f.) ; *Thurammina albicans* Brady (r.) ; *Nodosaria* (Gl.) *humilis* Roem. (r.) ; *N. (D.) fontannesii* Berth. (v.r.) ; *Marginulina linearis* Reuss (r.) ; *M. Jonesi* Reuss (r.) ; *Cristellaria humilis* Reuss (v.r.) ; *C. navicula*

¹ *The Naturalist*, July, 1921, pp. 235-240.

d'Orb. (v.r.); *C. sulcifera* Reuss (v.r.); *C. italica* (Defr.) (v.r.); *C. gibba* d'Orb. (f.); *C. complanata* Reuss (v.r.); *Polymorphina fusiformis* (Roem.) (f.); The commonest species are *Anomalina ammonoides* (Reuss) and *Globigerina cretacea* d'Orb., which outnumber all the other species put together. Mr. Hollis has prepared a series for the Bucks County Museum at Aylesbury.

Upper Portland.—Long Crendon. A cream-coloured marl, locally known as "Wychert" or "Witchet", was examined, but yielded no Foraminifera. Ostracods are plentiful.

Kimmeridge Clay (latissima-beds).—Stewkley. Dark shale which could not be satisfactorily broken up. No Foraminifera were found.

Kimmeridge Clay (virgula-beds).—Brill. A small sample of the clay sent to the writer contained a few Foraminifera, but the relative abundance cannot be judged on such scanty material. The following species occur: *Haplophragmium* sp.; *Nodosaria raphanus* (Linn.); *Vaginulina harpa* Roem.; *Cristellaria italica* (Defr.); *C. crepidula* (F. & M.); *C. rotulata* (Lam.); *Pulvinulina* sp. Dr. A. Morley Davies¹ has noted Foraminifera from this locality, but they were not identified specifically. The five species fully identified above occur also in the Hartwell Clay.

Oxford Clay (pre-cordatum zone).—Quinton Road Junction. A sandy clay containing much quartz yielded abundant Foraminifera. The list of species is given in full, as the Oxford Clay forms do not appear to have been recorded previously.

<i>Species and relative abundance in the Oxford Clay of Quinton (Bucks).</i>		<i>Geological range as previously recorded.</i>
* <i>Haplophragmium</i> cf. <i>æquale</i> (Roem.)	a.	L. Cretaceous.
<i>Nodosaria communis</i>	v.r.	Permian to Recent.
<i>Lingulina carinata</i>	c.	Lias to Recent.
<i>Fronicularia</i> cf. <i>varians</i> Terquem	f.	Lias.
<i>Flabellina Deslongchampsii</i> Terquem	f.	Lias.
<i>Rhabdogonium</i> sp.	r.	
<i>Marginulina linearis</i> Reuss.	f.	L. Cretaceous.
* <i>Vaginulina harpa</i> Roem.	f.	Hartwell Clay—L. Cret.
cf. <i>discors</i> Koch.	r.	Hartwell Clay—Gault.
* <i>Cristellaria crepidula</i> (F. & M.)	c.	Lias to Recent.
* <i>cultrata</i> (Montf.)	f.	Lias to Recent.
<i>gracillissima</i> Reuss	v.r.	L. Cretaceous.
<i>gibba</i> d'Orbigny	c.	Lias to Recent.
* <i>Polymorphina fusiformis</i> Roemer	f.	Lias to Recent.
<i>Vitriuebbina irregularis</i> (Auctt.)	a.	Lias to Oxford Clay.
<i>Pulvinulina</i> sp.	a.	

* Occurs also in the Hartwell Clay.

GENERAL CONCLUSIONS.

The Foraminifera from the Hartwell Clay above described comprise thirty-seven species belonging to thirteen genera, and may be tabulated as follows:—

¹ *Q.J.G.S.*, vol. lxiii, 1907, p. 32.

		Number of species.	
		Chapman, 1897.	Neaverson, 1921.
LITUOLIDÆ.	<i>Reophar</i> . . .	—	1
	<i>Haplophragmium</i> . . .	—	2
	<i>Thurammina</i> . . .	—	2
TEXTULARIIDÆ.	<i>Tritaxia</i> . . .	1	—
LAGENIDÆ.	<i>Lagena</i> . . .	1	4
	<i>Nodosaria</i> . . .	1	4
	<i>Fronicularia</i> . . .	—	2
	<i>Marginulina</i> . . .	1	2
	<i>Vaginulina</i> . . .	2	4
	<i>Cristellaria</i> . . .	8	11
	<i>Polymorphina</i> . . .	—	1
	<i>Globigerina</i> . . .	1	2
	<i>Pulvinulina</i> . . .	—	1
		7 genera.	12 genera.
		15 species.	36 species.

In order to analyse the results Chapman's list (*Proc. Geol. Assoc.*, vol. xv, 1897, p. 97) is merged with the new record, as the Hartwell forms have not been fully described before.

Thirty-seven species of Foraminifera have been found in the Hartwell Clay and associated clays. Of these one form is not specifically identified, so will not be further considered. Thirteen (or 36 per cent) of the remaining thirty-six species were recorded from Jurassic deposits older than the Hartwell Clay, whilst twenty-three (or 64 per cent) were not known below the Cretaceous before the publication of Chapman's list. Further, twenty-two of the thirty-six species occur in the Gault of Folkestone, twelve in the Bargate Beds (Aptian) of Surrey, ten in the Speeton Clay of Yorkshire, and thirteen in the Lower Cretaceous of Germany. This confirms Chapman's general statement that the Foraminifera of the Hartwell Clay "present a facies comparable with that of the Neocomian (*sic*) and Gault". The relation is seen more especially with regard to the *Cristellaria*, which are represented in the Hartwell Clay by eleven species, eight of which are characteristic Lower Cretaceous forms. Other Hartwell forms connecting with the Lower Cretaceous are *Globigerina marginata*, *Vaginulina incompta*, and *Haplophragmium acutidorsatum*. The *Vaginulina*, however, present a general Jurassic facies; the commonest species, *V. harpa*, with its strong longitudinal ribbing, forming a marked contrast with the typical *Vaginulina* of the Gault which possess projecting sutures and marginal angles. In *V. discors* of the Hartwell Clay the longitudinal ribbing is not so conspicuous, but the limbate sutures and margins are still lacking. *Cristellaria* and *Vaginulina* are the dominant genera in the Hartwell Clay, and it is interesting to find the former represented by Cretaceous species, whilst the latter genus has a Jurassic aspect.

It is more difficult to compare the Hartwell Clay Foraminifera with those from older Jurassic deposits, as the latter have been somewhat neglected. The series from the Kimmeridge Clay and Oxford Clay of Bucks show a marked difference in the assemblage

of Cristellarians. In these deposits the ensiform Cristellarians abound, whilst the rotulate varieties (which predominate in the Hartwell Clay) are subordinate. The occurrence (though rare) of *Cristellaria gracillissima* in the Oxford Clay is noteworthy, as its previous lowest record is from the Speeton Clay of Yorkshire (Sherlock, 1914). The only common *Vaginulina* in the Oxford and Kimmeridge Clays of Bucks is *V. harpa*, though *V. discors* also occurs. These belong to the group with strong longitudinal ribs which, according to Berthelin, had its maximum development in Jurassic times. *Marginulina linearis* occurs in both the Hartwell Clay and the Oxford Clay of Bucks; this is the first record of the species below the Speeton Clay.

A noteworthy feature of the Oxford Clay Foraminifera from Quainton is the great abundance of the arenaceous form, *Haplophragmium* cf. *equale*, which exceeds in numbers all the other species collectively. In the Hartwell Clay arenaceous forms are uncommon. Porcellaneous forms are not found in the Hartwell Clay, but the Gault of Ford is remarkably rich in *Spiroloculina* and *Miliolina*, whilst *Vitriwebbina irregularis* is abundant in the Oxford Clay of Quainton. Thus the main features of the foraminiferal assemblages may be tabulated as follows :—

<i>Bucks, deposits.</i>	<i>Cristellaria.</i>	<i>Vaginulina.</i>	<i>Arenacea.</i>	<i>Porcellanea.</i>
Gault.	Rotulate varieties.	Limbate and marginate.	Rare.	<i>Spiroloculina</i> and <i>Miliolina</i> .
Hartwell Clay.	Rotulate varieties.	Longitudinally ribbed.	Rare.	None.
Oxford Clay.	Ensiform varieties.	Longitudinally ribbed.	<i>Haplophragmium</i> cf. <i>equale</i> , abundant.	<i>Webbina irregularis</i> Auctt.

A distinctive feature of the Hartwell Clay assemblage is the frequent occurrence of *Cristellaria fragraria*, which has hitherto been regarded as a characteristic Tertiary form. It is common at two horizons in the Hartwell Clay, and specimens from the higher bed show a more advanced degree of outcoiling than those from the lower. The occurrence of similar forms at widely separated horizons suggests that these forms should not be included under the same specific name. They may be "morphic equivalents" arising from different stocks and thus analogous with homeomorphic forms of Ammonites which are at least generically distinct. This question cannot be decided until more is known of the evolution and development of the Foraminifera.

The Tithonian Stramberg limestone, a deposit of approximately the same age as the Hartwell Clay, contains fourteen species belonging to seven genera.¹ The dominant forms are two arenaceous species (*Ammodiscus incertus* and *Involutina remesiara*) and the cosmopolitan

¹ Chapman, *Linn. Soc. Journ. Zool.*, vol. xxviii, 1900, p. 28. Perner, *Bull. Acad. Sci. Bohême*, 1898, p. 1.

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TABLE SHOWING DISTRIBUTION OF THE FORAMINIFERA OF THE HARTWELL CLAY IN SOME OTHER DEPOSITS.

Species.	Range in time as previously known.	Depth (in fathoms) now living.	Gault, Folkstone.	Apian, Surrey.	Speeton Clay, York- shire.	Lower Cretaceous of Germany.	Oxford Clay, Bucks.
1. <i>Reophax scorpiurus</i> Montf.	Jur.-Rec.	Any.	1		1		
2. <i>Haplophragmium acutidorsatum</i> Hantken.	L. Cret.-Rec.	Shallow.	2	2			
3. <i>H. aquile</i> (Roem.)	L. Cret.	—	3			3	3
4. <i>Thurammina albicans</i> , Brady .	U. Jur.-Rec.	1,900.	4				
5. <i>T. papillata</i> Brady	U. Jur.-Rec.	Deep water.					
6. <i>Tritaxia</i> (?) <i>variabilis</i> (Brady) .	Hartwell Clay to Rec.	Shallow.					
7. <i>Lagena hispida</i> Reuss. . . .	M. Lias.-Rec.	To 1900.	7				
8. <i>L. lævis</i> (Montague)	Sil.-Rec.	Any.	8	8	8		
9. <i>L. sulcata</i> (Walker & Jacob) . .	Sil.-Rec.	To 2,750.					
10. <i>L. apiculata</i> Reuss	Lias.-Rec.	To 2,750.					
1. <i>Nodosaria raphanus</i> (Linn.) . .	U. Trias.-Rec.	To 1,400.					
2. <i>N. seminuda</i> Reuss	Plioc.-Rec.	Shallow.					
3. <i>N. (D.) fontanensi</i> Berthelin . .	L. Cret.	—	13	13	13		
4. <i>N. (Gl.) humilis</i> Roem. . . .	Lias.-Eocene.	—	14			14	
5. <i>Fronicularia concinna</i> Reuss. .	Cretaceous.	—				15	
6. <i>F. granulata</i> Terq.	Lias.	—					
7. <i>Marginulina Jonesi</i> Reuss . . .	Hartwell Clay to Chalk Marl.	—	17	17	17	17	
8. <i>M. linearis</i> Reuss.	L. Cret.	—	18	18	18	18	18
9. <i>Vaginulina incompta</i> Reuss . .	L. Cret.	—			19	19	
10. <i>V. legumen</i> (Linn.)	Lias.-Rec.	To 2,000.		20			
1. <i>V. harpa</i> Roem.	Hartwell Clay- L. Cret.	—				21	21
2. <i>V. discors</i> Koch	Hartwell Clay- Gault.	—	22			22	22
3. <i>Cristallaria italica</i> (Defr.) . . .	Hartwell Clay- Recent.	To 725.	23	23			
4. <i>C. navicula</i> d'Orb.	Hartwell Clay- Chalk.	—	24				
5. <i>C. sulcifera</i> (Reuss)	Hartwell Clay to Gault.	—	25	25		25	25
6. <i>C. fragraria</i> (Gümbel)	Hartwell Clay- Recent.	155 (Torres St. 350 (S. Amer.))					
7. <i>C. humilis</i> Reuss	Hartwell Clay- Gault.	—	27			27	
8. <i>C. convergens</i> Born.	Hartwell Clay- Rec.	Deep water.	28	28			
9. <i>C. cultrata</i> (Montf.)	Lias.-Rec.	rarely < 100	29	29	29		29
10. <i>C. Roemeri</i> Reuss	L. Cret.	—				30	
1. <i>C. gibba</i> d'Orb.	Lias.-Rec.	< 500	31	31	31	31	
2. <i>C. complanata</i> (Reuss)	L. Cret.	—	32	32			
3. <i>C. crepidula</i> (Fitzel & Moll) . .	Lias.-Rec.	To 2,350.	33	33	33		33
4. <i>Polymorphina fusiformis</i> (Roem.)	Lias.-Rec.	To 2,400.	34		34	34	34
5. <i>Globigerina marginata</i> (Reuss) .	Cretaceous.	—					
6. <i>G. cretacea</i> d'Orb.	Cret.-Rec.	Any.	36	36			

species, *Cristellaria rotulata*, *C. gibba*, and *C. cultrata*. A specimen of *Vaginulina truncata* and one of *Haplophragmium neocomianum* connect the assemblage with the Lower Cretaceous. The only point of comparison with the Hartwell Clay is in the occurrence of the Cristellarians mentioned above. The Upper Jurassic of Switzerland has yielded arenaceous forms referred by Haeusler to *Thurammina albicans*, and similar forms are occasionally found in the Hartwell Clay.

Of the thirty-six species from the Hartwell Clay, thirteen (or 36 per cent) are known from the Hils of Germany. The foraminiferal assemblages of the two deposits are connected by (1) the dominance of *Cristellaria* and *Vaginulina*, and (2) the comparative rarity of arenaceous forms. A notable difference is the presence of twelve species of *Nodosaria* in the Hils against four in the Hartwell Clay. *Lagena* is not represented in the Hils assemblage, but four species occur in the Hartwell Clay.

The Foraminifera throw little light upon the question of the depth at which the Hartwell Clay was deposited. Nineteen of the thirty-six species are still living and eleven of these are recorded by Brady from both shallow and deep water. Of the eight species remaining, three, *Thurammina albicans*, *T. papillata*, and *Cristellaria convergens*, are characteristic of deep water, whilst five occur in shallow water. The balance of the evidence seems to be in favour of fairly deep water, since tests of shallow water forms could sink to the level of deposition. The Hartwell Clay itself shows great similarity with the Gault Clay both in the abundance of glauconite and in the presence of certain species of Foraminifera. Thus it is permissible to suppose that the depth of deposition would be similar, viz. between 800 and 900 fathoms according to Chapman's calculation for the depth of the Gault Sea.¹

SUMMARY.

1. Thirty-six species of Foraminifera are recorded from various localities in the Hartwell Clay and associated beds.

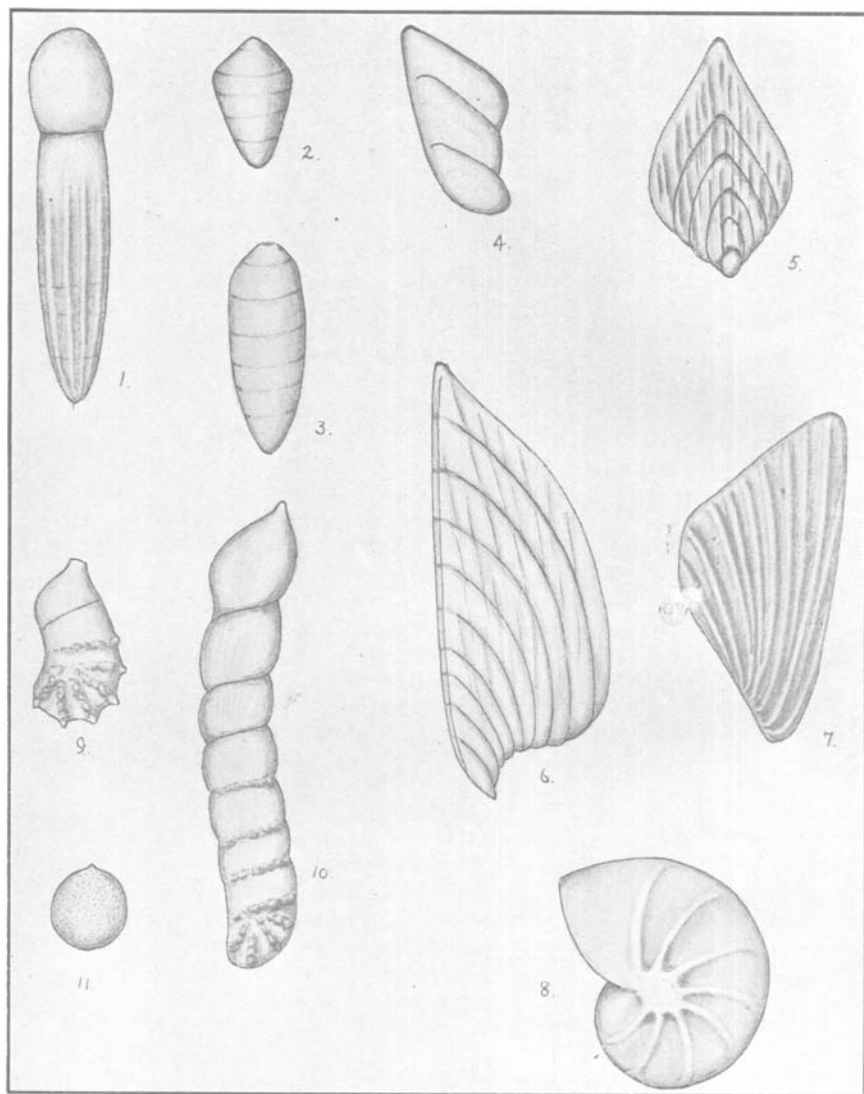
2. The assemblage of species is characterized by:—

- (a) the abundance of rotulate Cristellarians of Lower Cretaceous type, and of *Cristellaria fragaria*.
- (b) the common occurrence of *Vaginulina harpa*, a Jurassic type.
- (c) the rarity of arenaceous, and the absence of porcellaneous forms.

3. The Foraminifera from the Hartwell Clay are compared with those from other deposits in the Aylesbury district, and with those from foreign deposits of similar age.

4. The relative abundance of glauconite is a point of similarity between the Hartwell Clay and beds hitherto regarded as Kimmeridge Clay.

¹ *Nat. Sci.*, vol. xiii, 1898, No. 81, p. 305.



E. Neaverson, del. ad nat.

FORAMINIFERA, HARTWELL CLAY, BUCKS.

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EXPLANATION OF PLATE IX.

Photograph of *camera lucida* drawings of Foraminifera. All figures are magnified 30 diameters.

FIGS.

- 1.—*Nodosaria seminuda* Reuss. Hartwell Clay, Hartwell.
- 2.—*N. (Gl.) humilis* Roemer. Hartwell Clay, Long Crendon.
- 3.—*N. (Gl.) humilis* Roemer. Hartwell Clay, Hartwell.
- 4.—*Vaginulina incompta* Reuss. Hartwell Clay, Hartwell.
- 5.—*Frondicularia coccinea* Reuss. "Kimmeridge Clay," Wheatley.
- 6.—*Vaginulina discors* Koch. Hartwell Clay, Hartwell.
- 7.—*V. harpa* Roemer. Hartwell Clay, Long Crendon.
- 8.—*Cristellaria Roemeri* Reuss. Hartwell Clay, Hartwell.
- 9.—*C. fragraria* Gümbel (short form). Hartwell Clay, Long Crendon.
- 10.—*C. fragraria* Gümbel (long form). Hartwell Clay, Hartwell.
- 11.—*Thurammina albicans* Brady. Hartwell Clay, Hartwell.

NOTE.—A series of specimens is deposited in the Bucks County Museum, Aylesbury, and therefore only a few of the more characteristic forms are figured here.

On a Local Alteration in Limestone Shales at Wensley, Derbyshire.

By C. S. GARNETT.

A SMALL stream forms the boundary between the Parishes of Wensley and Winster, on the north-west of the former; and hereabouts its bed, in the Limestone Shale, is probably about 30 feet above the Carboniferous Limestone. On the Winster side, the shales form a wooded slope (Whites Wood) rising 100 feet in about 200 feet, and on this side the shale is quite normal and of the black colour usual in the lower beds of this formation. On the Wensley side the ground rises more gradually, and the actual bank of the stream averages not more than about 10 feet in height. Here, an altered shale is exposed and can be traced (through the activity of moles) in the fields behind.

There appear to be two small areas of alteration, just over 100 yards apart; and in the case of the larger, of a traceable area of about $\frac{1}{2}$ acre.

At the place of the larger exposure the shale beds are thrown upwards and lie in a confused manner—not unlike the upward bursting caused by the weight of hills behind. On this (the south) side the ground gradually rises from just under 500 feet at the level of the stream, to 1,000 feet in just under half a mile; on the opposite side it rises to 800 feet in a quarter of a mile.

In the areas under consideration the shale in its upper beds, instead of being black in colour, appears bright brick-red from a little distance, and on closer examination is found to be almost white or of a buffish tint within the laminæ, whilst at the surface of these it is quite bright red. This distribution of colouring matter is best seen in the harder portions; where the shale was softer the redness is more evenly distributed in the clay, but the red colouring matter is in places almost or quite absent. The black carbonaceous matter has been completely removed, and