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THE ORIGIN OF THE ST. PETER SANDSTONE.

ARTHUR C. TROWBRIDGE.

Originally, all sedimentary rocks were thought to be marine. When the St. Peter sandstone was first recognized as a distinct formation, it was assumed to have had a marine origin. More recently, however, the marine origin of many sediments has been doubted, and the criteria for distinguishing various sorts of sedimentary rocks have been worked out. As early as 1907 evidences were presented for the eolian origin of the St. Peter sandstone, although there are those who have never accepted the evidence as conclusive. In the literature of the subject, the matter is not settled.

In connection with field work in the Driftless Area during the last twelve years, the writer has had opportunity to study the formation in many places and to collect evidence bearing on the problem of its origin. The conclusions arrived at are here recorded.

The characteristics of marine sediments deposited in agitated water and of eolian deposits have been listed. Reference to these lists will help to render the present argument clear.

The St. Peter sandstone certainly has some of the characteristics of eolian deposits. The material is sand of uniform texture and of a size which is commonly transported and deposited by the wind. The formation contains so few fossils that many geologists believe that it contains none. No wind-deposited sand contains abundant fossils. The thickness of the sandstone formation varies greatly within short distances, as is true of all eolian deposits. There are places where an irregular stratification appears in the sand, which suggests eolian stratification. The shapes of the sand grains, when seen under the compound microscope, are not notably different from the shapes of sand grains taken from existing sand dunes.

There are, however, other features of the sandstone and other interpretations of the above-mentioned points, which are in harmony with the marine rather than with the eolian theory. These points are discussed in separate paragraphs.

It is difficult to understand how eolian deposits could be distributed continuously over so wide an area as the St. Peter sandstone covers. The formation is known in Minnesota, Wisconsin, Iowa, Illinois, and Missouri at least, and it probably covered originally practically the whole area of these states. Its extension west, south, and east from this area is not known accurately. The eolian theory presupposes that this whole area was a desert during the St. Peter epoch and that deposition of sand was so great and so general that the underlying rock surface was buried everywhere. Sand could be so distributed by deposition near shore in a shallow sea, provided the shore was migrating toward or away from the land areas of the time. Such seems to have been the history of the St. Croix sandstones which are distributed even more widely than the St. Peter is known to be.

There is no known source for such a great amount of eolian sand, so widely distributed. There seems to be no deposit of eolian sand today far from its source. The sands of the Atlantic Coast, of the vicinity of the Great Lakes, of Kansas and Nebraska, of the Great Basin, of the Sahara, can all be traced to a near-by source. Within the area over which the St. Peter is distributed, there is no possible source for the sand. The Prairie du Chien dolomite formation which everywhere underlies the sandstone could not have furnished the sand. So far as is known, there was no considerable area of Cambrian sandstone exposed anywhere, at the time the St. Peter was deposited. More likely the sand was prepared by the mature weathering of igneous rocks in the land area of Canada, transported by streams or by waves and currents to its present position, and then deposited in the sea.

It is pointed out by the writer elsewhere in this volume, that the St. Peter sandstone lies on the irregular surface of the Prairie du Chien formation. The relief of this surface is more than 200 feet. In it are sharp, steep-walled, narrow valleys 150 feet or more in depth. The surface seems to have been in maturity when the deposition of the sandstone began. Rough topographies, such as this, interfere with sand depositing winds, and it is unlikely that sand could be so laid as to fill up all the valleys, spread over all the divides, and bury all the hills.
On the other hand, sand could and would be so deposited if a sandy sea existed over the surface for a long time.

The variation in thickness of eolian sand is due to the irregular piling up of the sand into dunes. It is most commonly the surface rather than the base of the deposit which is irregular. Save for a slight structural dip the surface of the St. Peter formation is horizontal. Its variable thickness is due to unequal altitudes of its base rather than of its upper surface. Such variability could be obtained more easily under marine than under eolian conditions.

The St. Peter sandstone is conformable with the Platteville limestone above. Between the sandstone and the limestone there is the Glenwood shale. The contacts between sandstone and shale and between shale and limestone are parallel with the general dip of all the strata and there is no evidence of erosion or other break in deposition on either contact. The change from sand to shale and from shale to limestone is normal as a result of a gradually deepening or advancing sea. It is not clear that an eolian deposit could grade conformably upward into marine deposits. The Glenwood and Platteville are known to be marine.

The stratification of the sandstone, as an evidence of its origin, is inconclusive. Indeed it is doubtful if sand deposited by the wind can ever be certainly distinguished from marine surf deposits by the means of stratification alone. Eolian sand is deposited on the lee slopes of sand dunes and assumes its angles of rest. These slopes may be oriented in any direction. Similarly sand is dumped over the fronts and sides of deltas, bars, spits, hooks and barriers along irregular coast lines, and takes certain angles of rest. These slopes also are oriented irregularly. The only difference is that in the one case the sand is dry and in the other case it is wet. This difference would give rise to slight differences in the degree of dip in cross bedding. But this dip is influenced by so many other factors, such as the sizes, shapes and specific gravities of the grains, and perhaps by the strength of air or water currents, that the presence or absence of water at the time of deposition might well be obscured. For the most part the St. Peter sandstone is massive and devoid of stratification lines. In a few places, irregular stratification appears, but the writer has not been
able so far to determine whether it is due to wind or to waves and littoral currents. The deposit might be either eolian or marine, so far as can be determined from the stratification.

Although it is true that the St. Peter sandstone is not highly fossiliferous, it does contain fossils and all of the remains are those of marine animals. Sardeson has described thirteen species of pelecypods, seven species of gastropods, three species of cephalopods, three species of brachiopods, one doubtful bryozoan and one porifera. In addition the borings of marine worms have been found in the formation at various places. Most of these forms have been collected from the upper part of the formation, but others occur lower down. Certain it is that they occur in the sandstone itself. Geographically, they have been found at Fountain, and near St. Paul in Minnesota, and near Beloit, Waterloo and Baraboo in Wisconsin. Sardeson explains the relative rarity of fossils in the formation on the ground that most of the shells were dissolved from the porous sandstone by ground water. This explanation seems to be satisfactory. After all, the formation is little if any less fossiliferous than other well-known sandstones, such as the Jordan.

It is doubtful if there are in this country sand grains which owe their shape entirely to wind action. The sand dunes are the result of reworking marine, lacustrine, fluvial or fluvioglacial sands. It cannot be known then what the shape of a strictly eolian sand grain is. It is possible that the St. Peter sandstone is eolian and yet its grains might have been shaped by a sea and been only slightly modified by the wind. The fact is that the grains of the St. Peter cannot be distinguished from those of the Cambrian marine sandstone, under the low objective of the compound microscope.

Finally the St. Peter sandstone is so nearly identical, lithologically, with the marine Cambrian sandstones that it is impossible to distinguish them, except by stratigraphic position or fossil content. The texture, textural range, and stratification found anywhere in the St. Peter can be duplicated in the Cambrian sandstones. They seem to have had the same origin.

It is believed, therefore, that at least the most of the St. Peter sandstone is marine. A sea probably covered the area now occupied by the formation. It seems to have advanced

slowly, probably from the south. To the north, there was the Laurentian land area, on which igneous rocks were maturely weathered. Quartz, liberated from granitic rocks by the decomposition of associated silicate minerals, was broken to pieces, transported by streams, shaped somewhat, moved about by waves and currents in the sea, and deposited near the shore, as the sea advanced over the land. It is entirely possible that some sand was picked up by the wind from the beaches, transported a little way inland, and later submerged beneath the advancing sea. In this way some eolian deposits may have been incorporated within the formation which is generally marine.

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