to have a perfect substitute take our place. This Christ did, being Deity and being sinless.

But if presumed evolution is true, then man has developed very gradually from the beast, there were no two distinctly first people, and man is improving instead of having fallen from a perfect creation. If supposed evolution is true there is no occasion for salvation. Christ becomes a martyr instead of the Savior, a man ahead of his time instead of the Redeemer. This is the issue.

References

[1]Darwin, Francis, Editor. 1903. More letters of Charles Darwin. Appleton and Co., Vol. 2, p. 115.
[2]*Ibid.*, p. 374.
[3]Darlington, C. D. 1961. Darwin's place in history. Macmillan, p. 60.
[4]Gould, Stephen Jay. 1975. This view of life: Catastrophes and steady state earth, *Natural History,* LXXXIV (2):14-18.
[5]Ward, Henshaw. 1927. Charles Darwin. Bobbs-Merril, pp. 300 and 304.
[6]Darwin, Charles. The descent of man. New Edition, Revised and Enlarged, 1890. D. Appleton and Co., p. 84. Also The origin of species, and The descent of man. (Modern Library Edition, apparently no year given). Random House, p. 519.
[7]*Ibid.*, p. 89. Also Modern Library Edition, p. 528.

THE FORMATION OF CROSS STRATIFICATION: A NEW EXPLANATION

Douglas E. Cox*

Cross stratification has been invariably associated with a sedimentary cause, yet it exhibits significantly different features from those of sediments formed experimentally. Features of cross stratification are contrasted with those of sediments, and it is shown that cross stratification must have a completely different origin. A possible non-sedimentary process forming stratification of surface rocks involves the release of pressure on rocks being elevated from great depths of burial under water. Shattering due to expansion of diffused water disintegrates the rock in successive layers, forming stratified sand. In this new explanation of cross stratification, it is shown how such a process can account for the unique features of cross stratified rocks found in nature.

The Nature of Cross Stratification

The phenomenon of cross stratification has long been considered a sedimentary form of stratification, as the synonyms "current bedding," "torrent bedding," "turbulent bedding" and so forth indicate. The label "false bedding" is another synonym now considered obsolete, although still in use among English geologists, that may reflect an early suspicion that there was something incongruous about it. But that cross stratification is sedimentary in origin seems to have been universally assumed by modern geologists.

A full list of synonyms given by Shrock[1] included "cross bedding," "foreset bedding," "false bedding," "oblique bedding," "diagonal bedding," "inclined bedding," "current bedding," "torrential bedding," "flow-and-plunge structure." All these terms refer to the same geologic phenomenon. Some are merely descriptive, others imply a specific kind of sedimentary environment of formation.

In this paper, since the mode of formation is the subject in question, a non-genetic term will be used: cross stratification. Shrock gave the following definition of cross stratification, which he refers to as cross lamination:

> Cross-lamination is the designation now generally used for that structure, commonly present in granular sedimentary rocks, which consists of tabular, irregularly lenticular, or wedge-shaped bodies lying essentially parallel to the general stratification which themselves show a pronounced laminated structure in which the laminae are steeply inclined (as much as 33°) to the general bedding.[2]

Examples of this kind of stratification are shown in Figure 1.

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In this definition a genetic environment is cited: the cross laminations are said to occur in "granular sedimentary rocks." It is cross stratification that distinguishes these rocks as sedimentary.

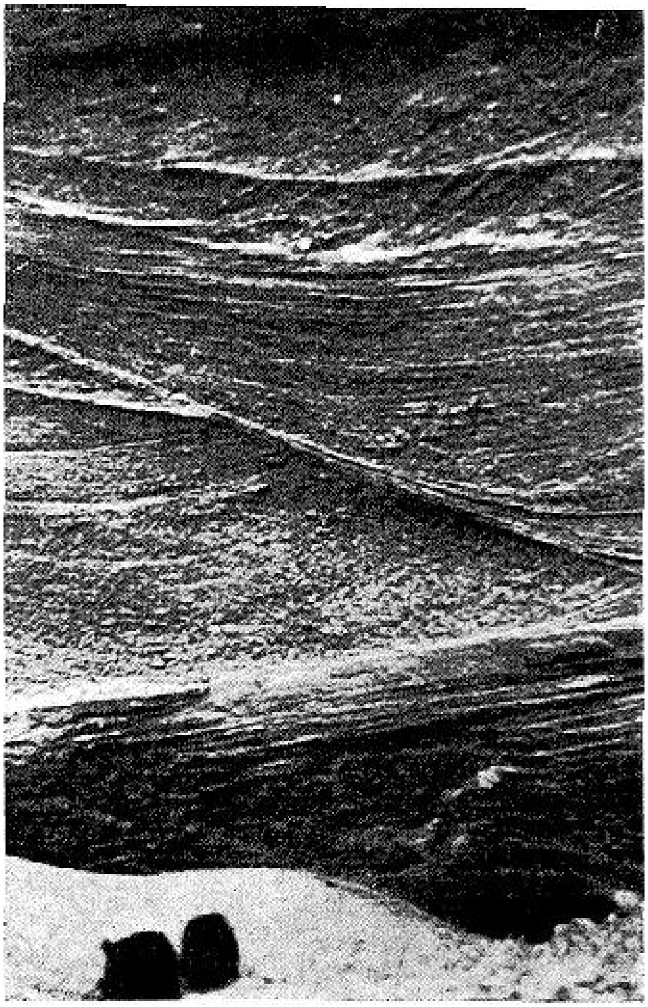
The main reason for identifying this form of stratification with a sedimentary origin seems to be that no other cause has been imagined. No non-sedimentary geologic process that forms a pattern of stratification seems to be going on at the present time, and past causes in geology are limited to processes that exist today, according to the principle of uniformitarianism.

The uncertainty about the nature and origin of cross stratification, apparent from the obsolete label "false bedding," arises from the contrast between this form of stratification and other forms, sometimes designated "true bedding."

The fact is, in geology, there are two forms of stratification with distinctly different characteristics, and why this is so has never been understood. Both "false bedding" and "true bedding" have some similar features. Both consist of successive planar surfaces that are referred to as stratification. Both may exhibit inclined strata, and both kinds occur in rocks and unconsolidated sands, in apparently similar environments.

In the geologic literature it seems that one form is often confused with the other, and both forms are associated with one environment of formation, and a common origin. This has created a lot of problems in geology. In this article an attempt is made to distinguish between these two forms of stratification, and an explanation of the source of confusion is presented.

A few definitions are necessary. In this article the term "cross stratification" means the natural pattern of stratification that is exhibited in undisturbed sand and sandstones, to which the term is usually applied in geology. This pattern occurs in the unconsolidated materials covering vast areas of the continents.



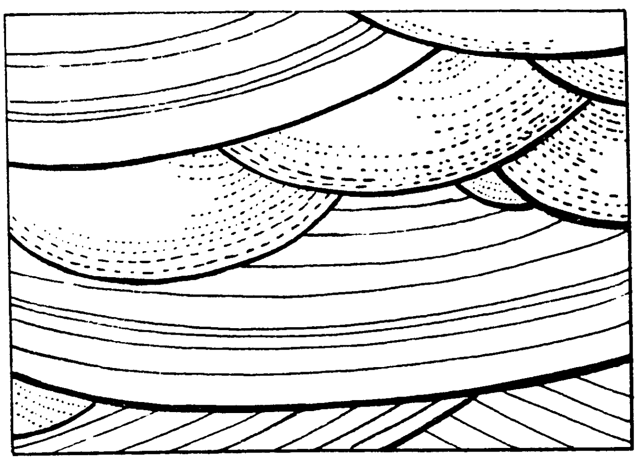


Figure 1. This shows typical cross stratification in sand. Above is a photograph of cross stratification exposed in a pit. Below is a drawing made by Valerio Racca from another photograph of cross stratification exposed at Campbellville, Ontario.

Sedimentary stratification, for the purposes of this article, will refer to patterns of stratification that are formed by *observed* depositional processes in nature and in experiments. The pattern of stratification formed by these observed processes may include inclined bedding, but this is not necessarily included in the term "cross stratification" as it applies in this article, unless the features of the sedimentary pattern include *all the other features* of cross stratification that occur in natural formations.

As will be pointed out, inclination of the strata is by no means the only feature of natural cross stratification that has to be explained.

Sedimentary Origin Assumed

Let us now consider some of the reasons for the identification of cross stratification with a sedimentary origin. In the sand and gravel formations exhibiting this pattern there are rounded stones and pebbles, that supposedly have been rounded by abrasion of the surfaces over long ages of time. This would mean that the strata in which these stones and pebbles occur was also water-laid, and therefore of a sedimentary origin.

It seems evident that the rounded stones have been worn by abrasion, since there are many of them in the beds of streams and rivers. Streams that dig channels through the unconsolidated layers of the earth often expose the pattern of cross stratification in sand and gravel, and the stones in these layers fall into the beds of the streams.

Actually they are quite round before they fall in, yet it seems that they are being rounded by the action of the water. There is an association of the action of the currents with the smoothness of the stones, that has often been mistaken for cause and effect.

Similarly the pattern of cross stratification in the sand and gravel is associated by proximity with the stream and currents that exposed it by erosion of the banks. Sometimes it is supposed that the streams have not only exposed the pattern, but have actually formed it. And indeed currents do redeposit sand in sand bars in the bed of the river, that may have inclined strata.

Geologists have identified the pattern of cross stratification found in sands before their erosion with the pattern formed by deposition in the streams, a sedimentary pattern. There seemed to be no reason to distinguish between the two. This is a quite convincing association (although it by no means constitutes proof of a sedimentary origin for cross stratification), and it is not really surprising that cross stratification has been assumed to be sedimentary.

Stratification seems to be proof enough of a sedimentary origin in geology. Currents in streams produce inclined bedding in dunes and ripples. These patterns are labeled cross stratification, and associated with patterns with which they bear little resemblance. The association of natural cross stratification (as defined in this article) with these sediments has led to the association of the phenomenon with a sedimentary origin.

The assumption has not been questioned, no alternative cause for stratification being known, and continued use and application in geology has made it pretty difficult to see the weakness of this assumption. However, sometimes in science it is necessary to put even the most firmly established "facts" to the test, resulting in the detection of error.

A Closer Look

Let us now consider some of the distinguishing features of cross stratification, and compare these with characteristics of sediments. Shrock[3] identified three common forms of cross stratification; tabular, lenticular, and wedge-shaped. These are illustrated in Figure 2.

In a paper on the classification of cross stratified phenomena in 1953, McKee and Weir[4] identified three main classes of cross strata; simple, planar and trough. A more elaborate system, based on six criteria and developed from that of McKee and Weir was proposed in 1963 by Allen, who suggested:

> . . . a better understanding of cross-stratification can be reached if cross-stratified units are classified using six objective criteria. Briefly, these are as follows: (1) whether the cross-stratified unit is a single set, or a coset formed of two or more similar sets, (2) the physical size of the set of cross-strata, (3) the character of the lower bounding surface of the set of cross-strata, (4) the shape of the lower bounding surface of the set of cross-strata, (5) the relation between the cross-strata in the set and the lower bounding surface of the set, and (6) the degree of lithological uniformity of the cross-strata.[5]

Allen identified 15 different types of cross stratification based on these criteria, and suggested how each of these might have been formed in a sedimentary environment.

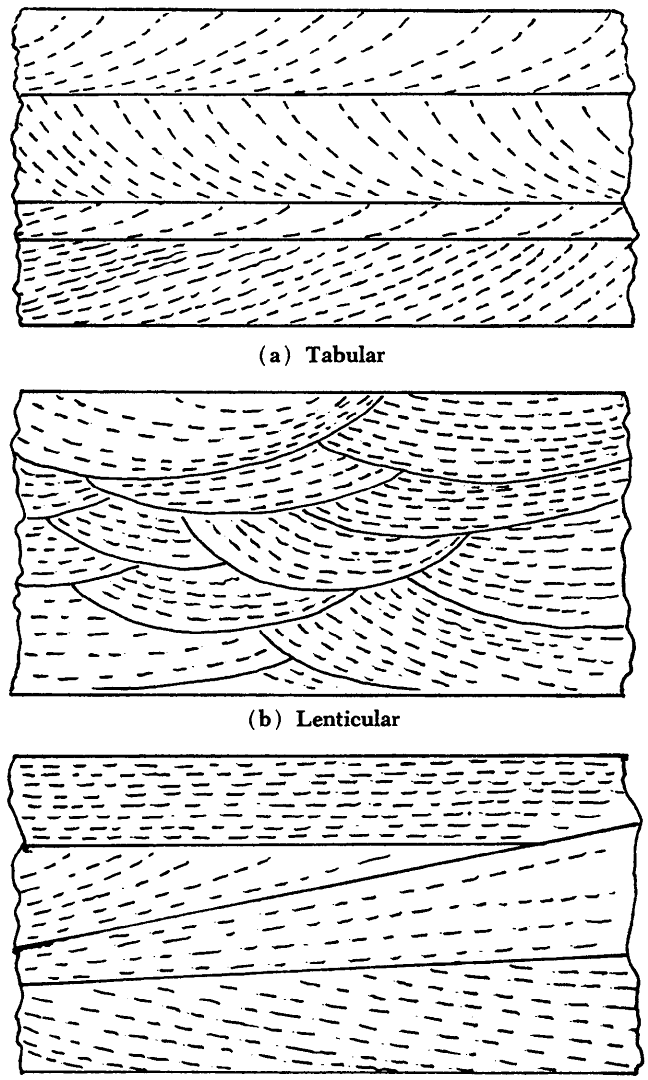
A typical pattern of cross stratification would include smooth arcing planes arranged in sets of lenticular form. Sets are generally horizontal, and the pattern consists of series of sets, bounded above by intersecting concave planes that form lower boundaries of overlying sets.

The cross strata in a set are generally inclined at an angle of about 30° to the horizontal. It may vary considerably, sometimes reaching 60° or even curving around beyond the vertical. In these instances it is often described as "contorted," since geologists find it difficult to understand how these could represent an original pattern. Just how such contortion of the stratification could have been caused is not clear.

Inclined strata in a set curve around at the lower boundary of the set toward the angle of the lower boundary. Inclined concave upwards planes in cross strata provide a reliable "way-up" criteria in geology. The radius of curvature of planes in a set increases downwards.

In cross stratified sands and gravel, the pebbles and stones are embedded in such a way that the strata do not wrap around the embedded object, but jut up against the surfaces. There is no thickening of the strata on the lee or downslope side of embedded objects, or turbulence effects that could indicate current deflection during deposition of the strata caused by stones or pebbles.

These are arranged in the planes of stratification, usually with flat surfaces and long axes parallel to the bedding, and they often lie in the boundary of a set. The configuration of the strata around pebbles and stones in sand and gravel resembles precisely that of cross stratified sandstone in the vicinity of concretions.



(a) Tabular

(b) Lenticular

(c) Wedge-shaped

Figure 2. The three common classifications of cross stratification: (a) tabular, (b) lenticular, and (c) wedge-shaped, are illustrated, as labelled.

The shape of grains in the cross stratified sands is extremely angular. According to glacial theorists, cross stratified sands of the Quaternary were formed supposedly by outwash streams from the melting glaciers, that redeposited glacial till. These sands are described by Reineck and Singh:

> An important feature of glacial sediments is the presence of numerous labile minerals, e.g. feldspar, ferromagnesian minerals as unaltered, angular grains even in silt and clay-sized fractions. The sand fraction is characterized by extremely angular sediment grains. . . . Sand grains of glacial sediments show characteristic surface features if studied by the electron microscope. Such features show abundantly conchoidal fractures, minor striations, imbricate breakage blocks, and small-scale indentations.[6]

This description applies to particles in typical cross stratified sands, that are called "glacial sediments" by the authors. The present study concerns the question of whether these sands ought to be designated as sediments at all. Of course glacial theorists assume that they are, since the so-called glacial theory is an attempt to explain the environment of the formation of these sands with the pattern of cross stratification, as well as other features associated with them.

The scale of cross stratification may vary greatly, and it is known to occur in a vast scale in some sandstones, with foresets measuring hundreds of feet. In unconsolidated sands the foresets are commonly of the order of a few inches to a few feet.

These are some of the features of cross stratification, which may take many forms. A different set of characteristics apply to "true" or sedimentary bedding, the pattern produced in observed sediments such as those formed by experiments in the laboratory.

Some Laboratory Experiments

Experiments by McDonald[7] on the formation of dunes by precipitation of sands suspended in currents showed that there was a sorting of the sediment according to grain size. The larger particles were deposited before finer sized grains, and in the dunes and ripples formed by experiment the inclined strata of the dunes contained a graduation in particle size from large at the top to fine at the bottom.

Other common characteristics of sediments formed in currents are greater thickness of deposition on the lee side of embedded objects, and deflection of the current around the embedded object creating turbulence. The thicker strata on the lee side are caused by slowing down of the current as a result of its deflection by the object.

The scale of dunes and ripples formed experimentally is quite limited. Their size cannot be increased by faster current flow, because this would only serve to erode them away. Changes of speed and direction of the currents destroys many of the structures formed by precipitation, as Middleton[8] found out while investigating the phenomenon of antidunes.

Power in 1961 had supposed that some cross bedding had been formed by antidunes, but Middleton concluded that this was unlikely. The sediments he produced exhibited very faint laminations, low angles of inclination of strata, in lens-shaped sets. The structures formed in his experiments did not look anything like the pattern of cross stratification common in nature.

Attempts to preserve the antidunes by stopping current flow suddenly merely resulted in their destruction. As Middleton stated,

> When the flow was suddenly stopped (as might happen in nature due to a diversion of the flow through a break in the bank of a stream) the antidune bed-forms were rapidly destroyed as the flow waned, and the final bed-form was a somewhat irregular but nearly flat surface partly covered with small ripples. Although the antidune bed-forms were destroyed the internal structure was still partly preserved.[9]

Sedimentologists have had great difficulty in producing sedimentary patterns resembling those in natural cross stratified sandstones and sand. These experiments were designed to confirm ideas about how the different structures in cross stratification can be interpreted in an environment of sedimentation.

Usually these involve currents, and shallow, swift flowing streams or flood plains in which an abundant supply of precipitate is available, conditions that should be comparable to those created in flume experiments. Yet a completely different kind of structure is invariably produced. Matthews described results of flume studies in 1961 by Simons et al:

> With low current velocity, small ripples were formed. As velocity increases, the height of the ripples increases. With still greater velocity, the shape of the ripples begins to flatten down. With even greater velocity, a planar bed form is achieved and no sediment is deposited. This picture is the transition from tranquil to rapid flow regime. Finally, with still greater stream velocity, antidunes are formed. Sediment accumulation on antidunes occurs on the updip side of the bed form; the antidune may actually migrate upstream with continuing sedimentation.[10]

However, as was evident from the results of Middleton's studies, there is still no evidence that typical patterns of cross stratification, like those of natural cross stratified sand and sandstone, can be formed in any sedimentary environment. Kukal has stated;

> Current stratification is one of the most frequent primary sedimentary structures. In the literature, many attempts at its genetic interpretation are recorded. Unfortunately, none of these attempts has been successful. . . .[11]

Sedimentary Origin Questioned

In view of these completely different sets of characteristics of the two patterns of stratification, that is, cross stratification and sedimentary, it would be quite rash to assume that cross stratification is really a sedimentary phenomenon.

Geologists have begun to distinguish between "recent" and "ancient" sedimentary environments, because it does not seem that cross stratified formations are actually being formed at the present time. The particular conditions for the formation of cross stratified patterns have not been determined, and yet cross stratification is thought to be sedimentary anyway.

It could be that the two patterns have a quite different origin. If not a sediment, it would be reasonable to consider a non-sedimentary and non-depositional origin for the pattern of cross stratification. Such a cause might involve an alteration of a previously homogeneous rock, producing a pattern of stratification. Since cross stratification is a common characteristic of unconsolidated material, this might well be a disintegration process that acted on surface rocks in the past, but which is not acting anywhere in geology at the present time.

A Possible Alternate Explanation

A possible process by which a pattern of stratification could have been formed, apart from a sedimentary environment, involves a disintegration process accompanying the release of former high pressure. Former deep burial of the continents under water, followed by elevation to the surface, could cause such a lowering of pressure. Because of the influence of the principle of uniformitarianism, the effects of pressure have all too often escaped the attention of geologists.

In laboratory experiments over the years a great deal has been learned about the behavior of materials under pressure. Some investigators have studied the various effects of the release of high pressure.

In one such experiment, that may prove to be quite significant for geologists, although unrecognized as such until now, samples of quartz and glass were subjected to high pressure in the presence of water, and the pressure was subsequently released. Possible conditions to which rocks would be subject, if they were raised from great depths of burial under water, were simulated.

The investigators, Poulter and Wilson,[12] were not at all interested in the geologic applications of their investigations, but were actually concerned with the problem of shattering of windows in high pressure apparatus. These men found that if pressure was released rapidly, there was fracturing of the material due to expansion of the occluded water within the solid.

Water had diffused into the glass and quartz at high pressure, and when the pressure was released it diffused out again. If there was not sufficient time for the water to escape, it began to expand inside the solid, causing sudden disintegration. This experiment is discussed below by Hamaan:

> Poulter and Wilson found that glass and fused quartz are permeable to a number of liquids at pressures of the order of 10,000 atm. Ether, ethyl alcohol and water diffuse into the materials under these conditions and diffuse out again if the pressure is slowly released. If, on the other hand, the pressure is released rapidly the liquids are unable to escape in time and their expansion within the solid causes it to fracture. When the pressure is applied rapidly and immediately released there is no breakage because the liquid has had insufficient time to diffuse into the solid. The fact that the fractures are caused by liquid trapped within the solid, and not by internal strains arising from hydrostatic pressure, is proved by the absence of any breakages when the pressure is applied by parafin oil or glycerol. The effect was confirmed by Bridgeman, who found that a heavy-walled, glass capillary, sealed at each end and compressed in water, will break into layers like onion skins when pressure is released.[13]

A similar effect would apply in geology if there had been former high pressure on the rocks of the earth's surface, due to great depths of burial under water, and rapid elevation of these rocks again to the surface.

Some sediments, such as dolomite, seem to have been formed at great depths and pressure. This chemically precipitated rock does not form at ordinary pressures and temperatures, but only under deep burial and high pressures.

Where this rock occurs on the continents today, it is evidence of former high pressure and deep burial. The subsequent elevation of these sediments to the surface would be accompanied by release of pressure. If this release of pressure was rapid enough, it could provide an environment where the generalizations based on the experiments by Poulter and Wilson would apply in geology.

Other Possible Effects of Pressure

In rocks and sediments formed under pressure some pressure-related effects such as diffusion would be evident, especially during the precipitation of sediment. Water would be present in the rock during precipitation. As grains of sediment accumulated some water would have been trapped in the rock.

At high pressure there would also be some water diffused in the crystals of the rock. Some materials such as quartz, in solution with water, and carbonates, may have been diffused to some extent in the rocks as well. These penetrate throughout the rock by diffusion at high pressure, and when pressure is lowered they crystallize, causing the sediment to solidify.

As pressure is released when rocks are raised again to the surface, some changes occur due to adjustment of diffusion equilibria. Some minerals cannot remain diffused at the lower pressure, and become precipitated. Concretions have evidently been formed in this way, and various other effects in the rocks.

Water may remain diffused after the rocks have become quite solid, since it is much more compressible under pressure. A considerable amount of water may be squeezed in between the molecules and inside the crystal lattices of the rock.

Some of the water within rocks at high pressure may consist of water of hydration, that is present in many rocks. Adjustment of pressure may cause a change in the equilibrium amount of water of hydration. As pressure decreases there may be some water precipitated because of this.

What Happens When Pressure Is Released?

Water diffused in rocks at high pressure is expelled when the pressure is released. The rate at which the pressure is released, as Poulter and Wilson showed, has quite an effect on the manner in which this diffused water is expelled.

As pressure decreases there would be transport of the diffused water upwards through the rock, just as the diffused water in the quartz and glass samples slowly diffused out during gradual release of pressure. The water must move to regions of low pressure. In rocks it would have to exit at the surface.

Near the surface, the diffused water may become precipitated and occluded within the rock before there was time for it to diffuse out. This could occur during a continuous release of pressure, as when the rocks were being gradually raised from the depths. Pressure at the rock surface would be continually lower than inside the rock. More water would be expelled, that would not have sufficient time to diffuse out gradually.

Near the topmost surface of the rock there is a considerable pressure built up because of the expansion of this occluded water. It is a compression in the plane of the rock surface. In these conditions there could be shattering such as that reported by Poulter and Wilson, resulting from pressures within the solid due to expansion of the occluded water, but on a much greater scale.

In a quartz-rich, consolidated rock this shattering would be a form of brittle fracture. Some characteristics of brittle fracture may help geologists to understand how such a process could have produced the unique features of cross stratification.

Consistent with the idea of brittle fracture in compression, it was supposed by Griffith that the material is filled up with tiny cracks and flaws, called "Griffith cracks." Stress at the tips of these cracks causes them to grow. Research by Brace and Bombolakis determined that the most stressed crack is inclined at an angle to the plane of compression of about 30°. According to these investigators;

> In compression the most severely stressed crack is inclined at about 30° to the axis of compression. Such cracks, when either isolated or placed in an array, grow along a curved path which becomes parallel with the direction of compression. When this direction is attained, growth stops, unless applied compression is increased considerably. Cracks in certain *en echelon* arrays start to grow at much smaller applied stress than that required to enlarge an isolated crack.[14]

When this information is applied to the shattering of a rock surface because of expansion of occluded water near the surface, it is clear that innumerable tiny cracks in the surface would bend into the direction of compression. These cracks would become parallel to the rock surface.

This would cause shattering of a thin lamina of the rock surface. The rock would be converted into particles of sand, having angular shapes, and exhibiting conchoidal shapes and striations.

Sand of this type is characteristic of the unconsolidated cross stratified formations in geology. The striations on the particles result from abrasion with other particles in stress during the disintegration of the rock surface.

Nature and Results of Shattering

McClintock and Walsh,[15] in their investigations of Griffith cracks in rocks under pressure, supposed that these would close up in compression, and considered the effects of friction on the surfaces of these cracks. In the surface of the rock, pressure of the expanding water would build up until the friction and forces of molecular cohesion were overcome.

At a limiting "brittle strength" for the material, shattering occurs with explosive suddenness. It is characteristic of brittle fracture that disintegration is rapid. Schiedegger wrote;

> Brittle fracture is the only type of fracture that occurs in completely brittle substances. It is that type of fracture which is theoretically best understood. It is characterized by a high velocity of propagation, producing a bright, smooth fracture surface. . . .
>
> The high velocity of the spread of a crack in brittle fracture can be explained by noting that the only work required for the latter is that necessary to overcome the cohesion between the atoms on either side of an existing crack. This work is so small that it can be supplied by the elastic energy stored in the material just prior to its disintegration.[16]

Once a particle in the rock surface has been dislodged, shattering in the surrounding area would be rapid because of the rate of release of confining pressure in the surface of the rock.

Immediately upon disintegration of a thin lamina another surface of the rock would be exposed. Pressure of occluded water would begin to build up in this surface also, and shattering would occur producing another thin lamina that is parallel to the first.

Continuous disintegration of successive laminae in this way would produce a series of layers of sand particles from the previously homogeneous rock. They would exhibit a pattern of stratification that was not sedimentary in origin. The phenomenon would proceed downward from the surface, the lower strata being the last formed.

This pattern of stratification would result from the release of pressure on rocks being raised from great depths of burial under water. According to this new explanation, the features of cross stratification, as found in natural sands and sandstones, are the effects of this pressure-related disintegration.

Results to Be Expected

Let us now consider whether such a disintegration process could produce two of the characteristics of cross stratification: (a) inclined strata, and (b) concave upward shape. According to the new explanation offered here, disintegration starts when a particle is dislodged in the surface of a rock because of compressive stress in that surface caused by expansion of the occluded water.

Then it would be reasonable to suppose that the disintegration of the rock would spread radially outwards from the first dislodged particle. Since this would take a few moments, there would be a tendency for the shattering of the next surface to begin before the process of shattering of the previous surface had been completed. It would spread outward in an ever widening circle centered at the point of origin.

The next surface would begin shattering, and successive surfaces, while the previous surfaces were still in the process of disintegration. A consequence of this would be that the shape of the rock surface would change during shattering. The penetration of disintegration would be enhanced by higher pressures a little lower in the rock, where less water has had opportunity to diffuse out. The shape of the strata formed by disintegration, as a result would be concave upward.

Inclined strata, particularly the common 30° inclination of cross stratification, would result from shattering proceeding laterally at the most preferred angle for disintegration in compression.

These two features of cross stratification, then, are both indicative of a process of disintegration. The scale of the pattern might vary considerably in a disintegration, and might depend on such things as water content of the original rock, rate of release of pressure, and degree of consolidation during shatterign. In sandstones there must have been lithification of the disintegrated rock by crystallization of diffused silica or carbonates. This evidently preserved the pattern in the grains.

Propagation of the disintegration would end at the bedrock underlying the unconsolidated material, and a corollary of this explanation is that the features of the bedrock surface would represent a typical plane of the disintegration as it proceeded downward through the cross stratified material. It would be comparable in shape to any such surface that could be traced in the cross stratified sands.

The surface of the bedrock below these materials in fact does exhibit concave depressions, with smooth surfaces, and angles of inclination similar to the structures in the cross stratified sands above.

Also it is frequently scratched and grooved, as a result of the movement of sand and boulders across it. The motion of the disintegration product, according to this explanation, probably occurred at the time of shattering and would have been caused by expansion in the lateral plane.

The unconsolidated sands and gravels, with the pattern of cross stratification, have embedded in them many pebbles and stones and boulders. These are usually rounded and smooth, and are embedded in the strata, without any evidence of turbulence around them, that could have resulted from currents present during the precipitation of the sand and stones. There is no thickening of the bedding on their down-slope sides, where they occur in inclined strata. This would be expected if there was a current present at the time of their deposition.

The absence of these effects is quite incompatible with a sedimentary origin of these structures. Those who accept a sedimentary origin explain inclination of the bedding by postulating that a current was present. Lack of turbulence effects indicates no current was present. The source of this contradiction lies in the assumption of a sedimentary origin for the pattern of cross stratification, and the stones and pebbles associated with it in sand and gravel.

The Question of Embedded Stones

According to the disintegration explanation, there is no need for the effects of currents to explain cross stratification. However, it is necessary to account for the roundness of the stones, and their variety of composition, and how they could have been formed in the environment of disintegration.

It is proposed that the stones have become rounded in basically the same manner in which concretions become rounded, which have similar appearance, composition, and configuration in the strata. Concretions have evidently been formed by the reconstitution of the constituent minerals of the sediment.

As would be expected in the deposition of sediments, the material comprising a sedimentary rock is a mixture, formed at great depth in some instances. At the time of the deposition of the sediment, when the rock was unconsolidated, there was apparently some ionization, as well as diffusion of the materials comprising the sediment.

The pressures existing in the environment of sediment deposition resulted in certain diffused and ionized minerals remaining in the rock at equilibrium. As pressure was changed, however, the equilibrium also changed. Precipitation of certain diffused minerals within the sediment would occur as the pressure dropped, when the rocks were elevated from the depths. In this environment inside the rock, the concretions formed by precipitation of diffused material, to maintain diffusion equilibria.

The sediments, precipitated in an unconsolidated condition, must have hardened during the release of pressure. Cementing material diffused throughout the rock at high pressure crystallized when pressure decreased, lithifying the rock. At the same time there was precipitation of some of the minor constituents of the rock in concretionary centers.

Sometimes it seems that the whole rock is reorganized into concretions. These appear to "grow" by a process of purification of the individual centers, as precipitate was attracted into them and other matter was expelled.

Possibly electro-static forces attracted precipitate from the environment into concretionary centers. Ions could migrate, in these conditions where there would be diffusion and ionization within the rock, like electrons in a conductor. So while concretions formed within rocks being hardened because of a lowering of pressure, they became rounded because of differences in pressure between their interiors and exteriors.

Possibly the pressure inside concretions was greater than in the surrounding matrix, because matter was being squeezed into them by forces of electro-static attraction, and diffusion equilibria were causing some minerals to be expelled from the rock, while their growth would have been restricted by the hardness of the rock in which they were being formed. Presumably concretions are round and have smooth surfaces as a result of such possible changes.

Differences in pressure within concretions might be the reason they would be left intact when the matrix disintegrated around them, during the shattering process. The stones and boulders would be formed by the shattering of the rock around concretions, which are left intact, embedded in the sandy strata. Since they have not been dropped into their positions from above, and there have been no currents associated with their origin, there would be no reason for dents in the strata around them or turbulence effects, that would be necessary in a sedimentary environment.

The disintegration explanation developed here clarifies these problematic questions in accounting for the features of cross stratification.

This treatment of the origin of stones and boulders, suggesting a concretionary process of reconstitution of a rock, and shattering of the matrix around them in successive layers from the top downward, solves the difficulty of accounting for the stones and boulders in cross stratified formations. They are not water-worn, and have not been transported, either by glaciers or streams. A variety of otherwise almost insoluble difficulties are accounted for with this disintegration explanation.

The presence of disintegrated boulders, "sand balls," and so forth in the cross stratified materials, which could not have been transported into their positions or worn round by abrasion, is explained. They have been formed in place. Many of these will exhibit a pattern of cross stratification inside, a result of disintegration. Rocks identical to the bedrock below are abundant in the gravels, since they have been formed by a reconstitution of the bedrock.

The pattern of cross stratification may show successive sets with inclined strata oriented in different directions, and there need not be any preferred orientation in a cross stratified formation. This is easily explained in the disintegration explanation, yet a sedimentary origin could occur only if currents reversed repeatedly, without destroying the pattern in underlying beds.

Conclusions

In conclusion, it has been shown that a process causing stratification may have acted on rocks of the earth's surface in the past, that is not sedimentary. Such a process would have been overlooked by geologists because of the principle of uniformitarianism, according to which past causes are limited to those found acting at the present time.

This form of stratification involves the rapid release of former high pressure on surface rocks. According to the new explanation, cross stratification, as found in natural sands and sandstones, is an effect of the shattering that accompanied release of high pressure when the continents were raised from great depths of burial under water.

The amount of pressure involved was sufficient to cause diffusion effects in recently precipitated sediments. With the new explanation a complete reinterpretation of the significance of the phenomenon of cross stratification is possible, opening the way for new insights into the recent history of the earth.

References

[1]Shrock, R. R. 1948. Sequence in layered rocks. McGraw-Hill, New York, p. 242.
[2]*Ibid.*
[3]*Ibid.*, p. 245.
[4]McKee, E. D. and G. W. Weir. 1953. Terminology for stratification and cross-stratification in sedimentary rocks. *Bulletin of the Geological Society of America,* 64 (4):381-390.
[5]Allen, J. R. L. 1963. The classification of cross-stratified units, with notes on their origin, *Sedimentology,* 2:93-114. See especially page 111.
[6]Reineck, H. E. and I. B. Singh. 1973. Depositional sedimentary environments. Springer-Verlag, Berlin and N.Y., p. 181.
[7]McDonald, B. C. 1972. Fluvial sedimentary structures formed experimentally in a pipe, and their implications for interpretation of subglacial sedimentary environments. Department of Energy, Mines and Resources, Ottawa. Geological Survey of Canada, paper 72-27, p. 14.
[8]Middleton, G. V. 1965. Antidune cross-bedding in a large flume, *Journal of Sedimentary Petrology,* 35 (4):922-927.
[9]*Ibid.*, p. 924.
[10]Matthews, R. K. 1974. Dynamic stratigraphy. Prentice-Hall, Inc., Englewood Cliffs, N.J., p. 31.
[11]Kukal, Z. 1971. Geology of recent sediments. Academia, Prague, p. 442.
[12]Poulter, T. C. and R. O. Wilson. 1932. The permeability of glass and fused quartz to ether, alcohol and water at high pressure, *Physical* Review, 40 (5):877-880.
[13]Hamaan, S. D. 1957. Physico-Chemical effects of pressure. Butterworths Scientific Publications, London, p. 89.
[14]Brace, W. F. and E. G. Bombolakis. 1963. A note on brittle crack growth in compression, *Journal of Geophysical Research,* 68 (12):3709.
[15]McClintock, F. A. and J. B. Walsh. 1962. Friction on Griffith cracks in rocks under pressure, *Proceedings of Fourth U.S. National Congress of Applied Mechanics (Berkley),* p. 1015.
[16]Schiedegger, A. E. 1963. Principles of geodynamics. Academic Press, N.Y., p. 138 and 139.

MATHEMATICIANS DO IT AGAIN[1]

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Creationists have often argued, rather qualitatively, that if evolution had really happened, the many gaps in the "fossil record" would be most improbable. That is true. The purpose of this paper is twofold: to obtain somewhat more quantitative estimates of the improbability, and to calculate from the presence of gaps in the fossil record being given empirically, the probability that evolution occurred. It is shown that that probability is vanishingly small; one may as well say that, the gaps being admitted, it is impossible that evolution occurred.

Bayes' Theorem

Given the fact that there are still many large gaps in the fossil record, what is the probability that the evolution model is valid? An approach to answering this type of question may be made by using Bayes' Theorem.

Some special notations are needed. The symbol p[A] denotes the probability of the event A. The symbol p[A|B] denotes the probability of event A given that event B has already happened.

For example, if F represents a gap that has been filled and E represents the evolution model then p[F|E] denotes the probability, assuming the evolution model, that this gap has been filled. On the other hand p[E|F] denotes the probability, given that a certain gap has been filled, that the evolution model is valid.[2]

In this use of Bayes' Theorem, it is assumed that either the evolution model (denoted E) or the creation model (denoted C) is valid; but both cannot be valid. That is, the following is assumed:

$$p[E] + p[C] = 1. \qquad (1)$$

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