tic-looking mass composed of rounded pieces of rock differing in lithological character both from the matrix and from one another, occurring along what looks like the strike of the rocks, and yet may be able to make out that it is entirely a superinduced structure due to brecciation in place and subsequent decomposition of the broken rock.

From these observations we may also learn another lesson, viz. that crushing may take place without producing any effects analogous to metamorphism properly defined, and may act in aid of true metamorphism or other chemical change, chiefly by comminuting and preparing the rock for chemical reaction.

V.—ARCHÆAN ROCKS.

By G. H. KINAHAN, M.R.I.A., etc.

(Read before the British Association, Manchester, 1887.)

AT the present time the American geologists, both those of the United States and the Dominion of Canada, are at variance as to the groups the Archæan should be divided into; it is however unnecessary to enter into this controversy, as the strata may be conveniently grouped, as in Selwyn's map (1884), into *Norians* or *Labradorians*, excessively coarse gneiss or other granitic rocks; *Laurentians*, gneiss and granite; and *Huronians*, schists with subordinate gneiss.

Some of the authorities both in the States and the Dominion would have us believe that the Archæans originally accumulated as crystalline foliated rocks; that is, the minerals were deposited by chemical action from solution. Others, however, hold that at one time they were ordinary sedimentary rocks, which during one or more successive periods of metamorphic action were changed into their present conditions. The present school of English Archæan geologists seems from their writings to coincide with the Americans, who believe in originally crystalline accumulations.

The facts in favour of the first theory seem to be obscure; we are indeed told that "chemistry forbids" an ordinary sedimentary rock changing into a schist, gneiss or granitic rock; yet in the field we can walk along beds that change from unaltered rocks through schist into gneiss, and thence into metamorphic granite. Such a change may be quite contrary to the chemical laws laid down by such Archæan geologists for their own guidance, but they are patent facts effected by the GREAT CHEMIST, and to be ocularly learnt by any ordinary observer who carefully works out any large tract of metamorphic rocks.

In connection with this subject the value of lithological characteristics may first be mentioned. It is now generally well known that any rocks, no matter to what period they belong, from the newest Tertiaries to the Archæan, if they have been subjected to sufficient metamorphic action, will be changed into schist and gneiss; that is, that foliation will be developed in them, although originally they may have been ordinary sedimentary rocks, volcanic

rocks, or even granite. Of course rocks that have once been metamorphosed, may again be so placed that they are subjected to a second, third, or even more periods of action; each, if not too excessive, further developing the foliation. The American rocks called Norians or Labradorians have excessively coarse foliation, some of the measured plates being at least a foot in length; these rocks at one time were considered on account of their structure, to be the oldest Archæan: but further research has demonstrated that they are as young, if not younger, than the associated rocks; as they originally were protrusions or intrusions, generally the latter, possibly of granite, into their associated rocks, and that their present structure is solely due to metamorphic action at successive times. In Ireland intruded courses and tracts of granite in the Castlebar District, Co. Mayo, and near Glenties, Co. Donegal, have been altered into a very coarse gneiss by metamorphic action, while in Slieve Croob, Co. Down, the margin of the granite intrusion has also by a similar process been changed into gneiss. It therefore appears evident that if any kind of rock, by sufficient metamorphic action, can be changed into crystalline foliated rock, such structure or composition by themselves cannot be taken as a test of the age of the rocks.

Dana, Le Conte, Selwyn, George Dawson, and other American authorities specially point out that between the American Archæan and the later rocks *there are the distinct records of a vast lapse of time*. In the Dominions this is most conspicuous, the unaltered fossiliferous *Primordial* or *Cambrian* rocks lying unconformably on the Laurentian gneiss, and the Huronian schists; the old rocks having been tilted, crushed up, metamorphosed and afterwards excessively denuded, prior to the *Primordial* or other later rocks having been deposited on them.

In Europe alone there are in different places representatives of the different Passage Beds between the different geological groups; there are, as Passage Beds between the Cambrian and the Ordovicians, the *Arenig group*; between the Ordovicians and the Silurians, there are the *Llandovery* or *Mayhill Sandstone group*; between the Silurians and Carboniferous, there are the *Devonians* or *Old Red Sandstone*, and so on upwards; it is therefore natural to suppose, that somewhere on the face of the globe there are rocks that represent the equivalents of the Passage Rocks between the Archæan and the *Primordial*; but if such rocks occur in England or Ireland, which to me appears very questionable, they are not the equivalents of any of the American Archæans, and ought not to be so called, but should be grouped as "Passage Beds" under a new and distinct name.

Except in Scotland, where it has been demonstrated by Murchison, there are no authentic records of a great lapse of time between the so-called Archæans and the later rocks. Circumstances have prevented the writer from being intimately acquainted with the English tracts now declared to be of Archæan age; but he has visited some of them, and in fact believes he was the first to suggest that the rocks in one of them might possibly be Archæan. Now, however, since the real Archæan rocks have been seen and studied, such a suggestion in refer-

ence to them, or any other tract of English metamorphic rocks, would be much more cautiously given. With respect to the Irish metamorphic rocks, however, statements can be more confidently made, and to him it would appear that *no rocks in that island are the representatives of the American Archæan, or even of the at present unnamed, or unrecognized, "Passage Beds" between the Archæans and the Primordial.*

Prior to 1878, as has been pointed out in papers published by the Royal Dublin Society and the Royal Geological Society of Ireland, first Jukes and Sterry Hunt, and afterwards Murchison and the writer, pointed out that the equivalents of the Laurentian rocks might exist in places in the provinces of Connaught and Ulster (*Cos. Antrim, Tyrone, Donegal, Leitrim, Sligo and Mayo*). Subsequently Hicks suggested that my supposed Cambrians in Tyrone (*Slieve Gallion District*) were more probably of Archæan age; while still more recently Drs. Callaway and Hull have stated that they have proved the existence of Archæan rocks in different places. But none of the tracts so exalted have the characteristics considered essential by Dana, Le Conte, etc., as *nowhere in Ireland are there records of a great lapse of time between the accumulation of the strata said to be Archæan and those of Cambrian or Ordovician ages.*

As to the rocks at Greenore and Kilmore, Co. Wexford, said to be Archæan, the first are evidently a metamorphic protrude of exotic rocks, and the second are interstratified with their fellows; the rocks in both cases being so intimately intermingled that it is absurd to attempt to separate them; here therefore there is no record of a vast lapse of time between the Archæans and Primordials.

In North-west Ireland, that is, the portions of the Provinces of Connaught and Ulster, between Galway Bay and the eastern boundaries of the Cos. Londonderry and Tyrone, there was one large tract of metamorphic rocks. This has now on it, in places, patches of Silurian and Carboniferous rocks, thus dividing it up into subordinate tracts; yet the connection between all of them is very conspicuous and can be easily traced out.

In Ulster there is an unconformability in these metamorphic rocks; but some of the strata above and below this unconformability have general characters so similar that it is disputed by some; the so-called Archæan are *a portion only of the rocks* below the unconformability. In places both in Ulster and Connaught portions of both the older and later rocks are unaltered, and contain fossils or markings that are considered to be fossils.

In North-west Galway and South-west Mayo, in the unaltered portions of these rock-tracts, there are fossils of Llandeilo types, and after tracing the equivalents of these fossiliferous rocks northward and north-eastward through North-east Mayo, Sligo, and Leitrim, into Donegal, Tyrone, and Londonderry, it induced the opinion, published some years ago (1878), that the later rocks in Ulster, that is, those above the unconformability, represented the upper portion of the Irish Ordovicians (*Volcanic and Slate Series*), and perhaps in part the Llandovery (*Passage Beds between the Ordovicians and Silurians*); while the strata below the unconformability

are the equivalents of the Arenig (*Passage Beds between the Ordovician and Cambrian*) and part of the Cambrian; the lower portion of the Ordovician (*Dark shale series*) being absent. And if the markings near Fintown, Co. Donegal, in the black shales belonging to the rocks below the unconformability (*gneiss and schist series*), which were exhibited at the British Association Meeting, Birmingham (1886), turn out to be Graptolites of Arenig types, as some consider them, *such evidence ought to prove the correctness of this suggestion.* This classification originally was made from petrological or stratigraphical evidence.

The Galway area, declared to be of Archæan age, is as follows. To the south-east granitic-gneiss with metamorphic and intrusive granite; these are margined by gneiss and schist; while in the western portion of the area there are rocks, principally argillaceous, very slightly altered, with intrudes of granite. The south-east granitic-gneiss can be traced, first northward, then north-westward, through schist into the "Doolough bed," in the neighbourhood of Killary Harbour; the latter rocks having in them fossils of Llandeilo types; while westward this granitic-gneiss can be traced through schist into the slightly-altered rocks margining the western coast. The latter rocks have all the characteristics of the "Doolough beds," although fossils have not as yet been found in them.

The supposed boundary of the Archæan area is an arbitrary line drawn nearly westward from Clifden to Oughterard; while both north and south of this line the major portion of the rocks are lithologically identical. *Therefore there are no records of a vast lapse of time.* Stratigraphically it seems proved, *that the so-called Archæans of Galway, instead of being the oldest rocks of the country, are the equivalents of the latest Ordovicians.*

In North-west Mayo (Erris) the tract that has been given a brevet rank is a patch of granite and gneiss, in sub-metamorphic rocks. Here there is a marked distinction between the lithological character of the rocks; but there are no records of a lapse of time, as there is no basal conglomerate in connection with the sub-metamorphic rocks, which the description given in the Geological Survey Memoir has led some to believe. The rocks in this tract have undergone much more metamorphism than those in the adjoining county, which led Griffith to believe they were older; possibly they may be of Archæan age—or the still-unnamed Passage Beds; but it seems more probable that they are of the same age as the rocks in North-east Mayo and South Donegal, which are as much, if not more altered, and whose age probably is either Arenig or Cambrian.

In North-east Mayo, Sligo, Leitrim, and Donegal, there are no hard boundaries to the tracts of the so-called Archæans; as the rocks in general graduate one into another, except in a few places where faults or intrudes occur. So gradual is the change, that the supposed boundaries have several times been changed. In fact, they are like the rolling fences of a farm adjoining a common, one time here and another time a mile or more away; yet, in reference to the Archæan boundary, each successive line is

said to be an "undoubted line of a double hiatus !!! the rocks on one side being Archæan, and on the other the equivalents of the Ordovicians." Yet on both sides of such boundaries there are in places identical rocks; this difficulty has, however, been got over by mapping all rocks inside the lines as gneiss, and those outside as schist—regardless of their lithological characters.

If the Fintown markings are not fossils, *all* the rocks below the unconformability may be of any age, from Arenig to Archæan, *but all must be included*, as they are portions of one regular series. They, however, cannot be the American Archæan, but, possibly, under such circumstances (that is, the Fintown markings not being fossils), they may represent the unnamed passage beds between the Archæans and the Primordial.

In the Co. Tyrone, the rocks of the Slieve Gallion district are more or less similar, lithologically, to the Huronians of Ontario. To the south of them there is a well-marked break in time between them and the fossiliferous "Pomeroy beds" (Llandovery?). Northward they are bounded by schistose rocks that lie on them unconformably; yet, but for this unconformability, the rocks above and below it are lithologically so similar, that they might be considered as belonging to one group. These Slieve Gallion rocks, although having lithological and other characters that might possibly suggest an Archæan age, are evidently, as has been pointed out in previous writings, the eastern extension of the rocks of the Pettigoe District, South Donegal, in which case they belong either to the Arenig or the Cambrian. The Pettigoe rocks in the new classification have not been given a brevet rank, but are said to be the equivalents of the Ordovicians.

The most northern portion of Ireland, Innistra Hull, off Malin Head, Innisowen, Co. Donegal, consists of gneiss. Possibly this may be a bit of the Laurentian Hills, separated by a convulsion of nature and strayed away, to be stranded and find a home off the coast of Ireland. More probably, however, it is of Arenig age.

It should be mentioned that the natural unconformity in the metamorphic rocks of Ulster is treated very cavalierly; as in some places it is recognized and pointed out as "the undoubted proof of the Archæan age of the rocks below it," while in all places where its position proved that the gneiss and schists below it must be portions of one and the same series, it is ignored and is said not to exist. It may also be interesting to record, that the two advocates for the presence of Archæans in Ireland are at variance; as the one rejects the idea of there being Archæans in South-east Wexford, while the other seems to say that there cannot be Archæans in Donegal, as the so-called "Laurentian gneiss" is an intrusive mass.