a thickness of at least 50 feet. The reddish or yellowish-brown lower boulder-clay, which is often varied by a light bluish or greenish tint, contains the greatest number of large boulders. In many places, from Penrith to Workington, and elsewhere, it attains a great thickness. It has been mainly derived from the waste of the volcanic rocks and Coal-measure shales of Cumberland. The underlying bluish-grey clay rises to a height of at least 900 feet near Troutbeck railway station. It may be traced in the railway cutting not only between Troutbeck and Bassenthwaite lake, but between Cockermouth and Workington; between Marron Junction and Bridgefoot, where it is distinctly overlain by the reddish-brown clay; south of Branthwaite station, at Ullock station, where it is covered by a cargo of enormous boulders of sandstone, limestone, porphyry, etc.—the latter surmounted by red clay, sand, and gravel; and in other places. I have not seen any decided blue clay much farther north than the river Derwent. It would appear to have been chiefly derived from the waste of the Skiddaw Slates. There can be no doubt that in a great part of Cumberland, as well as in West Yorkshire (*see my paper on West Riding Drifts in the forthcoming Proceedings of the West Riding Geological Society*), there are four boulder drifts, two or three of which are often found in vertical succession, and the order of which is never found reversed. The extent to which these drifts have been removed by denudation, and the absence of sufficiently extensive sections, are probably the reasons why no very decided instance, so far as I am aware, has yet been discovered, in which all the four drifts are present.

In a few months I hope to be able to communicate an article, with a map, on the Drifts and Glaciated Rock-surfaces of the country between Whitehaven and Blackcombe, including the Eskdale granitic area.[1]

NOTICES OF MEMOIRS.

I.—On the Correlation of the Jurassic Rocks in the Department of the Côte-d'Or, France, with the Oolitic Formations in the Counties of Gloucester and Wilts, England.[2] By Thomas Wright, M.D., F.R.S.E., F.G.S., etc.

THE department of the Côte-d'Or, which forms the northern portion of the Duchy of Burgundy, contains a very complete

[1] In Professor Harkness' paper on Shapfell Blocks in the Quart. Journ. Geol. Soc. for November, it is stated that Shapfell granite does not occur in the Boulder-clay of the Eden valley, though Criffell granite is found in this clay. The Eden valley clay may have nearly ceased to accumulate before the high-level granite of Wasdale Crag began to be dispersed, and imbedded in the *pinel* or Boulder-clay of the mountains, in which it is associated with polished and striated stones and boulders. (*See article on Shapfell Boulders*, Geol. Mag., Aug., 1870.)

[2] Read at the Meeting of the Cotteswold Club, Aug. 31, 1869, and published in the Proceedings for 1869, pp. 143-237.

development of the Jurassic series. The region has naturally formed the subject of many important memoirs by French geologists, and no one has paid more attention to it than M. Jules Martin, who has carefully examined the palæontology of all the beds. His cabinet contains a large series of fossils from the different Jurassic stages, stratigraphically arranged, and including all the type specimens which he has figured and described in his works. Dr. Wright has had the opportunity of carefully examining this collection, and the result of this examination is here laid before the members of the Cotteswold Club.

Dr. Wright publishes a valuable table, prepared by M. Martin, of all the stages of the Jurassic rocks exposed in the Côte-d'Or, wherein are pointed out their lithological characters, and the leading fossils contained in them. Having studied the beds in ascending order, he commences with—

1. The Rhætic Beds.—In the Côte-d'Or these beds are composed of sandstones and marls, with the characteristic *Pecten Valoniensis, Avicula contorta, Cardium Rhœticum, Lima præcursor*, and species of *Chemnitzia, Anatina, Myophoria*, etc. At Macigny they appear to be entirely arenaceous, with beds of arkose; the whole deposit rests on granite. The same lithological character prevails at Montigny, Semur, and Pouillenay. M. Martin has detected the bone-bed in several localities,—at Savigny, where it appears to occupy the upper part of the *Avicula-contorta* zone, at Memont, and at Remilly, where it is interesting to learn the complete transition, both lithological and palæontological, which obtains between the Lias and Rhætic strata. In the West of England, particularly where the white Lias is developed, the junction of these beds is generally well marked, and rather by a change of sedimentary condition than of unconformity. While nothing could be more gradual than the passage upwards of the New Red Marl (Keuper) into the grey marls of the Rhætic series.

A good number of species have been collected from the *Avicula-contorta* zone in the Côte-d'Or. Of reptiles, two species of *Termatosaurus*; of fish, 14 sp.; of Gasteropoda, 8 sp.; Conchifera, 46 sp., etc. Also one Echinoderm, one Coral, a Sponge, two Annelids, and a couple of Plants. The absence of Cephalopoda is marked, and but one species, *Belo-* (or *Geo-*?) *teuthis*, found by Mr. Boyd Dawkins in the grey marls at Watchet, has been recorded in this country. Dr. Wright gives some account, with sections, of the British Rhætic beds. They are well known from his previous publications, and the labours of Messrs. Charles Moore, Bristow, Etheridge, and others.

2. Lias.—M. Martin divides the Lias into four stages:—1st. *Hettangien* or *Infra-Lias*; 2nd. *Sinémurien* or *Lias inférieur*; 3rd. *Liasien* or *Lias moyen*; 4th, *Toarcien* or *Lias supérieur*. The *Hettangien* is shown by Dr. Wright to represent the two lower stages of our Lower Lias—the zones of *Ammonites angulatus* and *A. planorbis*. The *Sinémurien* comprises two zones: *a*. Bluish marly limestone, with *Ammonites oxynotus, A. stellaris, A. Birchii*, etc. *b*. Marls and limestone, with *A. bisulcatus* (vel *Bucklandi*), *A. Scipionianus*, and

A. rotiformis. These are equivalent to the other Lower Lias zones, those of *A. Bucklandi, A. Turneri, A. obtusus, A. oxynotus*, and *A. raricostatus*.

The *Liasien*, which attains a considerable development at Semur, represents our Middle Lias, and the *Toarcien*, which attains nearly 500 feet, our Upper Lias. The "Upper Lias Sands" appear to be represented in the Côte-d'Or by ferruginous limestones and clays; they are included in the *Toarcien*. In the Cotteswolds, where they consist of sand and calcareous sandstones, and the distinction is sufficient to give a separate name to them, there is a diversity of opinion as to whether they are more closely related to the Upper Lias clay or to the Inferior Oolite. The probability seems that, in this respect, they occupy much the same position as the Rhætic beds, which belong as much to the Trias as to the Lias, and that similarly the sands form a passage between the Upper Lias clays and the limestones of the Inferior Oolite. The name should therefore be of a less particular kind, and have reference rather to any peculiar features of the beds themselves, or to the locality where they are best exhibited.

3. Inferior Oolite.—The *Oolithe Inférieure* (or *E'tage Bajocien*) is well developed in the departments of the Côte-d'Or, Saone-et-Loire, and the Rhone, and it will bear, in many respects, the same divisions which this stage presents in the Cotteswold Hills. M. de Ferry has well described the Inferior Oolite of the neighbourhood of Mâcon, and Dr. Wright here reproduces a generalized section of the beds in the Jura Maconnais, in order to show how well the structure of our English Oolite is repeated in the centre of France. The Côte-d'Or presents a section essentially the same. It is divided by M. Martin into five stages.

4. Great Oolite Group.—In the Côte-d'Or, according to M. Martin, the *Bathonien* stage exhibits six palæontological zones, all perfectly distinct, and which represent, as Dr. Wright shows, the beds from the Fuller's Earth to the Cornbrash, inclusive. Dr. Wright gives a detailed description of the beds which occur in the West of England. The identification of this great Oolite group is essentially palæontological.

The Northampton sands, until lately considered to represent the Stonesfield slate (Great Oolite), are now referred, on palæontological grounds, to the Inferior Oolite. Between the Great Oolite and the Forest Marble there sometimes occurs a bed called the Bradford clay. Although considered as merely a local thickening of a Forest Marble-clay, Dr. Wright remarks that when this is wanting, it is almost impossible to distinguish the upper beds of the Great Oolite from those of the next formation.

5. Oxford Clay.—The Oxford clay, or *Oxfordien*, of the Côte-d'Or, is divided into five stages. The lowest, a very fossiliferous stage, represents the Kelloway rock. The other stages consist in the main of marls, in which the lower calcareous grit appears to be represented.

6. Coralline Oolite.—Ammonites, so useful in the other Jurassic formations, being rare in the Corallian strata, other leading fossils

have to be substituted in correlating distant beds. In France, Germany, and Switzerland, the beds admit of a triple division. The first, in descending order, characterized by numerous species of *Nerinæa* and *Diceras arietina*, is termed the "Nerinæan zone;" the second, remarkable for the large number of corals it contains, the "Coral zone;" and the third is called the "Echinidian zone," from the abundance of Echinoderms in it. Of these three zones the Coralline Oolite, Coral Rag, and Pisolite, of William Smith, may, in Dr. Wright's opinion, be correlated with the second and third zones just mentioned. The newest or Nerinæan zone is absent in England, and this forms a distinct group, according to M. Martin, to which he gives the name *Séquanien*, while he applies the term *Corallien* to the other beds just below it, and which lie above the *Oxfordien*.

7. KIMMERIDGE CLAY.—The Upper Jurassic rocks were found by Dr. Wright to present a greater diversity of character in different regions than the members of the middle and lower divisions: the difficulty of establishing the synchronism of their several stages increases in the ascent from the Coral Rag to the summit of the Purbeck series. Our chief obstacle is considered by him to be the want of a better classification, and a more detailed study of the Kimmeridge Clay, and Portland formations of England. M. Martin divides his *Kimméridien* into—1. Marls and compact limestones with *Ostrea virgula*. 2. *Calcairesà Ptérocèren* with *Ostrea virgula* sparingly.

8. PORTLAND BEDS.—M. Martin makes two divisions of these beds, which are composed of marly limestones, the upper with *Trigonia Boloniensis* and *Pinna supra-jurensis;* the lower with *Ammonites gigas*. Dr. Wright points out the divisions made by other geologists. It is, however, in the environs of Boulogne-sur-Mer that perhaps the beds are best studied, and he therefore devotes some attention to the section given by M. Pellat. This he gives in a condensed form. The Portland beds are here divided into an Upper, Middle, and Lower, and comparing them with the section at Hartwell, he comes to these conclusions—1st. That in England the *Lower Portlandien*, or the beds with *Perna rugosa* and *Pterocera Oceani*, is absent. 2nd. That the *Middle Portlandien* is represented by the dark sandy clays of the brick-yard at Hartwell, containing *Ammonites biplex, Cardium Morinicum*, and *Ostrea expansa*, etc. A portion, likewise, of the overlying fossiliferous sand, with green Glauconitic grains, belongs to this group. 3rd. The *Upper Portlandien*, so largely developed in England, has at its base the non-fossiliferous sands without Glauconite, and in its middle and upper portions the true calcareo-siliceous limestones and other beds forming the Portland stone.

The correlation of our English strata with others at a distance is a subject of the highest interest, and although this sketch does little justice to Dr. Wright's elaborate paper, our object is gained by bringing it under the notice of the readers of the GEOLOGICAL MAGAZINE.—H.B.W.

II.—On the Cause of the Motion of Glaciers.

By James Croll, of the Geological Survey of Scotland.

[Philosophical Magazine, September, 1870.]

THE ice of a glacier is now almost universally believed to be, not a soft plastic substance, but a substance hard, brittle, and unyielding. The power that the glacier has of accommodating itself to the inequalities of its bed, without losing its apparent continuity, is referred to the property of regelation possessed by ice. All this, says Mr. Croll is now plain; but what impels the glacier forward is still a question under discussion. The answer generally given is that gravitation alone is the force which does this. But as the ice of the glacier descends with a differential motion, we have not only to explain what causes the glacier to slide on its bed, but also what displaces the particles of the ice over and alongside one another. The Rev. Canon Moseley[1] has lately investigated the cause of the descent of glaciers, and he has found that the amount of work performed on a glacier during its descent through a given space is enormously greater than the work of the weight of the glacier descending through that space. He has determined that the aggregate work of the resistances which oppose themselves to its descent in a given time is about thirty-four times the work of the weight in the same time; consequently it is physically impossible that the mere weight alone of the glacier can be the cause of its descent.

He has further shown that the mere weight of the ice is wholly insufficient to overcome the cohesion of the crystalline particles, so as to break their connexion and cause them to be displaced one over the other. And this point Mr. Croll regards as fully established.

Mr. Croll reviews Canon Moseley's paper, and also the observations of Messrs. Mathews and Ball, published in reply to it.[2]

It is generally supposed that the ice-particles of a glacier are in a hard, solid, and crystalline state, and that, owing to differential motion, the cohesion of the ice-particles is broken, and that these solid particles are forced over and alongside one another. Two particles separate, and the one moves past the other. "But," asks Mr. Croll, "were the two particles, at the moment when separation took place, both in the hard, crystalline, and solid state?" Canon Moseley does not prove this; he merely assumes it to be the case, and shows that if the particles of the ice are in this state, weight is insufficient to produce the descent of glaciers, and, therefore, some force in addition to it is required to cause the phenomenon. Mr. Croll argues that Canon Moseley has not proved his point; he has only shown, that *if* the glacier shears in the way that it is generally supposed to do, it cannot descend by its weight alone. Canon Moseley regards solar heat as the primary cause of glacier motion. The fact that a glacier moves more rapidly during the day than

[1] Proceedings of the Royal Society, January, 1869. See also Geological Magazine, May, 1870, p. 229.

[2] In reference to these replies, Mr. Croll states his inability to perceive that anything which they have advanced materially affects Canon Moseley's general conclusions as regards the commonly-received theory of glacier motion.

during the night, and during summer than during winter, proves that there must be some physical connexion between the heat of the sun and the motion of the glacier. Mr. Croll could never harmonize this fact with the commonly-received theory; and, while admitting the agency of heat, he remarks that heat is not necessarily the *cause* of glacier-motion. Gravitation may be the *cause*, and heat only a necessary *condition*.

To him there seems to be but one explanation, namely, that the motion of the glacier is *molecular*. His concluding remarks are as follow: The ice descends molecule by molecule. The ice of a glacier is in the hard, crystalline state, but it does not descend in this state. Gravitation is a constantly acting force; if a particle of the ice lose its shearing-force, though but for the moment, it will descend by its weight alone. But a particle of the ice will lose its shearing-force for a moment if the particle loses its crystalline state for the moment. The passage of heat through ice, whether by conduction or by radiation, in all probability is a molecular process, that is, the form of energy termed heat is transmitted from molecule to molecule of the ice. But at the moment that it is in possession of the passing energy, is the molecule in the crystalline or icy state? If we assume that it is not, but that in becoming possessed of the energy it loses its crystalline form, and for the moment becomes water, all our difficulties regarding the cause of the motion of glaciers are removed. We know that the ice of a glacier, in the mass, cannot become possessed of energy in the form of heat without becoming fluid; may not the same thing hold true of the ice-particle?

Thickness of Glaciers.—Appended to his paper is a note by Mr. Croll on the alleged limit to the thickness of a glacier. Experiments by Canon Moseley, on the crushing of ice, led this gentleman to conclude, that if a glacier be over 710 feet in thickness, the ice at the under surface must be crushed by the incumbent weight. Experiments previously made by Professor Phillips had led him to the conclusion that a glacier, exceeding 1,500 feet in thickness, would lose its solidity.

Mr. Croll maintains that, as a necessary consequence of the property of regelation, ice, after being crushed, would resolidify. So far as he is aware, there is no known limit to the amount of pressure which ice may sustain. On the Antarctic continent we have reasons for believing that the ice is in some places over a mile in thickness.

REVIEWS.

I.—On the Fossil Cycadean Stems from the Secondary Rocks of Britain. By William Carruthers, F.L.S., F.G.S., British Museum. Transactions of the Linnean Society of London, Vol. xxvi., 1870, pp. 675–708. 4to. 10 plates.

OUR knowledge of the true classification of the remains of fossil plants has greatly increased of late; not that any very large additions have been made in the number of species described since the days of Lindley and Hutton, but we have become better ac-