

V.—THE ORIGIN OF THE UPPER KEUPER OF LEICESTERSHIRE.<sup>1</sup>

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(PLATES XV AND XVI.)

THE following observations on the Upper Keuper are mainly from the Charnwood district, wherein the relations of the Keuper to the older rock beneath are easily studied. The observations are arranged under three heads.

1. *Condition of the Rocks beneath the Keuper.*—For the purpose of contrast the extensive weathering produced by our present moist climate may be first mentioned. This is well seen at Mountsorrel in the section on the east side of the main quarry. Here the granite has been denuded of its Keuper covering and has been exposed to the existing climate. It is disintegrated down to several feet below the surface, and is weathered to a considerable depth. Another good example may be seen at Huncote Quarry, where the South Leicestershire granite is so decomposed that the sand-martins nest in it. Spheroidal weathering occurs here. At Enderby also the Keuper has been removed by denudation, and spheroidal weathering is seen to a depth of 50 feet.

The Coal-measure climate also had a destructive action on these rocks. I know of no section showing Coal-measures deposited on Charnian rocks, but in 1904 I was able to watch boring operations near Peckleton in search of coal. Beneath the Coal-measures, at a depth of some 200 yards, syenite of South Leicestershire type was reached. About 45 feet of this were pierced, all of which was intensely weathered, resembling the South Leicestershire rocks where exposed to this climate.

In marked contrast is the condition of these rocks where they are overlain by Keuper. Everywhere beneath the marl the Charnian rocks are in sound condition right up to the very surface and often indistinguishable from the best stone at the bottom of the quarries. Indeed, the best stone is usually quarried from beneath the Keuper, and older workings in the surface rocks have been abandoned. From what I have seen in the Mendips and South Wales I believe the same surface freshness occurs in the Carboniferous rocks under the Keuper. This remarkable freshness suggests that, while the Charnian Hills were being buried by the Keuper deposits, a desert climate prevailed.

2. *The Surface Features of the Rock beneath the Keuper.*—It has been shown by Professor Watts that the subaerial features of the buried Charnian Hills are very perfectly preserved, with peaks, pinnacles, and precipitous slopes intact. Where the Keuper rests on massive homogeneous igneous rocks, their surfaces are generally smoothed, fretted, and curiously carved. Beautiful examples of wind-worn rocks at Mountsorrel have been described by Professor Watts. But in many other places also there are surfaces highly suggestive of wind erosion, as at Croft, Sapcote, Groby, etc. They are usually

<sup>1</sup> Reprinted by permission from Transactions of the Leicester Literary and Philosophical Society, vol. xii, part 1, 1908, pp. 28–34.

smoothed and pitted, and bear projecting carved knobs which are often coated with a red crust. At Narborough, where the rock is fine-grained and contains no evident quartz, the surface has taken a high polish. At the north-east corner of Croft Quarry a large surface of rock bared for quarrying may now be seen. Part of this was covered by Keuper Marl, and part had been denuded of Keuper by glacial agency and covered by Boulder-clay. The two parts are quite different: the former is comparatively very fresh, and from it project knobs of fretted stone covered with red crust containing round quartz grains; the latter is undulating, bare, and striated (Pl. XV, Fig. 1). At Groby, in the Sheet Hedge Wood Quarry, a precipitous slope was bared about a year ago, on which a vein of quartz projected, whose pitted and fretted surface looked very unlike the work of water, but rather as though blown sand had played upon it, picking out the druses and chloritic grains.

Another curious example I unearthed at Croft, two years ago (see Pl. XV, Fig. 1). It has since been quarried away. Along the joints in this rock fissures had been formed, which widen downwards, the undercutting being greatest on their south sides. This suggests the action of dew. But there is a conspicuous line, above which the surfaces are fretted and the crevices widen upwards. It may be that the rock was subsequently buried in desert dust up to the level of this line, while the part above it was exposed to the wearing action of drifting sand. At Bardon, Shepshed, and generally along the northern border of Charnwood, and also at Woodhouse and Swithland, where the rocks are broken or cleaved, the floor beneath the Keuper is rough and craggy, though the rocks are still comparatively fresh.

Worn slopes occur facing all points of the compass, and their distribution seems to depend most upon the nature of the rocks. Isolated rocks would be more favourably placed for wind-carving, and they would more easily be grooved by sand brushing through narrow gaps between them. Again, only massive and homogeneous stone would stand long enough to become carved, while rocks with cleavage or many divisional planes would crumble too quickly, and would moreover give rise to talus slopes. This may account for the possible wind effects being almost confined to the granitic rocks of Mountsorrel, Groby, and South Leicestershire.

3. *The Nature of the Keuper Deposits.*—In the open country the Keuper beds are almost horizontal, but around Charnwood they are often steeply inclined, and dip everywhere in the direction of the surface slopes on which they lie, the amount of dip depending on the steepness of the slope. Thus there is a radial direction of dip around the Charnian peaks, and where the Keuper is seen occupying depressions in the ancient land surface catenary bedding often occurs, e.g. at Croft and at Groby (Pl. XV, Fig. 2). And from the way the Keuper dips away from the hills it seems probable that the large valleys were filled in the same manner. This inclination of the beds might to some extent be explained by great contraction of the marl on solidification. But we should in that case expect the bending to be accompanied by fractures and slickensides. This, however, is not



FIG. 3.—Bardon Hill Quarry. Stone band in Keuper Marl starting from a buried crag.  
*T. O. Bosworth, vol. 5.*



FIG. 4.—Triassic Scree resting against the Syenite at Croft. Croft Quarry.  
*T. O. Bosworth, vol. 5.*

the case. Except at a distance from the older rocks, any traces of fractures in the Keuper are extremely rare, and there has apparently been little or no post-Triassic faulting in Charnwood. So that it seems probable that the beds were deposited with their present inclinations, somewhat in the manner of the loess.

Near the rocks the marl contains grit and stones, and there is generally a breccia at the base. The stones are of varied sizes; in some cases worn and in some cases very angular, but never smooth like ordinary pebbles. They are in a remarkably fresh condition, and often occur in bands in the marl, recalling the stone beds in the Persian deserts described by Blanford. In South Leicestershire they are much worn and fretted, and of very irregular shapes. They are generally pitted and sometimes polished. A year ago the section along the south end of Croft Quarry showed a 10 foot layer of these stones lying in a matrix of gritty marl. Similar stones occur throughout the 30 feet of marl above, and they are often situated with their grooves and ridges parallel with the bedding, as though they had been carved *in situ*. Each stone is surrounded by a thin red skin consisting largely of sulphates and carbonates of calcium and magnesium. This skin may be due to mineral matter filling up small spaces between the stone and the marl. Such spaces might well be caused by alternate expansion and contraction of volume, under the influence of temperature changes so marked in desert regions.

The grit particles at Croft are subangular, and some of the green bands are almost entirely composed of them. At Mountsorrel and at Groby there are both worn and angular stones in the Keuper, and some of them are very large. In Cocklow Wood very rounded examples are seen in the bed of a pre-Triassic gully. Considering that the summit of the hill on whose side they occur must have been within 200 yards, their shape is somewhat remarkable. The position of this gully has evidently been determined by a belt of shattered rock beneath. A similar example occurs at Groby, but in this case the stones are angular. At Bardon and Shepshed the stones are angular, and sometimes they lie in bands which may be traced to some crag projecting from the underlying rock slope (Pl. XVI, Fig. 3).

In the most easterly quarry at Groby a coarse breccia rests upon the rock, composed of angular fragments cemented together by white calcareous matter. Here, also, large and very angular blocks of beautifully fresh stone occur a few feet up in the marl. Their edges are extremely sharp, and they bear no traces of water action, but look rather as though they have been splintered off by frost action, and have certainly received no rough treatment since.

A scree sometimes forms the base of the Keuper when the slope beneath is steep. The best example is seen in the quarry incline at Croft, adjacent to an almost precipitous slope which faces south and is seen in section to a depth of some 20 feet. The stones are subangular and fresh (Pl. XVI, Fig. 4). The marl above also dips steeply to the south, but the angle of rest was apparently less for the fine material than for the stones.

All the material in the Keuper which has so far been mentioned is of purely local origin; and the scree, breccias, stone bands, and the grit in the marl are entirely derived from the rocks which they surround. Thus at Narborough these are all of the peculiar Narborough stone; at Mountsorrel they are all granite fragments; at Swithland they are chips of slate, and so on. Nowhere is there any mixture such as would occur in a beach, nor any evidence of shore drift. In this matter the Keuper breccias differ greatly from those of Permian age. Traced away from the hills the marl soon becomes free from grit, and no coarse local detritus seems to have travelled far. But at Woodhouse in a green band there is fine grit which can just be recognised as granite from Mountsorrel, two miles distant. Also at Swannington in marls low down in the Keuper there are sand beds with scraps of slate and quartz which must have travelled about  $1\frac{1}{2}$  miles.

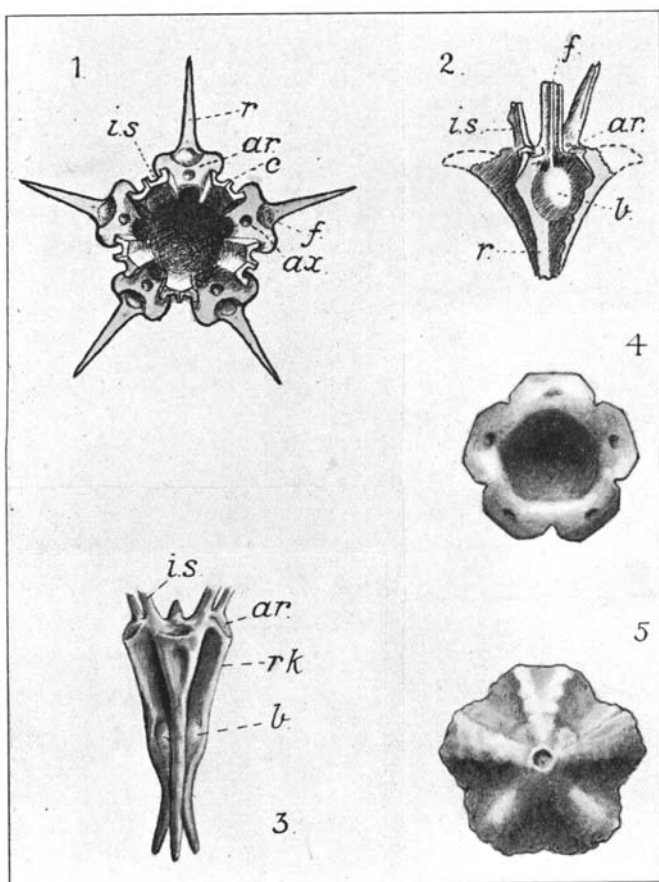
Of the normal Keuper marl there are many varieties. At Sileby both the green and the red beds are sandy, but more usually the red marl is of very fine texture and breaks with conchoidal fracture. Sometimes this has a kind of nodular structure and shows the bedding, and more rarely true laminated beds occur. The colour also varies greatly.

All the evidence of water action I have seen is confined to the green bands in the Keuper, and this evidence points only to shallow streams and salt pools. These green bands always contain quartz sand, and it is my experience that when suitably weathered they almost invariably show ripple-marks, and salt pseudomorphs which are sometimes clustered along the crests of the ripples. The ripple-marks vary greatly in size and character. If they are due to waves controlled by the wind they may indicate its direction.<sup>1</sup> For example, at Nottingham they strike N. 20° W., and at Gipsy Lane, near Leicester, they strike N. 40° W. But I have seen them striking in different directions in layers of the same green bed only half an inch apart.

Upper Keuper Sandstone occurs in lenticular beds at various horizons. It is usually grey and coarse. Near Leicester at the Dane Hills it is nearly 20 feet thick and is very uniformly false-bedded from the south-west. *Estheria* and fish-scales and fragmentary plant-remains lie on the false-bedding planes, which dip at 30 degrees. Very similar beds occur in Warwickshire and Worcestershire. Beds of similar sand dip steeply away from the Charnian inliers of Enderby, Croft, and Stoney Stanton, and they contain nuggets of the local rocks. Some beds consist of almost spherical grains and are apparently desert sand. Rounded grains are also plentiful in the marl, and at the base of the marl in South Leicestershire, resting upon the worn rock surfaces. In South Leicestershire there are no quartz rocks from which these coarse sands could be derived. Along the north and north-east boundaries of Charnwood, the sands are finer.

The heavy minerals also point to a distant source for the material.

<sup>1</sup> The author is collecting data, and would be greatly obliged for any information as to strike of ripple-marks.



New Chalk Crinoids from the '*Micraster cor-testudinarium* zone' of the Upper Chalk, Seaford Head, Sussex; from Dr. Arthur Rowe's Collection.

- FIG. 1.—Oral view of *Rozeacrinus alata* (gen. & sp. nov.), restored.  $\times 17$ .  
 „ 2.—Lateral view of *R. alata*.  $\times 10$ .  
 „ 3.—Lateral view of *R. communis*.  $\times 10$ , restored.  
 „ 4.—Oral view of *R. communis*.  $\times 14$  (the interradial spines are broken off).  
 „ 5.—Aboral view of *R. communis* (var. *rugosa*).  $\times 16$ .

*r*, radial wing; *ar*, radial articular facet; *f*, ligament fossa; *ax*, axial canal; *is*, interradial spine; *c*, carina; *b*, basal; *r.k.*, radial keel.



Heavy mineral separations have been made from a large number of localities throughout the country. The same minerals occur alike in sands and marls, in the grits in contact with the Charnian rocks, in the basal breccias, in the Dolomitic conglomerate, and in the Rhætic sandstones of South Wales.

The most notable feature is the abundance of garnet, particularly in the coarser sands, and in the basement beds resting on the Charnian rocks. This mineral varies in colour between pink and mauve, and contains a large percentage of iron. In some beds the garnets occur as almost perfect spheres, but in others as very angular fragments with conchoidal fractures. In South Leicestershire the heavy minerals often consist chiefly of garnet, but approaching Charnwood the amount of zircon increases, and on the north and north-east borders of Charnwood the proportion of garnet is very small. Tourmaline and rutile occur in smaller quantity, but are a constant constituent of all the separations; they vary much in size and are sometimes very round and smooth. Staurolite is also common. To these heavy minerals the Charnian rocks no doubt have made their contribution, especially in the case of zircon; for powdered South Leicestershire syenite yielded rutile and zircon, and abundant perfect zircons were obtained from decomposed Mountsorrel granite; also the Millstone Grit contains tourmaline. But in the main the heavy minerals of the Keuper must have come from some distant source.

Thus it seems that the Upper Keuper accumulated in a continental basin under desert conditions. Shallow pools and occasional water-flows were a feature of this desert, and much of the greatly worn dust and sand had doubtless been long drifted to and fro, both by wind and by water.

#### VI.—A NOTE ON SOME NEW CHALK CRINOIDS.

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(PLATE XVII.)

THE following is a brief account of some minute Crinoid calyces, which appear to have been hitherto undescribed, sent me by Dr. Arthur Rowe, who obtained them from the *Micraster cor-testudinarium* zone of the Upper Chalk.

From the number of specimens it would appear that they are fairly common at certain localities, but I have been unable to detect any traces of arm or stem plates. The calyces are well preserved, and that they are full-grown individuals seems evident from their uniformity in size and solidity.

*Mode of Occurrence.*—As I am indebted to Dr. Rowe for all my information as to the localities and horizons at which they have been found, I cannot do better than quote his letter to me on the subject:—

“A fossil so minute can only be seen on a well-weathered surface of a hard rock, and the only zones where I have found them *in situ* are those of *Rhynchonella Cuvieri* and *Holaster planus* in the Isle of Wight and at Dover. The best way to get them is from flint meal. Practically all I have, with the above-mentioned exceptions, are from that source. It is necessary, of course, to have hollow flints, and these only occur in quantity at a few favoured localities in the zones of *Micraster*