M.Sc. Thesis.

THE TRIASSIC SANDSTONE OF N.E. IRELAND WITH SPECIAL REFERENCE TO MINERALOGICAL CONSTITUTION.

by

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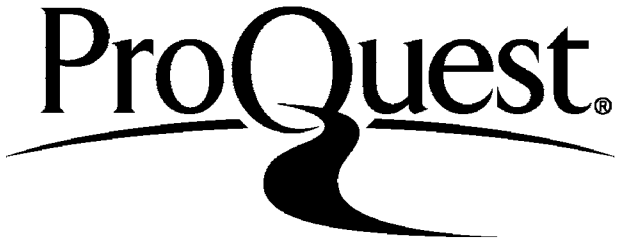

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WITH SPECIAL REFERENCE TO MINERALOGICAL CONSTITUTION.

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THE TRIASSIC SANDSTONE OF N.E. IRELAND

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INTRODUCTION.

Between the years 1869-83 the Triassic sandstone of north-east Ireland was examined and mapped by the Geological Survey under the direction of Professor E. Hull, M.A., F.R.S. The rocks were correlated with those of similar age in Lancashire and Cheshire, the lithological characters described and the exposures noted. Later the Belfast district was resurveyed under the direction of Mr. G. W. Lamplugh, F.R.S. In the Memoir published in 1904 as a result of the work he suggested that the Triassic sandstone should be correlated with the St. Bees sandstone rather than with that of Lancashire and Cheshire. Attention was also drawn to the probable incorrect mapping of the Trias near Belfast.

Up to the present, however, no steps have been taken to unravel the problem of the origin of the Trias in Ireland. The present investigation was undertaken in the hope of attaining something in that direction. It is concerned mainly with the mineralogical constitution of the Triassic sandstone, though the lithological characters have been re-examined and additional information gained concerning the conglomerate beds.

The rocks of Triassic age in Ireland are entirely restricted to the north-eastern counties, where they emerge in an almost continuous outcrop, in Antrim, Down, Armagh, Tyrone and Londonderry, at the base of the chalk and basalt escarpment of the Antrim plateau. A small faulted and isolated inlier occurs, farther south, near Kingscourt on the borders of the counties of Cavan and Meath.

Although the area over which Triassic sandstone is known to occur is of considerable extent, the number of exposures is exceedingly small. This is due to the general association of these soft

rocks with the larger valleys and depressions of the region and the thick covering of drift which everywhere conceals their floors. One has in consequence to rely on artificial excavations, stream-sections and occasional coast exposures. In many cases the sections noted by the Geological Survey are no longer visible, the old quarries being frequently filled with water, and the small stream sections grassed over.

II. MINERALOGICAL CONSTITUTION.

a. Localities visited.

Samples of sandstone have been collected and examined from the following localities :-

Co. Antrim. Belfast district - Falls Road, Skegoniel, Fort-william Park; White Abbey (north of Belfast Lough), Milltown (near Dunmurry), Cushendall district - Glenariff, Red Bay, Ballyeamon River; Murlough Bay.

Co. Down. Marino (coast near Holywood), Dundonald - stream dividing the townlands of Ballybeen and Ballyhaywood, stream west of Dunlady house; Red stone quarry between Dundonald and Newtownards, Scrabo hill, Ards Peninsula - Ballyhaft Cottage.

Co. Tyrone. Red Ford (near Dungannon), Torrent river, Coalisland.

Co. Londonderry. Moneymore - stream near Maple Lodge, Boherboy Cottage; Benbradagh (near Dungiven), Donald's hill. In the following streams which flow westward into the Roe :-

1. The stream east of Drumagosker.
2. The stream flowing from Kready mountain to Drummond bridge.
3. Curly river.
4. The stream which flows under Artikelly bridge (near Limavady).

b. Method of examination.

The method of treatment of the specimens may be shortly described. After crushing the rocks into sand and passing them through fine sieves, in order to separate the individual mineral grains, the sandstone was boiled in 30% H.Cl., with the object of removing the iron oxides coating the grains. The sands were later washed in running water to remove the fine dusty material and dried. A quantity, averaging about 60 gms. was then weighed and separated by means of a heavy liquid (usually bromoform) into two portions, one consisting of all the minerals with a specific gravity exceeding 2.8, the other of the lighter minerals, felspar and quartz. A record of the weight of heavy minerals thus obtained was kept.

In making these separations a separator similar to that described by Mr. W. F. Smeeth (1)* was used, its advantages being the absence of stop-cocks, which are liable to leak or become clogged, of small ledges on which the minerals can lodge and lastly that it is easily cleaned. Occasionally an additional separation was made with a bar magnet and electro-magnet.

Several specimens were thus examined from each locality, to ensure that an average sample had been taken and to note any variation in the different layers. A second separation, without the preliminary boiling in H.Cl. was also made in the case of the less ferruginous sandstones, to detect the presence or absence of minerals soluble in H.Cl.

c. Description of minerals.

The following is a list of the minerals identified, arranged according to their crystallographic systems :-

* The numbers in () brackets refer to the bibliography at the end of the paper.

(1) Cubic.
Garnet.
Magnetite.

(2) Tetragonal.
Anatase.
Rutile.
Xenotime.
Zircon.

(3) Hexagonal.
Apatite.
Calcite.
Dolomite.
Hematite.
Ilmenite.
Quartz.
Tourmaline.

(4) Orthorhombic.
Staurolite.

(5) Monoclinic.
Biotite.
Chlorite.
Hornblende.
Muscovite.
Orthoclase.

(6) Triclinic.
Microcline.
Plagioclase.

Garnet. This mineral is most abundant in the coarser beds. It occurs for example almost to the exclusion of the other minerals in the coarse sandstones near Dundonald railway station, its grains measuring as much as .5mm. in diameter. The average grain is only about.15 mm. Under the microscope the smaller grains are seen to be colourless, the larger ones, however, vary from pale to deep salmon pink. They are very angular and commonly diamond shaped, both angularity and shape being due to the development of the dodecahedral cleavage. In appearance they recall those figured by Dr. T. O. Bosworth (2) from the Coal-Measure sandstones of Scotland. One or two small crystals of garnet with dodecahedral form have also been seen.

Magnetite, recognisable by its magnetic properties and bluish-black colour in incident light, is never abundant. Though it occurs mostly as rounded grains, a few crystals with octahedral form have been noted.

Anatase occurs as aggregates of small crystals growing from grains of leucoxene, and more rarely as isolated rectangular crystals of tabular habit averaging about .05 mm. This form results from a combination of a broad basal plane (001) and exceedingly narrow pyramid planes (111). The crystals possess a high single refraction and vary from colourless to pale yellow. They are usually clear

but sometimes exhibit a cloudiness which is to be ascribed to decomposition. The crystal angles are always perfectly sharp, showing no signs of wear, which would seem to indicate that the whole of the anatase was derived from leucoxene after the deposition of the sandstone, thus bearing out the conclusion which was drawn by Mr. J. B. Scrivenor (3) on similar evidence from the sandstones of this age in Cheshire.

Rutile was observed as rounded grains averaging about .113 mm. in greatest diameter and less frequently as worn prismatic crystals, often striated parallel to the vertical axis and showing the following form :- (100)(110)(111). In the sandstone east of Drumagosker, near Limavady, grains as large as .37 mm. by .2 mm. occur. Geniculate and polysynthetic twins are present, though not very common. The colour varies from golden-yellow to deep reddish-brown, the former predominating; pleochroism is strongly marked: in yellow crystals O pale yellow, E deep amber and in brown crystals O reddish-brown, E dark red.

Zircon is most abundant in the finer sandstones, where it forms the predominant heavy mineral. It occurs as rounded grains and also as prismatic crystals, the largest of which have rounded terminations due to wear. The crystals vary from .075 mm. to .37 mm. in length and show the following forms, recorded in order of frequency :-

Prisms (100) and (110) with pyramid (111).
" (100) " (110) " pyramids (111)(311).
" (110) with pyramids (111).
" (110) " " (111) and base (001).

The zircons in the sandstone of Scrabo hill are perfectly formed crystals showing little sign of wear. They are fairly uniform in size possessing an average length .075 mm.

Zoning is not uncommon in the larger crystals. Inclusions are numerous and in the case of the zoned crystals are zonally arranged. They consist of zircon prisms, prisms and occasional

needles of rutile, slender prisms of apatite and long tubular glass inclusions.

The zircons are generally clear but some are cloudy, possibly as the result of decomposition. Occasionally pinkish coloured crystals resembling zircon have been observed which may be referrable to xenotime.

Apatite is probably characteristically present though its occurrence could only be ascertained in the pale coloured sandstones which it was possible to examine without a preliminary boiling in H.Cl. In these it forms one of the most abundant of the heavy minerals, occurring in colourless well rounded grains, ofter perfectly spherical and showing low birefringence colours and occasionally the imperfect cross cleavage. The grains vary from .075 mm. to .1 mm. in diameter.

Calcite is present as a cementing material and also occurs filling cavities in the sandstone near Limavady and in veins at Scrabo hill, in both localities exhibiting the scalenohedral form.

Dolomite. In the sandstone collected from Benbradagh small perfectly formed rhombohedra were found, averaging .05 mm. in diameter. These have been provisionally classed as dolomite. It should be noted, however, that they did not disappear on boiling for 10 mins. in 50% H.Cl. Also the twinkling effect shown by dolomite, when examined in polarized light, on rotating the stage, was not observed. The refractive index is practically the same as that of canada balsam and the crystals have to be mounted in water to be properly examined. The double refraction is high and straight extinction is shown with the diagonals of the rhomb shaped faces.

What appears to be the same mineral occurs also in elongated rhombohedra, which resemble monoclinic prisms terminated by basal planes.

The rhombohedra are sometimes intergrown, and in one instance a small rhombohedron was observed to be intergrown with an elongated crystal.

That the crystals were formed in place is clear from their perfect development.

Hematite. In addition to its occurrence as a cementing material, hematite is frequently present as large ragged plates.

Ilmenite was observed as rounded and ragged grains, forming often one of the most abundant of the heavy minerals. It shows signs of alteration to leucoxene, which not infrequently has entirely replaced it.

Leucoxene as an alteration product of ilmenite is abundant in rounded opaque grains, which are white, yellow or brown in colour. Anatase can frequently be observed growing from the surface of the grains.

Quartz occurs as rounded, subrounded and angular grains. The larger ones only show complete rounding, the majority being subrounded or subangular.

Strain shadows were very frequently noticed, a large number of the grains are composite, consisting of interlocking grains of quartz which sometimes show an elongation in one direction. These have evidently been derived from metamorphic rocks.

The researches of Dr. W. Mackie (4) on the quartz of the Scottish granites, gneisses and schists have shown that the type of rock from which quartz grains have been derived can be determined from the nature of the inclusions. An examination of the inclusions in the quartz grains of the Triassic sandstone of this area shows the following types to be present :-

1. Regular - zircon, tourmaline, rutile, biotite and possibly apatite.
2. Acicular - needles of rutile.
3. Irregular - glass (occasionally with enclosed bubbles), and very fine black inclusions, not determined.

Of these the regular type of inclusion is the most frequent.

Dr. W. Mackie says that 'It may be stated as a fairly general law that acicular and irregular inclusions pre-eminently abound in the quartz of granite; that the regular group is to be found in various proportions, but always in relatively large numbers in the quartz of gneiss and the younger schistose rocks."

Tourmaline. Its most common variety is of a deep brown colour and occurs as almost spherical grains, less frequently as prismatic crystals with rhombohedral and rounded terminations. Occasional striations parallel to the c axis were observed. Strong pleochroism is shown: O dark brown, E pale yellow. Blue tourmaline, exhibiting less strongly marked pleochroism, is also present in small amount, occurring as opaque spherical grains, splinters and small prismatic crystals of a bright blue colour. These blue and brown tourmalines sometimes grade to green and violet.

The blue tourmaline seems to be free from inclusions as in the case of that described by Messrs. C. B. Travis and H. W. Greenwood (5) in the Wirral Trias. The brown, however, is often crowded with inclusions, of which the most common are glass and iron-ore, while small crystals of rutile and zircon were also noted.

The brown tourmaline is generally very abundant, ranking as a rule next to zircon, whilst the blue, though almost always present, is only represented, in each separation, by a few grains.

Staurolite. This mineral, though almost invariably present, is never abundant, a few grains only being obtained as a rule from each separation. It occurs in pale yellow or greenish grains, sometimes showing slight pleochroism and a very characteristic toothed outline, due to fraying along the (110) cleavage, as described by Mr. T. O. Bosworth (6) in connection with the staurolite from the Keuper Marls around Charnwood. The grains average about .1 mm. in diameter, though in the sandstones rich in garnets from Dundonald they measure as much as .4 mm.

Micas. Both muscovite and biotite are present, the former invariably. Muscovite, occurring generally in perfectly oval flakes, forms one of the principal heavy minerals in some of the flaggy sandstones. Biotite is less frequently present.

Chlorite is sometimes represented, especially in the finer sandstones but is rarely abundant.

Hornblende. This mineral is very rare but was found in slight amount in the sandstones from Co. Londonderry, while one grain was detected in the sandstone examined from Red Ford, near Dungannon, Co. Tyrone. It occurs in small compact grains showing a tendency to prismatic habit due to breaking along the (110) cleavage. It is strongly coloured and shows marked pleochroism from yellowish green to bluish green. The extinction angle varies from 2° to 8°, and a convergent light picture can always be obtained, with an optic axis emerging near the margin of the field.

Felspar is usually very abundant. Rough estimates were made, by counting, of the percentage present in various specimens from the Lagan and Dundonald valleys. It was found to form as much as 30% to 40% of the bulk of the rocks. In some of the sandstones near Limavady it appeared to be so abundant that a special examination was made. A portion of the sand from the stream flowing under Artikelly bridge was suspended in potassium-mercuric-iodide of such a specific gravity as to separate quartz and felspar. The sand was separated into a lighter and heavier portion, and the operation repeated with the lighter, to make sure that no quartz remained buoyed up by the felspar. As a result 51% of felspar, by weight, was found to be present.

Orthoclase is the most common of the felspars. It occurs in grains which vary from rounded to angular and also in prismatic crystals. It is always more or less kaolinized.

Microcline is always present and seems to be most abundant in the Roe valley.

Grains of plagioclase were occasionally seen, which gave extinction angles indicating albite and oligoclase as the species present.

d. Distribution of the minerals.

From the tabular summary of the distribution of the minerals it will be seen, that with but few exceptions, the same suite of minerals is everywhere present, though the relative proportions vary. Examination of material collected from successive layers in various localities shows that this variation takes place in a vertical sense and is quite irregular, there being no definite increase or decrease of particular minerals as higher horizons are reached. The variation is partly dependent on the coarseness of grain of the sandstones, garnet and to a lesser degree staurolite being most abundant in the coarser sands, zircon and rutile in the finer layers. In view of this behaviour it was found impossible to trace any lateral variation.

It is noteworthy that occasional layers were found characterised by ilmenite almost to the exclusion of the other heavy minerals. This is notably the case at Scrabo hill, where the heavy minerals are represented by ilmenite, leucoxene, zircon and apatite. Only one small grain each of tourmaline and staurolite and a few grains of garnet have so far been detected at this locality, though 16 specimens, from different horizons were investigated.

III. BEARING OF THE MINERALOGICAL CONSTITUTION ON THE DIVISION OF THE SANDSTONE INTO BUNTER & KEUPER.

a. Divisions of the Triassic sandstone in Ireland.

In their classification of the Triassic sandstone of the north-east of Ireland, the Geological Survey have adopted the divisions which were determined in the complete development in Lancashire and Cheshire. They have recognised the following horizons :-

TABULAR SUMMARY OF THE DISTRIBUTION OF

HEAVY MINERALS IN N. E. IRELAND.

x = present; xx = frequent; xxx = abundant; xxxx = very abundant.

Locality.	No. of specimens examined	Garnet.	Anatase.	Rutile.	Zircon.	Apatite.	Hematite.	Ilmenite.	Tourmaline. (brown)	Tourmaline. (blue)	Staurolite.	Hornblende.	Leucoxene.
Skegoniel.	5	xxx		xxx	xxxx	xx	x	xxx	xxxx	xx	xx		xxx
Fortwilliam Park.	5	x	x	xxxx	xxxx	xx	xx	x	xxxx	xxx	x		xxxx
Falls Road.	3	xxxx	x	xxx	xxxx	xx	xx	x	xxxx	xx	x		xxx
Milltown.	3	xxxx		xxx	xxxx			xx	xxx	x	xx		xxx
Dundonald - Stream W. of Dunlady House.	2	x	xxx	x	xx	xxxx	xx		xxxx	x			xxx
Dundonald - Stream Nr. Station.	3	xxxx		x	x	x	xxx	x	x		xxx		x
Dundonald - Red Stone Quarry.	2			xxxx	xxxx			xxxx					xxxx
Scrabo.	16	x	x	xx	xxx			xxxx	x		x		xxxx
Ards Peninsula.	2	x	xxx	xx	xxx	xxxx	xxx	x	xxxx	xx			xxxx
Marino.	2	xxxx	x	xxx	xxx				xxx	x	xx		xxx
White Abbey.	2	xxxx		xx	xxx			x	xxx	x	x		xxx
Glenariff.	2	xxxx	x	xxxx	xx			xxx	xxx		x		xxxx
Red Bay.	6	xxx		xx	xx		x	xxxx	xxxx	x	xx		xxx
Ballyeamon river.	2	x		x	x			xxxx	x	x	xx		xxxx
Murlough Bay.	3	x	xx	x	xx		x	xxx	xxx		xx		xxxx
Red Ford - Nr. Dungannon.	2	x	x	xxx	xxxx		xx	xxx	xx	x	x	x	xxxx
Coalisland.	2	x	xxx	xx	xxxx				xxxx	xx			xxxx
Nr. Maple Lodge - Moneymore.	1	xxx		xx	xx		x	xxx	xxxx		x		xxxx
Boherboy Cottage - Moneymore.	2	xxx	xxxx	xxxx	xxxx		x	x	xx	x			xxxx

	No. of Specimens examined.	Garnet.	Anatase.	Rutile.	Zircon.	Apatite.	Hematite.	Ilmenite.	Tourmaline. (brown)	Tourmaline. (blue).	Staurolite.	Hornblende.	Leucoxene.
Benbradagh.	2	x		x	xx		xx	xxx	xxx	x		x	xxxx
Donald's hill.	3	xxxx	xxx	xx	xx	xxx	x		xxx	x			xx
Nr. Drumagosker.	2	xxxx	xxx	xx	xx			xxx	xx		xxx	x	xxxx
Stream from Kready Mt. to Drummond Bridge.	1	x	x	xxx	xxxx		x	x	xx		x	x	xxxx
Curly river.	2	xxxx		xx	xxx		x	xxx	xx			x	xxxx
Stream flowing under Artikelly Bridge.	5	xxx	xx	xx	xxx		xx	xxxx	xx	x	x		xxx

Lower Keuper Sandstone.
Upper Mottled Sandstone.
Middle Bunter Sandstone (Pebble beds).

Deposits of Middle Bunter Sandstone age have only been recognised in the neighbourhood of Cookstown, Co. Tyrone (7a). There the basement beds of the Trias consist of coarse sandy red breccia, containing fragments of the underlying granite and schist of Slieve Gallion and a few quartz pebbles. They pass up into a finer conglomeratic deposit with interstratified beds of sandstone.

The sandstone underlying the Lagan and Dundonald valleys and margining the head of Strangford Lough, has, with the exception of that of a few localities to be mentioned later, been assigned to the Upper Mottled Sandstone (8a)(9a). Strata of this horizon are likewise recorded from the western edge of the basalt plateau in the counties of Armagh (10), Tyrone (7a) and Londonderry (11)(12), occurring as far north as Magherafelt in the latter county. They have also been noted in two small isolated exposures north of this (13), one 1½ miles south-east of Maghera and the other 3 miles south-west of Garvagh. In the demesne of Spring hill, south-east of Moneymore, Co. Londonderry, pale red sandstone, resting on a fine pebbly grit, is exposed beneath chalk-rock and is seen to pass into white conglomerate. These beds, which are about 6 feet thick, rest on a sandstone which is classed as Bunter, and have been correlated by Professor Hull with the Lower Keuper Sandstone (7b). Mr. F. W. Egan, B.A. states that they "are limited in extent, and appear to form merely a small band that quickly dies out." Mr. Egan also records "A few beds of hard red shale and light reddish gray sandstone in the river Callan, two miles north of Armagh," which "are supposed to belong to this division." (10).

The sandstones of the northern localities, viz., those in the neighbourhood of Cushendall (14a) and Murlough Bay (15) in Co. Antrim, and those outcropping to the west of the plateau north of Dungiven (11)(12) and over a small area near Maghera (13), are regarded as of Lower Keuper Sandstone age.

The Geological Survey assign to the horizon of the Lower Keuper Sandstone the rocks of certain localities in the Lagan and Dundonald valleys, viz. a small patch protected by a dolerite sill, round Dundonald railway station (9b), the sandstone of Scrabo hill immediately underlying the capping sill of dolerite (9.c), a small outcrop on the south-east shore of Belfast Lough, about 1 mile north-east of Holywood (9d), the sandstone shown in an exposure near Falls road cemetery Belfast (8.b) and at the base of the Keuper marls north-east of Hullstown (8.c) and the beds exposed in a quarry about 2 miles north-west of Lisburn (8.c.).

In the case of Scrabo hill it is stated in the Memoir (9.e) that "The beds which form the base and flanks of Scrabo hill and vicinity answer exactly to these divisions [Upper Mottled Sandstone and Lower Keuper Sandstone], both in regard to relative position and stratigraphical and mineral characters. The beds which lie immediately beneath the dolerite, and are so largely worked for building purposes have a remarkable resemblance to those of the Lower Keuper Sandstone in the neighbourhood of Liverpool and Birkenhead; whilst the subordinate softer strata of bright red sandstone on which they rest are similar in every respect to the Upper Mottled Sandstone of Lancashire and Cheshire, which is so finely laid open in the railway sections near Ormskirk."

Near Dundonald railway station, a section, made by the stream forming the boundaries between the townlands of Ballybeen and Ballyhaywood, shows yellow and brown sandstones overlying a conglomerate containing angular chips of slate and fragments of vein quartz, beneath which is current-bedded red sandstone. Professor Hull (9.b) thinks that this conglomerate is probably the basement bed of the Keuper.

In the more recent Memoir on "The Geology of the Country around Belfast" published in 1904, Mr. G. W. Lamplugh, F.R.S. after referring to this classification notes that "to the west of the Lagan the Keuper Marls rest directly upon soft sandy beds presenting

the lithological characters of the "Bunter Sandstone" without the intervention of beds like those of Scrabo hill." (16.a). Later he draws attention to the fact that Prof. W. B. Dawkins has pointed out that the presence of thick Saltiferous Marl, resting on over 700 ft. of red and grey sandstone, in the north of the Isle of Man, proved in deep borings "links on the salt-field at Carrickfergus with those of Barrow and of Cheshire, and shows that the Irish Sea is a basin in which the salt-bearing Triassic marls were deposited." (17). Mr. Lamplugh (16.b) then concludes that "if the Triassic strata of the North of Ireland have been deposited in the same basin as the Trias of the Isle of Man and Cumberland, it is to this nearer quarter that we should look for correlation, and not to the more distant area of Lancashire and Cheshire. And if this course be followed, the Triassic sandstones of this part of Ireland may be regarded as the equivalents of the St. Bees' Sandstone, underlain as in Cumberland by the Lower Marls and with an attenuated representative of the Permian, comparable to that at Whitehaven and in the Isle of Man, occurring in places at their base."

In the small isolated exposure near Kingscourt, both Bunter and Keuper Sandstone has been recognised. (18).

b. Mineralogical differences between the Bunter and Keuper sandstone in Wirral.

It has been shown by C. B. Travis and H. W. Greenwood (19) that the Bunter and Keuper sandstones of Wirral "differ as to the physical condition of their component grains but are alike in containing the same minerals." The differences recognised by them are as follows :-

1). The Bunter contains a preponderating percentage of rounded grains, whilst the Keuper shows a high percentage of angular and subangular grains.

2). Difference in grain size of Upper Bunter and Lower Keuper - the grains in the Upper Bunter averaging .3 to .4 mm., whilst those in the Lower Keuper average .65 mm.

3). The occurrence of large grains of felspar in quantity in the lower beds of the Keuper, with an absence of any similar development in the Bunter.

4). The "regularity of grain size in the Upper Bunter and one might almost say throughout the Bunter series" contrasted with the "agglomerate of grains of widely different dimensions" which generally make up the Lower Keuper.

c. Absence of mineralogical differences between the Bunter and Keuper sandstone in Ireland.

Whilst the same differences between Bunter and Keuper would improbably be recognisable here, the sandstone having obviously been derived from a different source from that indicated by the authors in the case of the Wirral Trias, yet one would expect some corresponding change in the conditions of deposition of the two horizons. It is, however, impossible to distinguish mineralogically between the Bunter and Keuper sandstones as determined by the Irish Survey. Not only is the same assemblage of minerals present in each division, but the physical characters of the grains are identical. Detailed study of the rocks reveals no change in the source from which the material was derived, nor in the conditions under which deposition occurred. In this connection it may be remarked that the Geological Survey do not cite a single instance in which the Keuper sandstone can be seen resting on an eroded surface of the Bunter. Speaking broadly, they class all the northern sandstone as Keuper and the Southern as Bunter. In the case of the northern outcrops - in the Roe valley, Co. Londonderry; Murlough Bay and the neighbourhood of Cushendall, Co. Antrim, the sandstone has presumably been classed as Keuper on account of its stratigraphical position beneath the marbs and the absence of a recognisable break in the sequence. In Co. Londonderry, where excellent exposures are to be seen in the many streams flowing westward into the Roe valley, every gradation can be traced from the basal sandstones, through marly sandstones, to the true marls.

Whilst the main part of the sandstone in the south of Co. Antrim and in Co. Down and Co. Tyrone has been regarded as belonging to the Upper Mottled Sandstone, yet, as already mentioned the sandstones of certain isolated localities have been assigned to the Keuper. In the case of two of these exposures, viz. those in the demesne of Spring hill, south-east of Moneymore, and beneath the dolerite sill near Dundonald railway station, small local conglomerate beds have been taken as representing the basement rocks of the Keuper. With regard to the so called Bunter and Keuper on the flanks of Scrabo hill, the Geological Survey (9.c) confess their inability to determine any definite line or plane of demarcation between the two horizons. The beds exposed in the large quarries of Scrabo hill certainly differ from all others of Triassic age in Ireland, in their compact and hardened nature, but this may probably be ascribed to the intrusion of the dykes and sills of dolerite with which they are riddled, and not to any original difference on deposition.

The reason for the correlation with the Keuper of the other small exposures mentioned above, is not apparent.

This classification seems forced and unnatural when the similarity in mineralogical constitution between the "Bunter" and "Keuper" sandstones is borne in mind together with the fact that in the southern part of the area the so called "Upper Mottled Sandstone" is always followed by Keuper Marls. In connection with this question of classification three possibilities present themselves :-

1). The Bunter and Keuper sandstones may both be present, the latter lying directly under the marl, but indistinguishable from the lower horizon, there having been continuous deposition in the area.

2). Bunter and Keuper sandstone may be present and separated by a plane of erosion, as yet undetected on account of the scarcity of exposures, though in the Londonderry area this is seemingly absent.

3). The sandstones may all be of Keuper age. Strength is given to this view by the relatively small thickness of these rocks as compared with those of England.

Permian beds are only known to occur in three isolated localities in Ireland, namely, in Armagh, at Cultra in Co. Down, and at Tullyconnel in Co. Tyrone. Mr. G. W. Lamplugh (16.c) thinks that there "is strong reason to believe ---------- that other deposits of this period may be concealed beneath the Triassic marls and sandstones of the Lagan valley," for in three borings in Belfast marls were encountered beneath the sandstone. It seems probable that the fewness of outcrops and the discontinuity of this formation is due rather to erosion prior to the deposition of the Trias, than to deposition in isolated basins. If this be so, since it is in strong contrast with the conditions that obtained in England, where as Mr. H. W. Greenwood (20) and others have shown, general conformity exists between Trias and Permian, it is probable that at least the lower beds of the Bunter are absent in Ireland.

IV. SOURCE OF THE MATERIAL.

a. Source of the rock fragments in the conglomerate beds.

The conglomerate beds of Murlough Bay, Red Bay - Cushendall and the Roe valley were examined and rock fragments collected from them for identification.

In Murlough Bay the sandstone contains angular fragments of schist, brown quartzite, vein quartz and occasionally gneiss pebbles. All of these have evidently been derived from the underlying Pre-Cambrians.

The Trias is well exposed in the cliffs skirting Red Bay, between Cushendall and Waterfoot. The basal part near Cushendall is coarsely conglomeratic and consists of boulders of quartzite, vein quartz and mica-schist ranging up to 1 ft. 6 ins. in diameter. Of rarer occurrence are large rounded blocks of the underlying Old Red Conglomerate and fragments of the felstone porphyry of similar age. Higher up in the series the conglomerate becomes finer and grades through pebbly sandstone into fine sand. In the higher beds angular

schist fragments predominate though pebbles of quartzite, vein quartz and pink "quartziferous-porphyry" are not uncommon. Less frequent are pebbles of grey "quartziferous-porphyry", dark compact hornblende schist and a light grey gneissic rock.

Prof. G. A. J. Cole, F.R.S. very kindly examined some of the rock fragments collected from this district and from the Roe valley. He suggested that the grey gneiss was derived from the gneissic series north of Cushendun and that the "quartziferous porphyry" was probably a varietal type of the rocks (described in the Memoir by Mr. A. M'Henry, M.R.I.A. (14.d)) which are intrusive in the schist series north of Cushendun.

Since then the district indicated has been visited, and the rocks of the Tor Head series examined between Cushendun and Tornamoney. It was found that the schist and gneiss fragments from the Triassic conglomerate can all be matched there, whilst the pink and grey "quartziferous-porphyry" is similar to the dyke-rocks which traverse the series.

In the sandstone exposed on the west of the River Bush, Mr. R. G. Symes, M.A., F.G.S. (14.b) records the presence of "occasional pebbles of quartz and mica schist, derived from the metamorphic rocks which are very close."

East of Limavady conglomeratic beds are exposed in the stream which flows under Artikelly bridge. At the marked bend south of the Coleraine road the section is as follows :-

Boulder clay.
Red sandstone.
Conglomerate bed - about 2 ft. thick.
Red sandstone - " 4 " "
Conglomerate bed forming bed of stream.

The pebbles in the upper conglomerate bed rarely exceed 3 ins. in length and are usually smaller. The rock included in the order of frequency: quartzite, brown, green and grey; granite, white and pink and always very rotten; vein quartz and brown sandstone (very rare). One or two very small fragments of a white compact rock were also found, which Prof. Cole thinks might possibly be thoroughly disintegrated chert from the Carboniferous.

Prof. Cole, who examined some of the fragments, writes "The powdery fine grained granite is allied by the pink tinge of its felspars, to the granites of Tyrone which are probably of Pre-Cambrian age." Of another pebble he writes "This looks igneous. Possibly connected with what we may call the Tyrone granite series (Pre-Cambrian)." The quartzite he regards as possibly being Dalradian and the brown sandstone he says "might well come from the local Carboniferous."

The conglomerate beds of Cookstown which are described in the Geological Survey Memoir, Sheet 27, could not be located. That they are local in character, however, is seen from the following description, given by Mr. F. W. Egan, B.A. in the Memoir. "The lower portions are composed of a coarse sandy red breccia with some thin layers of sandstone, the former containing fragments of the underlying granite and schists, and a few quartz pebbles. Higher up they become finer, and less compacted; and at the top they become quartzose and assume the form of a fine conglomerate, with interstratified beds of sandstone." (7.a)

As described by Mr. J. L. Warren, B.A., F.R.C.S.I., small conglomerate beds are exposed in the Dundonald valley in Carnamuck Glen and the little stream to the west (9.f) and in the stream forming the boundaries between the townlands of Ballybeen and Ballyhaywood (9b). In each case the sandstone contains angular chips of slate and pebbles of vein quartz, evidently derived from the underlying slate rocks.

b. Source of the minerals.

The derivation of the sandstones is very clearly indicated by the assemblage of minerals present. It has already been shown that according to the laws laid down by Dr. Mackie, the quartz was derived from gneiss or schist, a conclusion which is upheld by the frequency of strain-shadows and schistose grains. The presence of the metamorphic minerals garnet and staurolite and the abundance of muscovite point in the same direction.

Twelve schist fragments from the conglomerates at Murlough Bay and Cushendall and two gneiss fragments from the latter locality were broken up and the heavy minerals examined. The following were found to be present :- Mica (in great abundance), chlorite, iron ores, leucoxene, zircon, rutile, apatite (in short prismatic crystals), garnet and brown tourmaline (showing well formed rhombohedral termination and frequently crowded with inclusions of iron ore). Thus, all the heavy minerals found in the Triassic sandstone are represented in the schist and gneiss fragments, with the exception of staurolite. It is almost certain that continued search would reveal its presence, however, since Dr. Geikie has found staurolite in the schists at Ballycastle (15). With the exception of mica, the heavy minerals in the schists are by no means abundant when compared with those in the Triassic sandstone. It is possible, however, that they occur in the same ratio with the light minerals (quartz and felspar) in both rocks, their presence in the schist being masked by the superabundance of mica.

Reference may be made to the fact that crystals of garnet and tourmaline have been noted in a few localities, by the Geological Survey, in the local schists. Garnets are recorded from the schists exposed in the Glendun river (in the neighbourhood of Cushendun) and its tributary the Bryvore (14.c) water and tourmalines from near Ballycastle (15) and the schistose ridge north-west of Maghera (13).

The question next arises as to whether the sandstone was derived directly from the schists or indirectly via the older sediments. A few specimens of Carboniferous sandstone from near Ballycastle and from the Roe valley, of Old Red Sandstone collected between Cushendall and Cushendun and of Ordovician slate from near Newtownbreda were examined in this connection. Each yielded the same suite of minerals as the Triassic sandstone and the same type of quartz.

In the north of the area, there can be little doubt that the main part of the sandstone was derived directly from the schists. Near Limavady, however, the fragments of the local Carboniferous sandstone, in the conglomerate beds, clearly indicate that that formation was providing some material. Similarly, in the neighbourhood of Cushendall the underlying Old Red Sandstone contributed at least to the basement beds. In the south the Ordovician and Silurian were yielding material, as shown by the presence of slate fragments in the small conglomerate beds in the Dundonald valley.

At one time it was hoped that some indication as to the part played by the older sediments could be estimated from the percentage, by weight, of felspar present. This idea, however, had to be abandoned. Nevertheless it should be noted that felspar is as a rule abundant.

In an early stage of this investigation it was also thought that the direction of flow and hence the localities of the rocks providing the material, might be ascertained from the variation shown in the percentage by weight of heavy minerals present. No general variation was, however, discovered and small vertical variations from layer to layer made it impossible to trace slight lateral variations.

With the same end in view, a record was kept of the direction of current-bedding observed in various localities. It was found, to be of little value, since the directions are very variable, though the balance of evidence is in favour of flow along the Dundonald valley in the direction of Strangford Lough. If this be so, then it would seem that the schists were directly contributing to the sandstone of even the most southern exposures.

Strength is perhaps given to the view that there was a main flow from north to south by the degree of rounding of the quartz grains. In the northern localities they vary from angular to subangular, whilst in the south a larger percentage are subrounded to rounded. This is capable, however, of other interpretation.

V. EVIDENCE AS TO THE EXISTENCE OF TWO BASINS OF DEPOSITION.

From the evidence of the conglomerate beds it is apparent that, in Triassic sandstone times, the rocks of the Tor Head series formed a ridge, from which material was carried both to the north and the south. Further evidence of this ridge is to be found in the northerly thinning of the sandstones. Their greatest development is in the Lagan valley where bores in Belfast and near Lisburn have revealed a thickness exceeding 500 feet, whilst in the neighbourhood of Carrickfergus the thickness has been estimated by Mr. Doyle as between 800 and 1000 feet. The estimate given by Mr. A. M'Henry, M.R.I.A. (14.b) of the combined thickness of the sandstone and marl near Cushendall, however, is only 300 ft. He records, moreover, that at the head of the Ballyeamon valley the Trias overlaps the Old Red Sandstone and thins out.

North of the ridge, in Murlough Bay and on the north-east slope of Carnamore Mt. the Geological Survey (15) give the total thickness of sandstones and marls as only 60 ft. In the last mentioned locality the rocks are described in the Memoir as a "limited lenticular deposit" which thins away rapidly both to the north and south.

On the west of the plateau the rocks of Slieve Gallion formed part of a ridge from which material was carried to the south-east. It was mentioned earlier that Prof. Cole recognised a resemblance between the rock fragments found in the conglomerates near Limavady and the Pre-Cambrians of Tyrone. In view of the distance between these conglomerate beds and the ancient Tyrone rocks, it seems more likely that the fragments were derived from a north-easterly extension of the Tyrone Pre-Cambrians, hidden beneath the basalt, than from the rocks now exposed.

Thinning towards the ridge cannot be well traced on the west of the plateau, since in the northern area the highest horizons of the Trias are overlapped by the basalt. It should be mentioned however, that only a little more than 300 ft. of sandstone were

passed through in the Bartley pits near Cadisland.

Thus both to the east and west of the basalt plateau there is evidence of a ridge of ancient rocks which existed in Triassic sandstone times. In this connection Professor J. K. Charlesworth, D.Sc. drew my attention to the fact that the northern boundary fault, which forms the northern limit of the Old Red Sandstone of the Central valley of Scotland and of Arran, can be traced across into Ireland. There it strikes across from Cushendun, on the north-east coast, through Cos. Antrim, Londonderry, Tyrone, Fermanagh, Leitrim and Sligo to the west coast in Co. Mayo, continuing to form the northern limit of the Old Red Sandstone. This fault coincides in a suggestive manner with the position of the southern boundary of the ridge and in consequence it may be concluded that it continues to bound the ridge beneath the basalt covering.

No evidence can be obtained as to the northerly extension of the ridge, now concealed by the basalt, though from the occurrence of conglomerate beds near Limavady it is probable that it lay at no great distance from that locality. That it narrowed considerably to the west and may have even been breached is apparent from the presence of two small outcrops of Triassic sandstone, one three miles south-west of Garvagh and the other near Maghera. The exposure in the Bush river in the east may lie in another transverse valley.

MAP SHOWING APPROXIMATE POSITION OF SCHISTOSE RIDGE.
Unshaded portions of ridge represent possible transverse valleys.

Hence it appearsthat the Triassic sandstone was deposited in two basins, separated more or less completely by a barrier of ancient rocks, which extended in a N.E. - S.W. direction as shown on the map.

Very little information can be gained as to the southerly extension of the southern basin. That deposition took place far to the south of the Lagan valley is known from the occurrence of the isolated outlier of sandstone and marl at Kingscourt. From the presence of chips of slate in the sandstones of the Dundonald valley, however, it may be inferred that such rocks were exposed close at hand. A study of relative elevations reveals the possibility that in early Triassic times a ridge of high land may have existed over a large part of what is now the Ards peninsula. Also Newry granite and the surrounding slates may have risen above the level of the sandstone, though nothing can be learned as to the extension of such ridges.

It is probable that the Triassic sandstone never extended much farther westward than its present boundary, for evidence of thinning is to be found there. Mr. G. H. Kinahan, M.R.I.A. in the "Geology of Ireland"states that "in Slieve-Gallion-Carn the Triassic rocks can be very little more than 20 or 30 ft. thick and farther northward at Mullaghmore, to the west of Moneyneany, they seem to be less than 10 ft. thick." (21.a) Again, near Stewartstown, the sandstone "seems to be very thin, as there is not room for more than 20 to 30 ft. in thickness between the Chalk and the Carboniferous rocks." (21.b). As already mentioned 300 ft. of sandstone were proved in the Bartley pits near Coalisland. To the west, in the Creenagh pit, however, it has a thickness of only 160 ft.

VI. CLIMATIC CONDITIONS AND AGENTS OF DEPOSITION.

Evidence of arid conditions in Triassic times is not lacking in Ireland. Thick beds of salt are intercalated in the Keuper marls in the neighbourhood of Carrickfergus and worked at Duncrue.

Layers and beds of gypsum are to be found in the marls north of Belfast Lough and in the district near Kingscourt, whilst the prevalent red colour of the sandstones and marls furnished additional evidence.

An examination of the degree of rounding of the quartz grains, however, does not lead to the conclusion that wind has played a very great part in the deposition of the rocks. The sandstone bounding the schistose ridge is composed for the most part of sub-angular and angular grains, though some of the coarse sandstone which forms the matrix of the massive conglomerates at Cushendall, contains a fair percentage of grains which are subrounded to rounded.

In the Lagan valley rounding is more common and some of the beds may be largely composed of wind blown sand. Yet even there angular grains are not wanting. Many of the fine sands are sub-angular whilst the coarse contain some angular grains.

From these considerations it would appear that the sandstone was carried down from the Pre-Cambrian and Palaeozoic highlands by numerous streams which spread out their debris over the basin floor. In early Triassic times boulders and pebbles were washed down the slopes of the schistose ridge and distributed close at hand. As the ridge was progressively lowered, the streams moved smaller and smaller fragments, until finally they were only capable of carrying sand.

Deposition may have been intermittant, taking place mainly during periods of heavy rainfall. The thin beds of sandstone, intercalated in the conglomerates, which usually vary from a few inches to a foot in thickness, possibly represent the drier periods.

Towards the south, wind action may have been more prevalent. Yet it should not be forgotten that the more noticeable rounding of the grains may possibly indicate the greater distance from the schistose ridge, or a derivation from pre-existing sandstones.

Rounded marl pebbles are frequent in the sandstones and sometimes occur, e.g. at Falls road, associated with the best rounded sands. This seems to indicate deposition of the sand in water, with sufficient movement to break up the marl bands, even if wind were the agent of transport. That the basin was occupied at least in places by pools of standing water, liable at times to shrinkage, is apparent from the presence of sun-cracks at Scrabo hill.

VII. SUMMARY.

In conclusion, the results of the investigation of the Triassic sandstone of north-east Ireland may be summarised as follows :-

1. The conglomerates are all local in origin. In the east of the area they were derived from the rocks of the Tor Head series and the sandstone and porphyry of Old Red age, and in the west from the granite and schists of Slieve Gallion and rocks similar to the Tyrone Pre-Cambrians.

2. The fragments in the conglomerate beds give evidence of the existence of a ridge of high land composed of the rocks of the Tor Head series and rocks similar to the Tyrone Pre-Cambrians. It extended in a N.E.-S.W. direction and was bounded on the south-east by the continuation of the northern boundary fault of Scotland.

3. This ridge separated the area of deposition into two basins, but it narrowed and may have been breached in the line of the Bush river and again a few miles east of Dungiven.

4. The assemblage of heavy minerals which compose the sandstones together with the abundance of inclusions of the regular type in the quartz grains indicates derivation either directly or indirectly from metamorphic rocks.

5. The same suite of heavy minerals and the quartz containing inclusions of the regular type occur in the local schists, the sandstones of Old Red Sandstone and Carboniferous age and the Ordovician slates.

6. In the north of the area the sandstone was mainly derived from the schistose ridge, whilst in the south the older sediments probably provided a large percentage of the material.

7. The sand and rock fragments were carried into the basins from the surrounding high land by stream action, though in the Lagan valley a considerable part of the sand may have been wind blown.

8. It is impossible to distinguish between the Bunter and Keuper sandstones, recognised by the Geological Survey, either by the assemblage of minerals present or by the physical characters of the grains.

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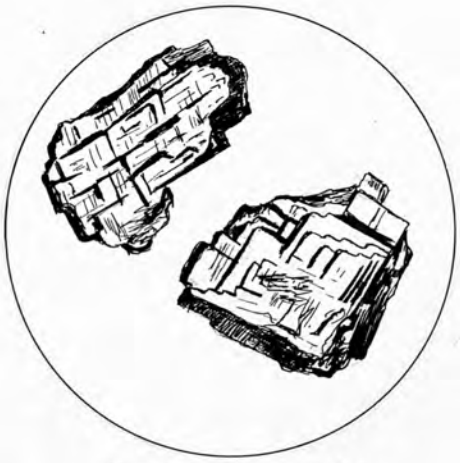
MAP SHOWING THE DISTRIBUTION OF BUNTER & KEUPER SANDSTONE AS DETERMINED BY THE GEOL. SURVEY & LOCALITIES FROM WHICH SANDSTONE HAS BEEN EXAMINED DURING THE PRESENT INVESTIGATION.

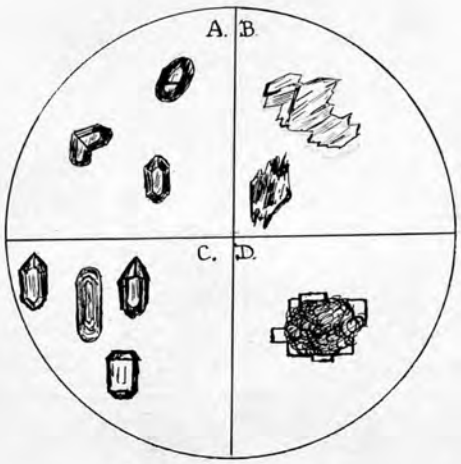
Heavy minerals from medium grained sandstone, Skegoniel.

Tourmaline. Staurolite
Garnet. Ilmenite (Leucoxene).
Zircon.



Garnets from coarse sandstone near Dundonald railway station.

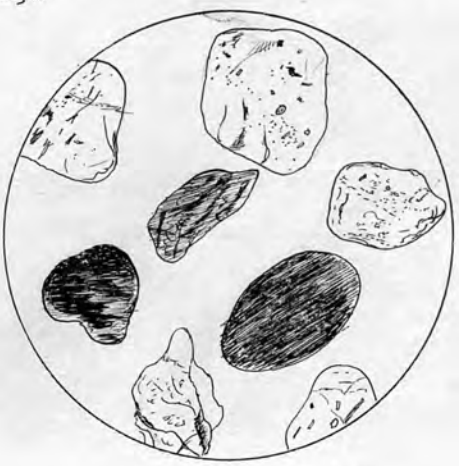
Heavy minerals from sandstone at Scrabo hill.
Ilmenite (Leucoxene).
Zircon.
Apatite.



A. Rutile.
B. Staurolite.
C. Zircon.
D. Anatase growing from Leucoxene.

Dolomite?
from Benbraclagh.

Angular sand grains from sandstone exposed in stream flowing under Arti Kelly bridge, nr. Limavady.



Rounded sand grains from Skegoniel, Belfast.