ON THE ORIGIN OF THE TRIAS.

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It is becoming more generally recognised day by day that the Triassic Rocks of Great Britain can best be explained by assuming that desert conditions existed during their formation.

In order to test this it may be well to examine briefly the conditions now existing in deserts and the activities now at work in those regions. While desiccation is one of the controlling factors in the deserts of to-day, we find none which are absolutely free from water. Deserts may exist with a comparatively large rainfall, provided it falls in a limited time, is quickly shed, and not stored up by glaciers, soils, or lakes.

Thus streams which exist in the rainy season soon become dry, and for the rest of the year they are not functional. In South Africa we constantly come across deep channels excavated by streams, their beds covered with large stones which could only be carried by torrents. During the dry season sands blow into the hollows and completely obliterate all traces of the stream courses. In the next rainy season the streams may or may not find their old channels, and thus by constant excavation and in-filling we get deposits covering the country, consisting mainly of blown sands with patches of gravel marking the sites of former streams.

Wind acting on deposits like those just described sweeps away the sand to longer or shorter distances to form heaps or dunes. The finer particles will come to rest at one place and the coarser at another. In this way we get a more or less perfect sifting into sizes. I have examined many samples of sand from the Sahara and other deserts, and find this sifting to be one of the chief characteristics of blown sand. In one place I was fortunate enough to get specimens of beds in vertical order, and found that while the grains were uniform in size for the same horizon, they differed very much from bed to bed. The stones too heavy to be moved by wind tend to drop down to a lower and lower level, and form a stratum composed wholly of large stones, with little or no sand intermixed. This

explains one of the features which strikes an observer in visiting a desert region, where he finds great stretches of pebbles of all sizes strewing the ground, while in the distance he may see the dunes of sand composed of materials which were formerly mixed with the pebbles.

When deposits such as these are worked up and re-worked up by wind action year after year, there is a tendency towards a concentration of particles of one size at one place. We shall see that in other respects *concentration* is the dominant feature of desert areas.

Another way in which the desert shows itself as an area of concentration is in the materials brought down by rivers in solution. Evaporation may take place during transit, and the sand through which the streams flow may be coated with salts. In flashes or shallow pools held up by the irregular disposition of sand dunes, water may remain for a longer period, even through the dry seasons, and then it becomes strongly charged with salts, which may crystallise out as common salt, gypsum, iron pan, carbonate of lime, and other substances. Mud and drifted vegetation carried down by the streams may be deposited at the bottom of these flashes, forming a puddle, and preventing the escape of water below. On drying, we have left a mud, strongly charged with salts, which cracks on desiccation, and this may take the imprints of animals which come to drink and impressions made by rain drops and runlets of water. Sand blowing into these shallow pools will bury the lower deposits, and preserve there the markings impressed on them. In the deserts of South Africa we often find white nodules in the sand consisting of carbonate of lime cementing grains of sand. These vary in size from a marble to gigantic masses. Sometimes they form continuous layers, and I have seen them 10, 20, or 30 feet thick. The carbonate of lime is precipitated out of solution by loss of carbonic acid, and after deposition it is not easily removed from the sand grains it coats. Hence carbonate of lime concentrates on land rather than in pools.

A third way in which concentration is seen in deserts is shown by the manner in which organisms tend to cluster round

places where water is more or less permanent. We should naturally expect to find plant life and aquatic animals more abundant in those places. A salt pan near Riverton, in South Africa, I found to be swarming with the little Crustacean *Estheria* (the most common and most widely distributed fossil in our Trias), and larger animals coming there to drink leave their footprints and other remains in the mud.

Now to apply these principles to our Trias. It is generally accepted that the material forming our Triassic rocks was originally river borne. I shall not stop now to discuss the origin or courses of these rivers, but, given the deposits and a desert or semi-desert condition of climate, we can see how wind would in places concentrate the coarser fragments, forming deposits like the Pebble Beds of the Midlands. Some localities may have escaped the sifting, and the Pebble Beds of Lancashire and Cheshire, in part, may represent these. In the latter counties we find very thick masses of sand, false bedded, in a way which suggests dunes rather than river deposits, and lenticular patches of pebbles interspersed at all horizons and very inconstant in extent. I have not made careful calculations, but it strikes me that if the pebbles in the Lancashire and Cheshire areas were concentrated as in the Midlands, they would make up a deposit quite as thick and of a similar nature. It has been asserted that the pebbles of the Midlands are larger in size than those further north. I know places in Lancashire and Cheshire where they range up to 6 in. or 8 in. in diameter, and my experience in Cannock Chase and other places in the Midlands is that assemblages of a larger size than this require looking for. Large pebbles are exceptional and do not characterise the beds as a whole.

On this hypothesis, the Pebble Beds of the Midlands and further North may differ only in one having been subject to the concentrating influence of wind and the other having to a large extent preserved its original character, and being abnormally thickened by the importation of fine material from the Midlands. We should naturally expect that the stones over which sand has drifted in the course of concentration would be etched or planed to form *dreikanter*. These are found in the Pebble Beds but are not common. Neither are they in existing deserts.

The striking feature of the Upper Bunter is the way in which the various horizons are characterised by even sized grains. In some beds it looks as if the material had been put through a sieve or a series of sieves of different meshes. A bed may preserve an even grain for a few inches only, and be succeeded by one of different size, but uniform for the same horizon. In no deposit laid down under water could this feature be so perfectly developed.

Coming now to the Keuper, we find the basement beds are characterised by the occurrence of pebbles and rolled clay nodules, and a thin band of marl, at least in the north, usually intervenes between the Keuper and Bunter. In places, as at Alton in Staffordshire, concentration of pebbles has taken place and wind etched pebbles are not uncommon.

The Lower Keuper, I believe, marks a pluvial phase following desert conditions. Above this the Keuper sandstone is characterised by an increasing frequency of marl bands. These are never of very great extent, and are always half lenses with the convex surface downwards. They may represent the flashes and shallow pools of the desert or semi-desert region, and it is on their shores we find the footprints of reptiles, *Estheria*, and other organisms, and pseudomorphs of rock salt. The last phase of the Keuper is represented by the Keuper Marls. It is a misnomer to call them Marls, as clay enters but little into their composition, except in a few localities. The mass of the rock is composed of exceedingly fine, splintery, angular grains of quartz which seldom exceed $\frac{1}{500}$ to $\frac{1}{1000}$ in. diameter. Large pools or lakes existed at this time with the concomitant beds of salt, gypsum, &c., and footprints, *Estheria*, and drifted plant remains are common. The Keuper Marls may represent the material accumulated by the feeblest currents of wind, the fragments blown furthest, and as such may be compared with the Loess of Eastern Europe.

Taken as a whole, we may regard the Trias formation as made up of a series of lenticular beds, irregular in their disposition and piled up mostly by wind action, but before they can be properly read we must know a great deal more about deserts, not only what they are, but what they do.