a little more, but the molecules of the stone remain stationary. The consequence is that gradually a vacuum is formed against the face of the stone. Now let us consider the molecules up-hill from the stone. Heat approaches the stone, and so do molecules. The second molecule from the stone melts, and comes down against the one touching the stone, which in turn melts as the other freezes. Now this last molecule cannot freeze, for no molecule of stone will yield to it as it yielded to its fellow, and so it remains for the time being a molecule of water. Gradually a great number of molecules of water get accumulated against the face of the stone. As their heat is conducted away they will exert a great force in freezing, and this, assisted by the vacuum forming against the opposite face, will force the stone a little bit down-hill.

Another very plausible application of this theory would be to suppose that the sun's heat in this molecular way got down from the surface of the glacier to its bottom, and there disengaged molecules of water, which would feed the stream which issues from under the glacier. Such action, however, would tend to keep boulders at the bottom of glaciers, whereas it is well known that somehow or other they get to the top.

IV.—ICE AND ICE-WORK IN NEWFOUNDLAND.¹

By JOHN MILNE, F.G.S.,

Professor of Geology in the Imperial Mining School of Tokei, Japan.

“And now there came both mist and snow,
And it grew wondrous cold;
And ice, mast high, came floating by,
As green as emerald.

And through the drift the snowy cliffs
Did send a dismal sheen;
Nor shape of men, nor beasts we ken—
The ice was all between.

The ice was here, the ice was there,
The ice was all around;
It cracked and growled and roared and howled,
Like noises in a swound.”—COLERIDGE'S *Ancient Mariner*.

WE often see a certain cause at work, and then its effect;—and the effect may be and is, doubtless, in many instances, peculiar to the cause. In Switzerland glaciers are known to have rounded and converted into “hummock”-shaped forms the rocks over which they have passed; whilst the rocks which were imprisoned in the ice, and used as tools to scour the rocky bed over which they moved, have in their turn also received a definite impression.

Hummocky tracts of land like those in Switzerland are to be seen in Scotland, Newfoundland, and other countries. Mounds of debris,

¹ The rough MS. of this Article was placed in the Editor's hands by his friend Mr. Milne early in 1875, but, owing to pre-occupation on the part of Editor and Author, was never put in type until this month, June, 1876. The author departed in August last for Japan, and has therefore been prevented from again seeing or revising his notes. The Editor trusts that this apology will be accepted by the reader should he find that the author has omitted to notice any papers on ice as a geological agent, which may have been published since that date.—EDIT. GEOL. MAG.

filled with scratched stones like those produced by a modern glacier, are to be found in many places. These and other appearances, which are peculiar to ice-action, are ascribed to it as their originators; for, whether they be of Permian or Pleistocene age, their origin would seem to be identical.

By studying the effects of modern volcanic outbursts, similar paroxysms can be shown to have occurred in bygone ages,—and it is only by having a knowledge of the present, that any true knowledge of the past can be obtained.

The action of ice upon the surface of the earth has been spoken of in all our Manuals and Text-books of Geology. De la Beche, Lyell, Ramsay, Jukes, Geikie, and others, all discuss it in its various forms.

The fact that existing glaciers had once a wide extension was not however observed earlier than 1821, when M. Venetz advanced the opinion with regard to those of the Alps. In 1836 these ideas were strengthened by the observations of M. Charpentier; but it was not until the distinguished naturalist Agassiz—fresh from the same Alpine school, where so many geological truths have been demonstrated—visited Scotland in 1840, that the curious rock-markings in that country were successfully shown to be identical with those produced by the glaciers of Switzerland.

Glaciers have been regarded from many points of view, and have been studied both mathematically and physically. Their effects have been noted, and they are now universally admitted to have been great tools in the modelling if not in the actual formation of the surface configuration of the earth. They were first suggested and shown to be a means of solving the puzzles of drift, rounded rocks, strange scratchings, and boulders, and ever since take the precedence of all other ice.

Their offspring, the Icebergs, have also been studied, and their work has been duly chronicled. The manner in which they bear rocks to warmer seas, and strew them broad-cast over the bed of the ocean, and even the way in which they may have aided in modelling a rising area, has long been dwelt on; but, being less important tools in Nature's workshop than their parents the Glaciers, deservedly without such emphasis. There is, however, another form of ice, which, from its unassuming appearance, although touched on by a few, has apparently taken too low a place in the rôle of actors with which it plays. This is the Coast-ice.

My first sight of large masses of floating ice was on my arrival at St. John's, Newfoundland, in the spring of 1872. On the morning of the 16th of May, we found ourselves wrapped in a fog, through which a high bold coast was dimly visible. At length it lifted, and we saw ourselves in a cliff-bound bay, at the head of which a narrow entrance showed us a harbour filled with ice and ships. Near us floated two great icebergs, whilst the sea around was covered with smaller lumps jostling against each other as they rose and sank upon the swell. This Arctic scene is depicted as occurring at the same place, but on a grander scale, in the frontispiece of "*Frost and Fire*," by J. F. Campbell, F.G.S.

This mass, consisting of floe-ice surrounding icebergs, was travelling southwards under the influence of the cold Arctic current, which, coming from the northern regions, after coasting along by Labrador, sweeps onward past Newfoundland, to sink beneath the warmer waters of the Gulf-stream in more southern latitudes.

On the coast of Newfoundland Icebergs generally make their appearance about the 1st of January. Their approach is heralded by a number of smaller pieces. When we reflect upon the origin of these bergs, it would appear that the greater number of them ought to be disengaged from their parent mass, the glacier, in summer-time. The semifluid mass, of which the glacier is made up, creeping slowly, like a frozen river, down the valley by the aid of heat, gravity, etc., has in summer-time its pace augmented by the increment it receives at this season of the year.¹ It then pushes itself rapidly forward into the ocean, and there by the buoyancy of the water the projecting ice-mass is detached and floated off. Why, therefore, is it that the bergs are not seen off the Coast of Newfoundland at the close of summer, or at the latest in the "fall" of the year? The answer to this may be obtained from the inference of Sir Edward Belcher, and other Arctic navigators, who tell us that in very high latitudes the ice appears to be in motion much earlier than it is farther to the South. On the 20th of May the western side of Smith's Sound has been found to be quite open for navigators in a boat, whilst Barrow Strait is not navigable till late in August. The consequence of this would appear to be that whatever ice may be set free far north early in the year is detained in more southern latitudes until the fall. Another cause also operating in keeping the ice off the coast until the spring of the year may be the wind. Although icebergs, with regard to their motion, and the direction of the wind, often present curious anomalies, yet this must to a slight degree be influential on their wanderings. In the "fall" of the year the prevalent winds on the North American side of the Atlantic are generally speaking from the west, which tend to keep all bergs out at sea, and thus, to observers on the land, they would be lost sight of; but in the spring of the year the winds are more or less northerly, which would only aid the current in bringing the ice along shore. The most apparent suggestion for the detention of the ice before reaching the shores of Labrador and Newfoundland is of course the distance it has to travel; but considering the steady rate at which this is carried on in the stream which bears them, the effects of wind, and the delay in the breaking up of the Southern Arctic barrier must have the precedence.

Theoretical considerations on the Flotation of Icebergs.—The icebergs I had the opportunity of seeing daily for several weeks whilst in the neighbourhood of St. John's, although irregular in their

¹ Sir James Ross, from his observations in the Antarctic Seas, infers from the greater difference between the temperatures of the sea and air in winter-time than in summer, that it is at the former season of the year that the greater number of bergs are detached.

outlines, were by no means of such varied forms as many that were seen afterwards. Several apparently very small pieces, projecting perhaps not more than a foot out of water, when approached showed themselves as considerable masses, their magnitude being hidden by their submergence. In the "offing" "islands of ice," as the bergs are here called, were to be seen moving southwards, whilst in the bay several of them were always to be seen aground. These latter, as they slowly rose and fell with the ever-varying swell caused by the wind and tide, were deranging and grinding away the beds on which they rested. The enormous power that one of these islands of ice must possess to do such work may faintly be conceived by approaching one of them in a boat, and then considering that, although there is a mountain above water, there is from seven to nine times its mass beneath the surface. The depth of water in which one of these ponderous masses of ice can ground may often be more limited than has generally been expressed. When the berg first leaves its parent the glacier, its sides may be more or less parallel to each other, and we may sometimes get a near approach to a prismatic form. In this case not only would there be about eight times the bulk of ice beneath the water as there is above, but also there will be about eight times the depth, and we might conceive, as Jukes and Geikie tell us in their "*Geology*" (p. 416), that if the mass rises "300 feet above the waves," we may imagine that it "has its bottom 2,400 feet below them." In the Arctic and Antarctic regions we may therefore understand the immense depths at which an iceberg can ground, and there disturb the strata. As bergs travel towards lower latitudes, as towards Newfoundland, what with the beating of the waves and the changing of temperature they of necessity lose a great deal of the regularity of character they may previously have possessed. The greatest loss appears to be upon the portion exposed to the atmosphere, but, perhaps, more noticeable "between wind and waters."

As this waste goes on, the berg must rise, and the ratio of the height of the exposed portion to the depth of that which is hidden grows greater. The result of this is that the exposed portion becomes less and less in diameter than that which is protected beneath the surface of the water, which at last may be looked upon as a kind of foot or pedestal.

That bergs, instead of descending in parallel sides beneath the surface of the water, rather extend outwards in the form of a broad base, depends on the assumption that the disintegration is carried on at a greater rate above water than below.

Apart from these theoretical considerations, it would seem from actual observations, that although icebergs have occasionally been seen in low latitudes to ground in deep water, as mentioned by De la Beche in his "*Geological Observer*," where one is recorded as being stranded in 720 feet of water on the Banks of Newfoundland, the bulk of them is only to be seen upon the shoals. In fact the grounding of icebergs is used by both the fishermen of Newfoundland and Labrador as a means of finding out shallows which may be used as fishing-grounds.

If a berg is seen to ground some distance out at sea, its bearings from the land are at once observed, and it is in this way that many of the banks have been discovered.

If, instead of taking such an extreme case as the one to which I have been referring, where the generally peaked appearance of a berg, as seen above water, might be imagined as standing on a wide-spread flat base beneath the water, we consider the portion of the berg beneath the water as being a general continuation of that above, even in this case it will be seen to be very improbable that the ice extends to the great depth which is usually assigned to it.

For example, in the accompanying figure let A B be the surface of water in which we see a piece of ice floating as indicated by the black line, the general direction of that beneath the water corresponding to that which is above. Approximating to such a figure, draw on the "give-and-take" system a many-sided pyramid, or in the limiting case a cone approximately equal in volume to that of the supposed berg. This is shown by the dotted line. We have given that the position of the cone beneath the surface of the water to that which is exposed are to each other in the ratio of 8 to 1. Therefore the volume of the whole cone, which we will call V , is to that which is exposed, which we will call v , as 9 is to 1, i.e. $\frac{V}{v} = \frac{9}{1}$.

But also, as similar solids are to each other in volume as the cubes of their corresponding dimensions,

$$\frac{V}{v} = \frac{9}{1} = \frac{(h + H)^3}{h^3},$$

where h equals the height of the small cone of ice above water, and H equals the depth of ice below the surface,

$$\text{whence } \frac{h + H}{h} = \sqrt[3]{9} = 2.080$$

$$\therefore H = h = 1.080$$

which is equivalent to saying that in a floating cone of ice the depth below the surface of the water is but very little greater than that which is exposed above. If the ratio of $\frac{V}{v}$ had been equal to $\frac{8}{1}$, then

H would equal h , or the depth below equal that which is exposed above. That the cone would tend to float with the apex upwards rather than

downwards, may be inferred from the fact that this latter position, where the base would be upwards, would raise the centre of gravity nearer to the surface of the water, and thus bring about a condition of equilibrium not so stable as if the apex had been upwards.

These considerations, it must be borne in mind, are purely theoretical, and are only used as a means of giving a clearer idea of some of the conditions under which ice may be found floating, and especially such ice as has suffered disintegration in its wanderings.

(To be continued in our next Number.)

V.—ON SCOTTISH MONOGRAPTIDÆ.

By CHAS. LAPWORTH, F.G.S.

(PLATES IX. AND X.)

§ I.—INTRODUCTION.

1. *Succession of Silurian Rocks in the South of Scotland.*—The oldest fossiliferous strata yet detected in the Silurian district of the South of Scotland are the dark Graptolitic shales forming the well-known Moffat Series. The total thickness of this group is under 600 feet, but it is nevertheless capable of separation into three very distinct palæontological divisions, each characterized by a large proportion of peculiar fossils. The first of these divisions is of Llandeilo age, the second represents a portion of the Bala formation of North Wales, and the third, or Birkhill division, appertains, at least in part, to the epoch of the Lower Llandovery.

But the formation of the highest importance geographically is a group of comparatively unfossiliferous shales and greywackes of enormous thickness; which—reposing on the highest division of the Moffat Series in some localities, and on the middle division in others—stretches in an almost unbroken sheet from St. Abb's Head to the Mull of Galloway, and occupies at least nine-tenths of the whole Silurian area. Its rocks are thrown into innumerable folds and contortions, and the inferior strata are exposed only in long narrow bands in the lines of the deeper anticlinals. This great group appertains wholly to the Middle Silurian epoch. To its lower division belong the Girvan rocks and the so-called Gala Group of the eastern and central districts. Its highest beds are the Hawick Rocks, formerly believed to be the most ancient strata in the South of Scotland.

To the south of the Hawick Rocks, and reposing conformably upon them, lie the more fossiliferous Balmae or Riccarton beds, which are of Wenlock age, and floor a long and narrow strip of country stretching from Kirkeudbright to the central portions of the Cheviots. Strata of Ludlow age occur only in the northern areas, where they emerge from below the Upper Palæozoic rocks of Lesmahagow and the Pentland Hills.

2. *Distribution of Rhabdophora in these deposits.*—Graptolites are met with upon several horizons in this succession. They are especially numerous in the Moffat Series, in all the divisions of which they occur in countless multitudes. In the Gala and Girvan beds they are found but sparingly, and in a few thin carbonaceous bands only. The Hawick rocks, though frequently swarming with the enigmatical *Protovirgularia*—like their equivalents in Wales and