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The preservation and interpretation of ripple marks and sun cracks

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THE PRESERVATION AND INTERPRETATION OF RIPPLE MARKS AND SUN CRACKS

by

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LIST OF ILLUSTRATIONS.

INTRODUCTION.

The Robideaux sandstone (Cambrian) which is rather extensively found in the vicinity of Rolla, Mo., offers exceptional opportunities for the study of ripple marks and sun cracks in place. Fig.1 shows the principal localities in which these structures are to be found in this vicinity.

The statement is made by Van Hise and others that ripple marks can be used in determining structures, and that to do this it is necessary to be able to tell whether a ripple mark is right side up or overturned. The rule as laid down by them is: That a normal ripple mark (right side up) has a wide trough separated by two sharp ridges. Having found some ripple marks the converse of this near Rolla in a structure which is not overturned, we have endeavored to determine how often this statement of Van Hise's is true, and if there are other criteria which might be used in the determination.

RIPPLE MARKS

Review of Literature.

The literature available upon the subject of ripple marks is very limited and non-committal. In fact but little work seems to have been done upon the subject. The following extracts are of interest:

"The rythmetical action of waves gives rise to undulatory lodgment known as ripple marks. They are usually not the direct product of the surface waves, since they are much too small. They are produced mainly by the vibratory movement of the undertow, but they apparently result from various other phases of vibratory agitation of the bottom waters. They are sometimes made by streams and stream-like currents. Ripples are also made by wind. Ripple marks are usually only an inch or two from crest to crest but in rare instances they attain much greater size. Examples of ripple marks 30 feet across are known. Occasional ridges and depressions of much greater dimension are produced, which are attributable to the formation of successive bars, or the building of wave cusps." *

* Chamberlin and Salisbury, Geology, Vol. I, pp.489.

"In irregular ripple marks the direct current carries the sand up the weather slope, while the vortex pushes it up the lee slope, hence long gentle slopes toward the wind, and the short steep slopes away from it. Considerable diversity in the form of the ripple, however, may be observed, depending upon conditions of wind, water, and sediment. No satisfactory inference can be drawn from the existence of ripple marks as to the precise depth of water in which the sediment was accumulated. As a rule it is in the water of only a few feet or yards in depth that this characteristic surface is formed, but it may be produced at any depth at which the agitation caused by the wind upon the upper waters may extend. Examples of it may be observed among arenaceous deposits of all ages from pre-Cambrian up." *

The structure of ripple marks is discussed by Van Hise ** as follows: "The forms of ripple marks may sometimes be of assistance in deciphering stratigraphy. Normal ripple marks consist of a series of sharp ridges separated by rounded hollows each of which, however, often has a slight sharp ridge in its center (fig.2).

* Gieke, Text Book of Geology; Vol.I, pp.642.

** Prin. of N.A.Geol.; 16th An., part I, pp.720.

The casts of such ripple marks have an entirely different appearance, consisting of broad, rounded ridges, each of which has a slight depression in the center, separated by steep depressions. Hence if the beds of a steeply inclined formation bear ripple marks, these determine at once which way the formation was uplifted. The decision may be as easily made when the minor elevations in the hollows are absent for in this case in normal position the depressions are gently rounded while the elevations are in the same form as in the previous case."

While many other authors give general descriptions of ripple marks, the above quotations include all the information presented. It is thus seen that while some methods by which ripple marks may be formed, and one by which structures may be determined from a normal ripple mark (if it is known to be normal); the actual number of definite statements, or facts, offered is very small.

Statement of Problem.

It is desirable, if possible, to obtain some data upon the methods of formation and preservation of ripple marks inasmuch as an understanding of these subjects is necessary for a full interpretation of the geologic evidence shown by these irregularities.

The relation of ripple marks to structures is an important one, for if we can definitely differentiate the mould of such a mark from its cast, it then becomes possible to tell whether a bed containing this structural mark is right side up or overturned, for ripple marks are formed in the unconsolidated sandy material before it becomes a rock through cementation and therefore the bed could not be overturned and have ripple marks subsequently formed upon it. Van Hise and others have claimed that the crests of ripple marks are narrower and sharper than the troughs, and one would gather from these statements that not only could the determinations always be made when ripple marks were exposed, but also that the crests of these marks are always more narrow than the troughs. In actual field work in this vicinity, the latter case has been found to be true only about 85% of the time.* Thus while it is true that in the ma-

*Average of about 30 ripple marked beds near Rolla, Mo.

jority of cases the crests are more narrow than the troughs, it is equally true that in many cases the crests and troughs are of equal width, and that in others the troughs are sharp and narrow,and the crests broad and rounded. It thus becomes evident that care must be used in determining structure by the relative widths of the crests and troughs.

Manner of Formation and Preservation.

The rythmetical oscillatory movement of the medium immediately above an unconsolidated rock member may cause an undulatory surface resembling waves,called ripple marks (pl.I). These ripple marks are apparently not caused by direct wave action, as evidenced by the fact that they rarely exceed 2 to 3 inches from crest to crest, with an amplitude which varies from 1/8 to 1/2 inch. Waves of this size are rather rare along a sea coast. It has been shown by experiment * that a current of water will cause ripple marks,doubtlessly in much the same manner that wind causes dunes and ripple marks on land. This action is apparently brought about by the current of the water pushing the

* W. Eggleston, Harvard geological laboratory.

material along until it reaches a place of lodgment where it piles up, the height being limited by the size of material and strength of the current, until a height is reached beyond which the current cannot raise the sand. The material is pushed up the front face of the elevation and falls down behind, causing the front face to have a gentle slope and the back one to have one that is more steep; hence the direction of the current may be determined by the slope of the sides of the ripple marks. Immediately back of this first crest there will be an eddy formed which will tend to gouge out the material immediately back of the crest and to prevent the deposition of any new material at this point. The translation of such an eddy by a current causes it to turn on itself in this manner  , so that for a certain distance immediately back of this point of "gouge", the movement in the eddy is upward, i.e., there will be a certain distance (limited by the size of the eddy and the speed of the current) in which the rotary movement of the eddy does not strike the bottom (distance a-b fig.3). At about the point where the eddy begins to gouge again a sufficient distance has been reached beyond the first ridge for the drag of the current to be again felt upon the bottom, causing another large ridge to be formed as before, etc. (fig. 3). The above process is repeated again and again to form a series of ripple marks. It will be seen from the nature of the action that ripple marks having rather sharp, narrow major crests separated by a rounded hollow or trough, which contains a minor crest, will be the result (pl. II).

The preservation of ripple marks is only possible when the member containing the marks is sufficiently covered with foreign material (probably deposited from suspension after agitation of the water ceases) to maintain a contact between the ripple marks and the next stratum deposited. An overlying layer or formation being necessary to preserve the marks from the effects of erosion. It will be readily seen that if the intervening layer is thin, the overlying bed will contain a cast of the ripple marks below, and that this cast will be diametrically opposite from the ripple marks in shape (pl. III). The fact that the minor ridges usually do not appear upon ripple marked surfaces is probably due to the partial filling of the troughs by material similar to that composing the ripple marks, before foreign material is deposited so as to maintain a contact.

Relation of Ripple Marks to Depth of Water.

It seems apparent that ripple marks can be formed at any depth to which the oscillations (from waves) can be transmitted with sufficient force to move the particles of unconsolidated material. "A 300 foot wave 3 feet above mean level would cause in 6 fathoms an alternating current on bottom with maximum speed of 3 feet per second." * Similarly ripple marks may be formed at any depth where there is sufficient current to move the sandy particles. As it is known that currents exist at fairly great depths, it seems to be safe to say that the formation of ripple marks is possible at any depth at which sand is found.

Interpretation.

From the statement of the problem it will be seen that we are particularly interested in distinguishing a ripple mark from its cast. There are, so far as we know, but two ways of doing this:

* Hunt, Proc. Royal Soc., Apr. 20, 1882.

(I) Shape of marks.

(a) We find that for the average normal ripple mark the ratio of the width of crest to width of trough is about 1 : 3.*

(b) In some cases the troughs contain a minor crest which is located in the central portion of the trough (pl. II). This minor crest varies from nothing up to ¼ the size of the major crest. The converse of the above is naturally true of the cast of a ripple mark, the cast having a wide crest, (pl. IV) containing possibly a narrow trough in its center, flanked by two rather sharp troughs (fig. 4). This ratio of width between trough and crest has, as previously stated, been determined to be locally true in about 85% of the cases.

(2) Filling of troughs. Foreign material may be deposited after the ripples are formed, in fact it is almost essential to the maintenance of a contact between the ripple marks and the next stratum deposited. This material will naturally be deposited in the troughs, with perhaps the exception of a very thin film on the crests. Upon deposition of the next strat-

* Average of about 30 ripple marked beds in the vicinity of Rolla, Mo.

um this foreign material will be kept firmly in place so that the troughs of the ripple marks will contain most of the foreign material present (pl. V), while the crests will be tight against the adjacent layer. The converse will be true of the casts.

SUN CRACKS.

Review of Literature.

The available literature upon the subject of sun cracks, or as they are sometimes called, mud cracks, is even more limited than that upon the subject of ripple marks. An extract from Gieke * is as follows:

"Sun cracks show that during their deposition, strata have at intervals been laid bare to sun and air, for the cracks could not have been produced so long as the sediment lay under water. Their existence therefofe proves that the strata was exposed to the air and dried, before the next layer of water born sediment was deposited upon it."

Chamberlin and Salisbury bring out a little more information pertaining especially to the kind of sediments affected.

"Sediments are sometimes exposed between tides or under other circumstances, for periods long enough to permit drying and cracking at the surface. On the return of the waters the cracks may be filled and permanently preserved. These are known as sun cracks or mud cracks. They chiefly affect shales, but are occa-

* Gieke Text Book of Geology, Vol.I, pp.642.

sionally seen in limestone and fine grained sandstones."

Pertaining to origin and manner of preservation the following is quoted from Dana's Manual of Geology:

"The mud cracks made over a drying mud-flat are often preserved in the rocks and prove the mud-flat origin of the bed. Such cracks are necessarily limited by the depth of the mud. The cracks become filled by the sediment after a return of the waters and into this filling a cementing solution may pass from above. If the solution is silicious, the filling becomes harder than the rock on either side, so that when worn the surface is one of prominent intersecting ridglets. Moreover, the ridges are generally double, the filling having solidified against either wall of the crack until the two sides meet at the center, and become more or less perfectly united. Layers having such filled up mud-cracks are very common in stratified rocks."

Statement of Problem.

In the consideration of structures it is important that we obtain, if possible, some idea of the manner of formation and subsequent geologic processes of sun cracks, in order to be better able to interpret the

the geologic evidence which they show. The chief problem is a structural one, it being desired to determine if there are any features about a sun crack that will enable one to determine which was the upper, or lower end, of the crack at the time it was made. Having determined this, one can readily tell whether the bed containing the crack is normal or overturned.

Manner of Formation and Preservation.

Sun cracks are ridges upon the surface of a rock, which so intersect that they produce in general a hexagonal form. Their prominent position is due to differential weathering (plate 1). It is a well known fact that when a wet, muddy, or clay-like substance loses water that a shrinkage takes place, causing intersecting tension cracks to appear, the general form of which are roughly hexagonal in outline, a form which seems to be characteristic of all cracks due to shrinkage, where one dimension is much less than the other two. If there is a wet, muddy flat exposed either between tides or by elevation, the mud will dry, shrink and crack, material foreign, or otherwise, will be introduced by wind or water, or by both, until the cracks are filled. If upon cementation of the rock the material in the cracks is more closely cemented than the surrounding rock, and this is probable, for solutions can circulate best in the cracks, then upon weathering there will be differential erosion causing the crack filling material to stand up above the plain of the rock in which it occurs so as to form what is generally known as sun cracks. The formation of sun cracks in this [the usual] manner is undeniable, but field evidence does not show that they are all formed in precisely ~~the above~~ this manner, for there is evidence of well marked sun cracks which do not extend down into the rock upon whose surface their weathered forms occur, but seem to be cemented to this surface (fig.1).

The materials composing both the rock and the ridges (plate I) are the same, being a sandstone, cemented so as to closely approach the quartzite condition. There is no perceptible break in the bedding of the sandstone immediately below the ridges, and the ridges terminate abruptly against the underlying rock. Such sun cracks were probably formed under conditions where a layer of ~~sand~~ mud, or other soft material, was deposited upon the surface of a sand~~stone~~ layer. Upon exposure the mud, because of its high shrinkage, was cracked through, while the sand, having no shrinkage, was unaffected.

The shape of the cracks formed in the above manner will depend upon the thickness of the layer of mud. Thus if the mud is thick the shrinkage diminishes with depth and so produces a wedge shaped crack, but if the mud layer is thin, the whole shrinks, producing cracks wide at the bottom. Upon re-submergence sand is deposited in and over the cracks and mud. Then upon partial cementation of the sand, the result is two distinct layers of sandstone separated by a layer of mud, and in the case of the thin mud bed, joined to each other by the crack-filling material (fig.2). Upon the erosion of the upper layer of sandstone, the mud which had separated the two layers would be washed away, causing the crack-filling material to stand out in bold relief, and fulfill the conditions as they have been found. ~~(See~~ plate I).

Interpretation.

From the theory of origin of sun cracks it will be seen that the cracks are directly due to the shrinkage caused by loss of water, and as most of the water lost comes from the surface, we would expect the cracks to be widest here, diminishing in width as they extend downward, and this is the case when the depth of the mud is sufficient for the crack to "pinch out" or nearly so. However, when the mud layer is too thin with relation to the width of the crack there is not enough narrowing of the crack in depth for one to be able to determine which is the upper or lower end of it.

Hence in vertical cross section the widest and narrowest ends are bound to be the upper and lower portions respectively.