MEDIAL CHALK.

Cardiaster excentricus—Swaffham.
Cardiaster cordiformis.
Inoceramus, 4 or more species very abundant.
Belemnites, very rare; in the upper chalk very numerous.

LOWER CHALK (with Slickensides).

Polyptychodon interruptus.
Ichthyosaurus campylodon.
Discoidea cylindrica.
——— subucula.

CHALK-MARL.

Inoceramus Cripsii.
Turrilites tuberculatus. Pecten Beaveri.

2.—"On the Plasticity and Odour of Clay." By Charles Tomlinson, Esq., Lecturer on Science, King's College School, London.

It is a happy result of Bacon's method of inquiry that science is not required to explain the causes of things, but to state the laws of phenomena. Nevertheless, while these laws are obscure, and facts are scattered, theory may often do good service by collecting and marshalling them: for, as our great master of induction well observes, "Facts are the soldiers, but theory is the general." And again, "Truth is more easily evolved from error than from confusion." That is, a bad theory is better than none at all, for it serves to collect and arrange the facts, and thus makes them more easy to handle.

In these remarks must be found my excuse to-night for endeavouring to bind together some of the facts respecting a property of a very common substance; namely, the Plasticity of Clay.

The more I consider this property the more wonderful and inexplicable does it appear. Take a mass of dry clay; it cracks easily, and crumbles readily: add to it a certain proportion of water, and it becomes *plastic*—it obeys the will of the artist or the artizan, who can, out of this yielding mass, *create* new forms, or perpetuate old ones. Drive off the water at a red heat, and plasticity is for ever lost; *rigidity* takes its place: the clay is no longer clay, but something else. It may be reduced to powder, and ground up with water; but no art or science can again confer upon it its plasticity.

All this is very wonderful. There is another fact that is equally so:

if we combine the constituents of clay in the proportions indicated by the analysis of some pure type of that substance, we fail to produce plasticity. I have on the table specimens of Dorset clays, dry and crumbling; the same wet and plastic; and the same in the forms of casts of fossils, which have been passed through the fire, and have exchanged plasticity for rigidity. They are, in fact, in the form of *biscuit.*

With respect to the temperature at which clay becomes rigid, we have no accurate information. It is much lower than is generally supposed, as will appear from the following experiment:—I pounded and sifted some dry Dorset clay, and exposed it to a sand bath heat in three portions varying from about 300° to 600°. Specimens were taken out from time to time, and rubbed up with water, but they did not lose their plasticity. Some clay was put into a test tube with a small quantity of mercury, and heated until the mercury began to boil. At this temperature (viz. 650°) the clay did not cease to be plastic. The flame of a spirit-lamp was applied, and the tube was heated below redness, after which the clay on being mixed with water, showed no sign of plasticity.

In experiments of this kind, the first action of the heat is to drive off the hygrometric water. The clay then becomes dry, but is not chemically changed; it does not cease to be plastic. On continuing to raise the temperature, the chemically combined water is separated, and the clay undergoes a molecular change, which prevents it from taking up water again, except mechanically. With the loss of this chemically combined water, clay ceases to be plastic.

It was, I believe, first noticed by Brongniart,* that we cannot produce plasticity by the synthesis of clay. The fire clay of Stourbridge, for example, is a hydrated silicate of alumina, represented by the formula $Al_2 O_3$, $2\ Si\ O_2 + 2\ Aq$. If we mix one atom of the sesquioxide of alumina with 2 atoms of silica and 2 of water, we get a compound which cannot be called clay, since it is wanting in plasticity.

It is quite easy to obtain either alumina or silica in the gelatinous state; but we cannot obtain them in the plastic state.

Clay is almost the only substance in the mineral kingdom that possesses plasticity. In loam, if the sand be in large proportion, and in marl if calcareous matters abound, so as to deprive either material of plasticity,

* Traité des Arts Céramiques. Paris, 1844. Vol. i. p. 82.

it ceases to be clay. There are also certain silicates of alumina which are not plastic; such as bole, lithomarge, and fullers'-earth. Bole consists chiefly of a hydrated bisilicate of alumina, in which a portion of the alumina is replaced by sesquioxide of iron. Lithomarge also contains iron, and is sometimes so compact as to be used for slate-pencils. Fullers'-earth contains lime, magnesia, and iron, in addition to its principal ingredients.

There is probably no substance so indeterminate in its composition as clay. Regarding it, as Lyell does,* as "nothing more than mud derived from the decomposition or wearing down of rocks," it must necessarily contain a variety of substances; such as oxide of iron, lime, magnesia, potash, silica, bitumen, fragments of undecomposed rock, &c. These substances impair the plasticity of the clay, and impress upon it certain characters which are of more importance to the manufacturer than to the chemist, or the geologist. Brongniart† enumerates, and gives the analyses of no fewer than 167 clays and 28 kaolins, all of which are in use in the arts in different parts of the world. They probably all differ in plasticity, but they all possess it; and at a high temperature exchange it for rigidity. A rough method of measuring the plasticity of different clays is to note the length to which a cylinder of each can be drawn out in a vertical direction without breaking. In such a comparison, the clays must of course be worked equally fine, and contain the same proportion of water.

It is commonly stated that the ingredient that confers plasticity on clay is its alumina; and yet, strange to say, pure alumina alone, whether gelatinous, or after having been dried and ground up with water for a long time, never gives a plastic paste. Indeed nothing can be conceived less plastic than gelatinous alumina, as may be seen from the specimens on the table. We may drive off most of the water from this gelatinous hydrate, but it will not become plastic. Or we may form clay by mingling solutions of the silicate of alumina and the aluminate of potash. You see they are perfectly fluid. I apply the heat of a spirit-lamp, and we get an opalescent gelatinous mass, but still no plasticity. We have, indeed, formed a gelatinous clay.

* Manual (1855) p. 11.

† "Des Arts Céramiques," Atlas of plates.

We cannot say that the gelatinous state of alumina is the cause of plasticity in clay; for silica may be made as gelatinous as alumina, and silica is certainly not the cause of plasticity. It may be that the strong affinity of alumina for water (retaining a portion of it even when near a red heat) may be the cause of this property—just as turpentine renders wax plastic; and water and gluten confer the same property on starch.

We have seen that clay ceases to be plastic when its chemically combined water has been driven off. Still, however, water cannot be said to be the cause of plasticity, as a general property, since we have, in melted glass, a more perfect example of plasticity even than in clay; and few substances are more plastic than sealing-wax at a certain temperature.

A clear idea of plasticity, and of some of the other mechanical properties of matter, may probably be gained by considering them as variations of the forces of cohesion and adhesion, and by bringing these, in their turn, under Newton's great law of attraction directly as the mass, and inversely as the squares of the distances.

Now, if we suppose the distances between the molecules of matter to be 1-millionth or billionth, or 2, 3, 4, 5, 6, &c., millionths or billionths of an inch asunder, the intensity of their attractions will be 1, $\frac{1}{4}$th, $\frac{1}{9}$th, $\frac{1}{16}$th, &c., or, to represent it in a tabular form:—

Distances	1	2	3	4	5	6	7	8	9	10	&c.
Intensities of attraction	1	$\frac{1}{4}$	$\frac{1}{9}$	$\frac{1}{16}$	$\frac{1}{25}$	$\frac{1}{36}$	$\frac{1}{49}$	$\frac{1}{64}$	$\frac{1}{81}$	$\frac{1}{100}$,	&c.

Suppose the molecules to be of the same density, but at different distances apart, as represented in the upper line. At the distance of 1-millionth of an inch we get an intensity of attraction represented by 1. At 2-millionths of an inch the force of attraction is only one-fourth. Now, the idea is this, that the mechanical properties of matter,—such as porosity, tenacity, hardness, brittleness, plasticity, elasticity, &c., depend upon variations in the attractive force of the molecules according to the distances apart of such molecules. Thus, if the molecules of clay require to be 5-millionths of an inch apart in order to produce plasticity, the intensity of attraction between them will be represented by $\frac{1}{25}$th; but if such clay be passed through the fire, and the molecules, in consequence of the escape of water, be brought nearer together, and rigidly fixed at 4-millionths of an inch asunder, the force of attraction will then be $\frac{1}{16}$th.

Now, the method of arranging the particles of clay at that precise distance that shall impart plasticity, is one of Nature's secrets that we have not yet succeeded in penetrating. It may be that the circumstances under which clay is formed and deposited, or the time that has elapsed since its formation, or the pressure of the superposed layers, may have so arranged the particles as to enable them to become plastic when the proper proportion of water is added. It may be that a certain state of disintegration is required on the part of the alumina and the silica, so that their proximate elements shall be neither too fine nor too coarse; or it may be that the silica, in combining with the alumina, separates the atoms of the latter to precisely those distances required for the development of the property; or, lastly, the presence of a small portion of animal or other organic matter in clay may have something to do with this remarkable property.

Some experiments, which are now being conducted in France, show the presence of animal matter in quartz and various rocks, where its presence had not previously been suspected; and this may have as important an effect in modifying the properties of a mineral as the presence of minute portions of bodies, formerly entered as impurities, has in producing pseudomorphous crystals.

Still, the question recurs, Why is not a clay artificially formed from pure materials plastic? The answer is, that we do not know all the conditions of plasticity. We *do* know the conditions under which some mechanical properties exist,—such as the hardness of steel, the brittleness of unannealed glass,—and can confer or remove such properties at pleasure. But with respect to plasticity, we can only confer a factitious property of this kind on mineral substances by taking advantage of another property which it somewhat resembles, namely, *viscosity* or *viscidity*. Viscosity differs in plasticity in this, that the viscous body does not retain the form impressed upon it when the force is removed, as a plastic body does. The materials of the old soft porcelain of Sèvres had no plasticity; but this property was conferred by means of soft soap and parchment size.*

Without speculating further on the nature of plasticity, I may remark

* Brongniart (Des Arts Céramiques) says that the old *porcelaines tendres* were formed of 22 per cent. of fused nitre, 60 of Fontainebleau sand, 7·2 of salt, 3·6 of alum, 3·6 of soda, and 3·6 of gypsum. These materials were fritted and ground, and 75 parts taken, to which were added white chalk 17 parts, marl 8. This mixture was ground, sifted very fine, and made up into a paste with 1-8th soft soap and size, or, at a later period, with gum tragacanth.

that in the ancient philosophy the word was one of power. Derived from the Greek πλασσειν, or πλαττειν, "to form," or "to create," it not only included the arts of modelling in clay, but also sculpture and painting, and, by a refinement of language, poetry and music. Plato and Aristotle even supposed that a plastic virtue resided in the earth, or did so originally, by virtue of which it put forth plants, &c.; and that animals and men were but effects of this plastic power. They did not suppose the world to have been made with labour and difficulty, as an architect builds a house; but that a certain "efficient nature" (*natura effectrix*) inherent and residing in matter itself, disposed and tempered it, and from it constructed the whole world. Aristotle distinctly recognizes *mind* as the principal and directing cause, and *natura* as a subservient or executive instrument. Even in later times men have contended for the existence of a plastic nature, or incorporeal substance endowed with a vegetative life; but not with sensation or thought, penetrating the whole universe, and producing those phenomena of matter which could not be solved by mechanical laws. The learned Cudworth supports this view,* and the discussions into which it led him and other metaphysicians form a curious chapter in the history of the human mind. In England we do not now retain the term *plasticity*, except as a physical property of matter;† but in Germany it has still an extensive figurative meaning. The word *plastisch* still means *bildend* or *schöpferisch* (i. e. "creative"); and it is still applied not only to sculpture, but also to painting, poetry, and music. A German well understands the expression "plastische Gedanken," or "plastic thoughts."

Before concluding, I would refer to another property of clay, which seems to me as wonderful as its plasticity; namely, its *odour* when breathed on, or when a shower of rain first begins to wet a dry clayey soil. This odour is commonly referred to alumina, and yet, strange to say, pure alumina gives off no odour when breathed on or wetted. The fact is, the peculiar odour referred to, belongs only to impure clays, and chiefly to those that contain oxide of iron. This was pointed out by Brongniart as far back as 1816,‡ who also remarked that minerals which

* See "The True Intellectual System of the Universe," by Ralph Cudworth, D.D., 1678. A reprint has been published by Tegg, in which see Vol. I., p. 226, *et seq.*

† Dr. Johnson defines *plastic* as "having the power to give form."

‡ "Dictionnaire des Sciences Naturelles," art. *Argile.*

do not contain alumina, such as pulverized chalcedony, possess this remarkable property.

I have found that a pure kaolin, ground up in a mortar with a small quantity of water, emits a slight odour, which, however, becomes much more sensible if a little sesquioxide of iron be added.

Smooth quartz pebbles when rubbed together give an electric spark, and a fetid odour. It is commonly supposed that sea-side pebbles alone possess this property; but the odour belongs equally to those found among gravel overlying the chalk, and in ploughed lands where the surface is exposed to all the vicissitudes of the weather. It is quite possible that the odour of these pebbles may hereafter be traced to the presence of organic matter; but I cannot resist the reproduction here of a suggestive hint given me by my friend Professor Bloxam, who is reminded by the spark and odour from these pebbles of the presence of ozone.

What, again, is the cause of the odour in the narrow parts of stone buildings, not of new buildings alone, but of old ones, as in the staircases of old cathedrals?

I do not attempt to reply to these questions. It requires some amount of knowledge and experience to put them—but how much more to answer them!

A discussion followed, in which the President, the Rev. Mr. Wiltshire, Mr. Evans, and Mr. Cresy took part.

The President stated that the Committee of the Association, being fully persuaded of the benefit which the members would derive from having the opportunity to consult the publications of the Palæontographical Society (the Monographs on British Fossils), had resolved to purchase the same for the Library, and to request the co-operation of the Rev. Thomas Wiltshire and Mr. Rupert Jones in re-arranging in distinct monographs, and in a form suitable for binding, the various yearly volumes of that society; and that those gentlemen, having consented to carry out the wishes of the Committee, had not only done so, but had also drawn up the annexed table, which would both assist the members who might be subscribers to the Palæontographical Society in binding up their own copies in separate monographs, and further would show how large an amount of geological information of a most valuable description was now in the possession of the Association.

TABLE of the MONOGRAPHS, published by the Palæontographical Society, now in the Library of the Association. Those volumes marked * (fifteen in number) are complete and bound, and are ready for circulation amongst the members, subject to the Library-regulations.

SUBJECT OF MONOGRAPH.	Dates of the Years *for which* the Volume containing the Monograph was issued.	No. of Pages in each Monograph.	No. of Plates in each Monograph.	No. of Lithographed Figures and Woodcuts.	No. of Species described in the text.
The Mollusca of the Crag, by Mr. S. V. Wood:					
*Vol. I. (Univalves), complete	1847, 1855[1]	200	21	581	244
*Vol. II. (Bivalves), complete	1850, 1853, 1855, 1858[2]	344	31	691	253
*The Polyzoa of the Crag, by Prof. Busk, complete	1857	145	22	641	122
*The Tertiary Echinodermata, by Prof. Forbes, complete	1852	40	4	144	44
The Eocene Mollusca, by Mr. F. E. Edwards. Cephalopoda and Univalves, not complete	1847, 1852, 1854, 1855, 1858	332	33	578	161
The Eocene Molluscan Bivalves, by Mr. S. V. Wood, not complete	1859	74	13	188	70
The Malacostracous Crustacea, by Prof. T. Bell, not complete	1856	44	11	97	19
* { The Tertiary Entomostraca, by Mr. Rupert Jones, complete	1855	74	6	233	56
{ The Cretaceous Entomostraca, by Mr. Rupert Jones, complete	1848	41	7	176	27
*The Cretaceous Cephalopoda, by Mr. D. Sharpe, complete	1853, 1854, 1855	67	27	319	79
*The Great Oolite Mollusca, by Prof. Morris and Mr. J. Lycett, complete	1850, 1853, 1854	282	30	846	419
*The Fossils of the Permian formation, by Prof. King	1849, 1854[3]	288	29	511	138
*The Reptilia of the London Clay [and of the Bracklesham and other Tertiary Beds], by Profs. Owen and Bell, complete	1848, 1849, 1856[4]	150	58	304	39
*Fossil Cirripedes, by Mr. C. Darwin, complete	1851, 1854, 1858[5]	137	7	320	54
*The Reptilia of the Cretaceous formations, by Prof. Owen, complete	1851	118	39	262	18
*The Reptilia of the Cretaceous, Wealden, and Purbeck formations, by Prof. Owen, complete	1853, 1854, 1855, 1856, 1857	200	72	424	21
The Reptilia of the Oolitic formations, not complete	1859	16	7	40	2
*British Fossil Brachiopoda, Vol. I. The Tertiary, Cretaceous, Oolitic, and Liassic Brachiopoda, by Mr. T. Davidson, complete	1850, 1852, 1853, 1854	409	42	1,855	160
———— Vol. II. The Permian, Carboniferous, and Silurian Brachiopoda, not complete	1856[6], 1857, 1858, 1859	261	51	1,578	135
*The Oolitic Echinodermata, Vol. I., complete	1855, 1856, 1857, 1858	475	43	724	109[7]
*Tertiary, Cretaceous, Oolitic, Devonian, and Silurian Corals, by MM. Milne, Edwards, and J. Haime, complete	1849, 1851, 1852, 1853, 1854	384	72	800	319[8]
		4,081	625	11,312	2,489

[1] Title-page to Univalves. [2] Note to Crag Mollusca. [3] Two corrections of Plates. [4] Supplement. [5] Index. [6] Contains the Permian, which is complete. [7] British Species only reckoned. [8] Many of the Species are described, but not figured.

The following are the Library-regulations :—

LIBRARY REGULATIONS.

I. That the library be open on the evenings of ordinary meetings, and that members be at liberty to borrow the books, &c., of the Association, subject to the following conditions :—

II. That no member of the Association borrow more than one volume at a time.

III. That unbound numbers of periodical works be not borrowed from the library; and that maps, plates, or drawings be not borrowed except by special leave of the General Committee.

IV. That the title of every book, pamphlet, map, plate, or drawing borrowed, be first entered in the library-register, with the borrower's signature.

V. That no work of any kind be retained longer than one month, except by special leave of the General Committee; but at the expiration of that period, or sooner, the same be returned free of expense, and it may then, upon *re-entry*, be again borrowed, provided no application for it shall have been made in the meantime by any other member.

VI. That in all cases the books, &c., or other property of the Association, in the possession of any member, be produced to the Honorary Librarian *on the evening of the July meeting in each year.*

VII. That in every case of loss or of damage to any volume, or other property of the Society, the borrower shall make good the same; and that any property shall be considered as lost which is not returned within four months after application for it.

There will be an excursion to Cambridge on June 10th, to examine the Upper Greensand, and on August 6th to Lewes, to visit the Upper and Lower Chalk. The President also proposes, during the period the International Exhibition is open, to give one or more lectures in the building, on the geological specimens and mineral products contained therein. Timely notice of the trains for these excursions and of the days for the lectures in the International Exhibition will be forwarded to the members.

The back numbers of the Proceedings of the Association (price one shilling each) may be had on application to the Honorary Secretary.

Letters and communications to the Honorary Secretary, W. N. Lawson, Esq., may be directed either to the rooms of the Association, 5, Cavendish Square, W.; or to 28, Chancery Lane, W.C.