He seems to have an accurate understanding of the second law of thermodynamics, as any physical chemist should, but apparently fails to recognize that if the universe is an isolated system which is spontaneously increasing in entropy, it must have had an origin as a highly organized (low entropy) system some time in the past. This universal low entropy state could not have arisen spontaneously from a higher entropy state in accord with the second law, if the universe is indeed a closed system, because there could be no corresponding decrease in enthalpy. Furthermore, he apparently fails to recognize the necessity of a preexisting highly ordered energy conversion mechanism in order for the "supply of sunlight" to produce chemical organization on the earth.

In the discussion of the evolution of biological macromolecules (p. 149) the author seems to recognize the problems for the theory of chemical evolution which have been raised by mathematicians, and concedes that "no satisfying, detailed answer to the question of how biologically important molecules were initially selectively synthesized exists at present," but then appeals to hypercycles to somehow overcome these problems. As far as I know, creationists have not yet commented on the use of hypercycles to solve statistical problems associated with chemical evolution.

The limitations of experiments dealing with nonrepeatable historical events such as the origin of life is recognized (p. 149). Yet the final statement:

> However, it is clear that not only do no apparent physical laws forbid the spontaneous generation of chemical organizion, but there are conditions under which currently known theory seems to guarantee it (p. 149)

while being technically accurate as far as "chemical organization" is concerned, is misleading in this context concerning the origin of life. It seems to say that "not only do no apparent physical laws forbid the spontaneous generation of 'life,' but there are conditions under which currently known theory seems to guarantee it." Obviously, this is not actually the case. No exceptions to the law of biogenesis have ever been documented, and the more we learn about the complexity of living cells, the more obvious it becomes that spontaneous generation is, indeed, impossible.

In conclusion, my biggest concern relates to the somewhat misleading implications of the article which arise from its purpose to "shed some light on how life might have evolved," rather than the accuracy of the factual material itself.

Contributed by Larry Helmick

Kinetic Manipulations

The article is full of interesting kinetic manipulations; however the author admits that the universe as a whole is an isolated system. Therefore the argument based on the possibility of life originating in an open system is not valid.

His statement that an isolated system may at some point be far enough from equilibrium to become organized could allow for the kinetic behavior exhibited, but eventually disorganization *will* develop.

The author states that he has no idea of how the biologically-important molecules were initially synthesized and then proceeds to develop his theoretical work by disregarding this problem.

An interesting question for a creationist to ask is: how did the physical laws originate in order for the evolutionary process to follow them?

Contributed by Marsha Damon

SANDSTONE AND THE FLOOD ENVIRONMENT

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Received 20 July 1984, Revised 20 June 1985

Abstract

Terrigenous rocks, those that appear to have been formed on the land, seem incompatible with sediment deposition in the Flood environment. These include sandstones, gravels, and conglomerates. Concepts for reinterpreting these rocks are developed, based upon the evidence of diagenesis, the processes which cause alteration of sediments after deposition.

Interpretation of Sands and Gravels

James Hutton claimed that gravels were formed by the erosional action of rivers over long ages. He interpreted the abundance of rounded pebbles on the land and buried in rock strata as evidence for repeated uplifts and subsidences of the earth's crust and erosion of igneous and sedimentary rocks. The products of erosion eventually became the materials from which new sediments were formed, which were in turn uplifted and eroded, in an endless cycle. To many people, the presence of gravels and sands in the rock record is a compelling reason for assigning a great age to the earth. Hutton wrote:[1]

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> Gravel forms a part of those materials which compose our solid land; but gravel is none other than a collection of the fragments of solid stones worn round, or having their angular form destroyed by agitation in water, and the attrition upon each other, or upon similar bodies. Consequently, in finding masses of gravel in the composition of our land, we must conclude, that there had existed a former land, on which there had been transacted certain operations of wind and water, similar to those which are natural to the globe at present, and by which new gravel is continually prepared, as well as old gravel consumed or diminished by attrition upon our shores.
>
> Sand is the material which enters, perhaps in greatest quantity, the composition of our land.

But sand, in general, is none other than small fragments of hard and solid bodies, worn or rounded more or less by attrition; consequently, the same natural history of the earth, which is investigated from the masses of gravel, is also applicable to those masses of sand which we find forming so large a portion of our present land throughout all the earth.

Following Hutton, most geologists assume that conglomerates, or cemented gravels, and fluvial and aeolian sandstones, overlaid by shales and limestones can only be explained by continental and marine deposition respectively. They envision a cyclical pattern of uplift and subsidence, as if the earth were a creature slowly breathing in and out, lying half submerged in a vast sea for hundreds of millions of years.

These conglomerates and sandstones, if they really do prove intermittent periods of continental deposition during accumulation of the Phanerozoic sedimentary column, are fatal to the hypothesis that the bulk of these sediments can be attributed to the Noachian Flood. Some creationists have attributed sandstone formations to violent currents of the Flood waters. Bernard E. Northrup, reviewing an account of the Franciscan rocks of California, claimed that these were:

. . . the product of extremely catastrophic, violent processes occurring abruptly in time and involving the degrading of basement and continental self materials into rock paste and sands that were redeposited almost as rapidly.[2]

These ideas may be valid for certain types of sandstones, but it is doubtful that the currents of the Floodwaters would disintegrate basement rocks into sand-size particles. In the creationist concept of the deposition of much of the world's sedimentary rock in the period of about a year, (the duration of the Noachian Flood), the abundance of sand contained in sandstones presents a problem. Indeed there may be far too much sand in sedimentary rocks for it to have been formed by mechanical processes of rock disintegration on the continents.

Pettijohn, Siever and Potter listed the following processes as the major ones contributing to sand formation: weathering, explosive vulcanism, crushing, pelletization, precipitation from solution, and rock disintegration.[3] Garrels and Mackenzie estimated that sandstones constitute about 30 percent of the geologic column.[4] About a third of all sandstones are quartz arenites, sandstones consisting almost entirely of quartz.[5] The proportion of quartz in sandstones averages about 65 percent. These facts imply some very effective mechanism of sand production must have existed to supply the sand in the world's sandstones.

Sources of Sand

Experiments on rock crushing and abrasion have been conducted to determine which processes are more effective in producing sand. Abrasion of pebbles apparently produces silt and not sand.[6] Weathering and disintegration of granite may produce quartz grains in some regions, but this seems ineffective at the present time over much of the Canadian Shield, since the exposed rock surfaces show fresh looking striations that have been little affected by weathering, abrasion, or freeze-thaw processes of disintegration, in several thousand years.

Rounded sand grains are supposed to have been formed in continental environments, particularly by being blown about in deserts by the wind. This of course is incompatible with a creationist model of sedimentation in a Flood environment. But not all desert sands are rounded, as Folk has shown in his study of the sands of the Simpson desert in Australia.[7] These sands consist of angular grains, and no significant rounding seems to be occurring at the present time.

Conglomerates with well rounded pebbles are invariably interpreted as continental deposits, and the pebbles are thought to have been rounded by abrasion such as the action of waves on a beach. These may occur above thousands of feet of shale, and in a creationist interpretation, this order of deposition seems wrong. As well, the time for rounding of the pebbles by abrasion is lacking, and it seems unlikely that violent currents could have transported masses of pebbles and deposited them in the positions in which they are now found. In the Catskill Mountains of Southeastern New York there are coarse sandstones and conglomerates with pebbles of granite and metamorphic rocks, quartz, and feldspar. To supply the enormous quantity of sand which is contained in this region, geologists have proposed a slowly rising mountainous island called "Appalachia" located east of the area, and that these mountains were continuously eroded for millions of years, while the sand and pebbles piled up in shallow seas. Meanwhile, the earth's crust was steadily sinking under the weight of the sediments. A total of 600,000 km^3 of sand is thought to have been produced in this way, from Ordovician to Upper Devonian times.[8] But this is only one-tenth of the volume of the Silurian sands in the Appalachian mountains. Describing the Silurian strata in this region, Dott and Batten wrote:[9]

The Silurian strata of northeastern United States provide a classic example of transgressive facies recording the reduction of an old mountainous region by erosion. Had James Hutton lived in New York instead of Scotland, he still could have developed his theory of uplift, erosion, and burial of successive mountain systems.

Early Silurian clastic sediments clearly were derived from the core of the mobile belt east of New York. This is shown by the coarsening of sandstones eastward, and by orientation of current-formed features. Silurian quartz sandstones are widespread in the Appalachian mountains, comprising roughly 6 million cubic kilometers (1.4 million cubic miles). This staggering volume of sand with scattered quartz pebbles represents weathering, winnowing, and concentration from a tremendous volume of source rocks in the Taconian Mountains.

The volume of these sands and their localization in the Appalachian region poses problems for the uniformitarian interpretation, as visualizing a mountain range of sufficient volume to produce the required quantity of sand will illustrate. Such a mountain range would have to exceed the height of any existing mountains. As well, there is the question of what became of all the sand that was presumably deposited on the eastern side of the mountains of Appalachia. Berry and Boucot considered this hypothetical island a possible source for only a small fraction of the quartz sands of the Appalachians. They wrote:[10]

> Unfortunately, volumetric considerations strongly suggest that this island (or islands) was totally incapable of providing more than a small fraction of the quartz-rich terrigenous material present in the Silurian of the Appalachians.

The problem of the source of the sands of the Appalachians remains unresolved. Similar problems exist in accounting for the source of Silurian sands in the northern and western parts of the continent.[11]

Some sandstones which have been thought to be aeolian deposits, have been reinterpreted as marine in origin. The Navajo sandstone of Utah and Arizona has been presented in geology text books as a prime example of an aeolian sandstone. It was described by Dott and Batten as "a vast blanketing mass (approximately 40,000 km^3) of very well-sorted, prominently cross stratified sand," containing 90 percent quartz.[12] Spectacular large scale patterns of cross stratification were thought to represent ancient wind dunes formed on a vast Sahara-like desert, but Freeman and Visher have argued against the aeolian interpretation and in favor of a marine environment of deposition.[13] The upper Navajo sandstones are locally interstratified with thin carbonate rocks containing marine fossils.

This reinterpretation of aeolian sandstones as marine illustrates that criteria for explaining sandstones are only vaguely defined, and in fact little is understood about their formation. In a creationist model, it is obvious a marine interpretation of these sandstones would be preferred, but the idea of sand particles being deposited in pure quartz formations by violent currents, which ought to have eroded shales and silts and mixed them up with the sands, is hard to conceive.

Identifying the means of transportation of the sand from supposed source areas to regions where it was deposited is also a problem in the uniformitarian explanations. These are often far from the exposed source rocks in the granite craton (i.e., basement rocks). Certain parts of the craton are supposed to have been subject to subaerial erosion, the weathering of granite providing a source of quartz grains for sandstones being deposited elsewhere. Yet these regions from which quartz could have been derived are quite limited, since early Paleozoic sediments (especially Silurian) cover much of the area of the North American continent. These areas covered by sediments were protected from erosion for much of the time in which the Phanerozoic sedimentary record is supposed to have been formed, so could not supply sand for the deposition of sandstones. As well, examination of the relief of the granite basement below these protected areas shows little evidence of differential wearing down of the exposed parts as would be expected according to the uniformitarian assumptions.

Where was all the material from which later sediments were formed while the earliest Phanerozoic sediments were laid? Even if a seemingly inexhaustible supply of granite were available to supply quartz grains for sandstones, how could it be transported thousands of miles, and what could have caused the disintegration of granite to form sand in such vast quantities?

Uniformitarianism falters again when it comes to finding modern counterparts of ancient quartz sandstones, since nowhere are these seen being formed at the present time. Desert sands are generally derived from existing sandstones. Pettijohn and others wrote:[14]

> Because quartz arenites are by definition essentially quartz sands with less than five percent other constituents, they are exceptional sands. They are exceptional, that is, in the sense that sands of this character seem not to be forming today.

Diagenesis

New interpretations for these rocks are suggested by the findings of petrologists in recent years. Detailed mineralogic study of sandstones has produced some remarkable shifts in concepts. A pure quartz sandstone may not have been initially deposited as such, but has evidently undergone many changes since the deposition of the sediment, due to the movement of pore fluids through the sediment pile during compaction. This compaction results from a sediment that is initially in a hydrostatic stress state being unloaded by uplift or erosion of overlying sediments.

A sandstone consisting almost entirely of quartz is thought to have been subject to the action of pore fluids which removed all other minerals. Such a sandstone is called "mature." Some sandstones have been made progressively more mature by fluid movements, and have undergone repeated alteration, such as deposition and dissolution of various cements, compaction, and alteration of grain shape and size. These, and similar processes, which occurred at relatively low temperatures, constitute the class of processes called "diagenesis."

Sandstones of various types can be classified according to their stage of maturity. At the top end of the maturity scale are pure quartzities, consisting of quartz grains cemented by quartz. Below these are sandstones containing other kinds of grains such as feldspar, which is less stable than quartz, or rock particles, and quartz sandstones cemented by minerals such as calcite and clay minerals. At the bottom of the scale are greywackes, which are rocks consisting of rock fragments or pebbles cemented by argillaceous material (clay minerals), the grains and pebbles not in contact with one another.

Sediments may initially contain 50 to 80 percent fluids, and unloading of a sediment pile tends to cause a flow of these fluids upwards to the surface. The effect of unloading would be to create a pressure gradient, causing pore fluids to flow upwards towards the low pressure zone. The expulsion of fluids would result in further compaction of the rock. If the fluid flow was restricted by a layer of impermeable rock such as shale, a zone of over-pressured rock in which trapped fluids sustain pressures greater than hydrostatic could be formed. Many areas of over-pressured rock have been encountered during drilling for oil. The presence of these zones could be evidence for uplift of these areas from some depth of burial below the sea, or erosion of over-burden, or both.

As well, it is possible that over-pressured rocks may sometimes result from the migration of fluids from very great depths towards the surface, the fluids becoming trapped by the formation of an impermeable layer. Since rocks are usually well compacted, and considerable volumes of fluid have been forced out, it is likely that unloading associated with uplift has caused the compaction of rocks and expulsion of fluids they must have initially contained.

Evidence for grain and matrix alteration in sandstones has led geologists to conclude that existing sandstones may be much altered from the original sediment. E.C. Dapples, in a paper on sandstone diagenesis, noted the considerable diversity of opinion about the extent of the effects of diagenesis. He wrote:[15]

> The extent to which diagenesis has modified the original detritus still remains a subject of considerable diversity of opinion. Are the modifications so profound that the present-day mineralogy of the sedimentary rocks is only remotely akin to that of the detritus which was deposited? Is it possible that pure-quartz sandstones were never sediments of such composition, but are the products of substratal solution episodes during which episodes all minerals were removed except the most resistant ones?

Dapples wrote that there is considerable evidence that calcite has replaced quartz in many sandstones. There are various kinds of evidence for this, such as relics of former quartz grains in calcite crystals, and irregular surfaces of remaining quartz grains due to corrosion and partial replacement by calcite. He stated: "Silica alters readily into other forms, dissolves, and reprecipitates repeatedly throughout the history of certain sandstones."[16] Fluids moving through a sediment pile during compaction precipitate or dissolve certain minerals depending upon the concentration of ionic species, temperature, pressure, pH and Eh and other parameters, which may change rapidly during uplift because of faulting. At low pH, (i.e., acid conditions) quartz is relatively insoluble, but calcite dissolves, and moves upwards in the sediment pile to be re-deposited where pH is higher. By this process, a calcite cement may be almost entirely removed from one horizon in the pile, to be replaced by quartz, which could possibly precipitate if the pH changed from a high to a lower value.

If pH is very high, (nine or higher), quartz solubility is increased significantly. Existing quartz grains in a sandstone can be corroded, the dissolved silica moving upwards in the sediment pile, to be re-deposited at another level, perhaps at lower temperature and pressure, where it may form overgrowths on existing quartz grains. Geologists believe processes such as these have produced mature quartzites with quartz grains cemented entirely by quartz. A mature sandstone of this kind is illustrated in Figure 1.

Quartz Solubility: A Dilemma

There is a problem, though, with the uniformitarian explanations of sandstone diagenesis, because highly alkaline fluids, which can dissolve significant amounts of quartz, are only rarely encountered in sandstones. Quartz is only slightly soluble in solutions with pH values below nine. Quartz solubility is increased

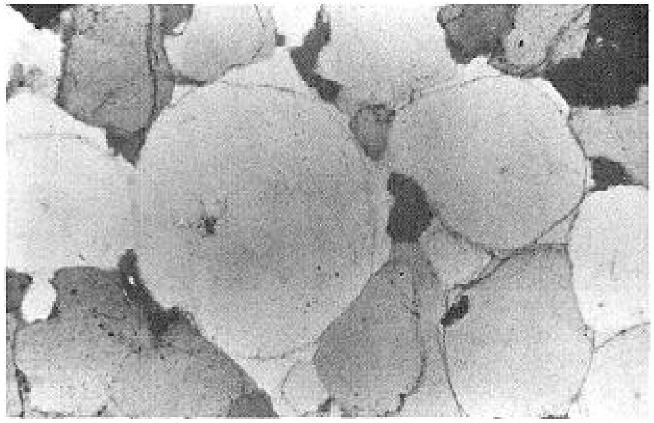

Figure 1. Quartz grains of a mature sandstone (Potsdam formation) seen in thin section. All grains seen are quartz. Rounded grains have been enlarged by quartz overgrowth in optical continuity. Dark outlines of the rounded grains are due to a thin coating: of hematite. (38x)

dramatically in solutions with higher pH. and at elevated temperatures and at high pressures.

If quartz solubility was only slightly more than its value in meteoric waters or sea water, each unit volume of quartz deposited as overgrowths on grains in a sandstone would require some 10^5 unit volumes of pore fluids to have passed through each unit volume of the rock. Calculations show this is unlikely, even for sandstones thought to be hundreds of millions of years old.[17,18]

The solution to this problem may be that sandstones were formed in conditions unlike those existing at the present time, and that their diagenesis involved pore fluids with compositions that could not have been stable over long periods of time. The presence of 'evaporite' minerals in the sediment pile suggests that high concentrations of sodium and potassium cations with hydroxyl and carbonate anions may have generated the high alkalinity.

So-called evaporite minerals and volatiles such as CO_2 may have been dissolved in the Flood waters expelled from the earth's interior. High partial pressures of CO_2, together with cations such as Na^+, Ca^{++}, and Mg^{++} in solution, would tend to raise the concentration of bicarbonate and carbonate ions, increasing alkalinity.

Another source of CO_2, which may have been more potent in the environment of the Flood than in uniformitarian environments, is the production of CO_2 by bacterial decay of plants and animals buried in the sediments. During compaction of the sediments in the Flood environment, the sediments contained all their fossils freshly buried. CO_2 production in the months following burial would have a significant effect on processes of chemical precipitation sensitive to changes in pH.

Bissell and Chilingar suggested that alkalinity may increase because of CO_2 production in sediments on the ocean floor, contributing to the formation of dolomite. They wrote:[19]

> Another possible reason for the influx of magnesium from bottom waters into the sediment would be the decomposition of organic matter by bacteria with generation of CO_2. As a result of this process first the alkalinity $\Sigma(HCO_3^- + CO_3^=)$ would rapidly increase and then would decrease with loss of CO_2

from interstitial waters of the sediment. With increasing alkalinity dolomite could reach a saturation value and precipitate.

Strongly alkaline fluids may have transported dissolved silica upwards through the sediment pile during compaction. Changes in alkalinity at various levels could result in quartz precipitation.

Compaction in the Flood Environment

Clearly the potential for diagenesis of sediments is greater in the creationist model, in which the entire sediment pile was compacted at once, than in the uniformitarian one. One major period of sedimentation, in which a whole world of creatures was buried, was followed by uplift of the sediment pile as the continents emerged from the Flood waters.

Uplift of continents, and removal of the weight of overlying waters, which ran off towards the oceans, would initiate both the movement of pore fluids upwards through the rocks and the associated compaction of mud into rock. There was a much greater supply of pore fluids to cause diagenesis than in the uniformitarian model, which invokes multiple minor uplifts and presumably, successive periods of compaction for each additional thin sediment layer.

This kind of scenario provides only limited amounts of pore fluids for diagenesis. Once a rock was compacted, it is difficult to see how it could have once again become a significant source of fluids for further alteration of overlying sediments.

Interestingly, some geologists investigating diagenesis convey an impression that they consider the sediment pile to have been compacted in a single event, as the creationist model would predict, rather than invoking a long series of minor episodes of compaction. The extensive evidence for diagenesis seems to require more fluid movement through the sediment pile than their model would permit.

Fluids originating from within the earth which were released during the Flood and forced upwards through the sediment pile during compaction would have heated the sediments through which they flowed. Heat would also have been generated because of the work expended in forcing fluids through less permeable layers. The heat may have contributed to the solubility of quartz and various reactions during diagenesis. In the uniformitarian model, because of the very slow rates of uplift that are postulated, heat generated in this way would not be significant.

In the uniformitarian interpretations of sediment compaction, there is no significant pressure gradient to cause the flow of pore fluids, although in their discussions of diagenesis, geologists invoke extensive movements of fluids within rocks. These movements were necessary for the deposition of cements, replacement of minerals, the for-mation of secondary porosity, etc. A pressure gradient is required for any pore fluid movement to occur, by Darcy's law. Pore fluids cannot flow through rocks without a pressure gradient, any more than rivers can flow uphill.

Forced expulsion of pore fluids from sediments during compaction due to a pressure gradient can result in the concentration of dissolved species in zones below a thin layer of rock that acts as a semi-permeable membrane. The process is known as 'reverse osmosis.'[20] Because of the pressure gradient, the flow of pore fluids through the rock will result in a more concentrated solution at the high pressure side of the rock layer. This could possibly lead to precipitation and the formation of strata.

Growth of Sand Grains

There is abundant evidence, in the form of quartz overgrowths on quartz grains in many sandstones, for quartz precipitation both on existing grains and as a cement. Quartz grains may be well rounded, and rounded grains have been enlarged by the growth of quartz in optical continuity with the grains. Blatt discussed the source of silica for the overgrowths observed in sandstones, and he stated the major source of silica was 'vertically circulating groundwaters' from shales underlying and interbedded with sandstones, pressure-solution contributing less than one-third of the quartz present.[21] However, groundwaters are unlikely to have been very effective in dissolving and transporting the amount of silica required for the formation of overgrowths. In the environment of the Flood, waters expelled from the earth's interior may have contained much dissolved silica because of their high alkalinity. These fluids may have been released from beneath piles of unconsolidated sediments and would precipitate silica as they ascended to regions of lower pressure.

As the continents were uplifted, faulting in basement rocks, the introduction of intrusives, and associated metamorphic processes beneath the sediments may have released hot fluids which contributed silica. The initial sediments deposited by Flood waters may have contained volcanic glass, from undersea eruptions during the Flood, which was subsequently dissolved and redeposited during compaction. It is suggested that existing shales may be very different from those that were initially deposited, and that they represent the remanent minerals from which silica and other more soluble minerals were removed.

Transfer of quartz to solution in one part of a sediment requires its deposition elsewhere, and this could be controlled by pH. As the fluids moved upwards, a change to more acid conditions would cause quartz to precipitate. This could result in the formation of quartz grains where none were present before. Considerable volumes of quartz must have been precipitated on quartz grains as overgrowths in quartz arenites. It would be expected, then, that quartz grains might have been formed by precipitation of quartz from solution at various levels within the sediment pile. (It is assumed that the flow of fluids expelled from the sediment during compaction was upwards through the pile, and that these fluids were responsible for the transportation of quartz which formed overgrowths.) Grains of quartz formed in this way would no doubt have been previously interpreted as detrital grains. It is suggested that such a process, associated with the compaction of sediments deposited during the Flood, could be one of the most significant primary sources of sand grains in sandstones. There is the possibility, also, that sand grains formed in this manner were subsequently eroded and redeposited in later stages of the Flood, forming sandstones of various types.

Rounding of quartz grains may have been due to certain conditions existing at the time of precipitation of the quartz. Alternatively, grains may have become rounded after their precipitation, because of the dissolving action of hot alkaline fluids flowing around them. The rate of flow of these fluids may have been a factor in causing rounding. Possibly the crystal facets of overgrowths developed on well rounded grains were formed by fluids flowing more slowly than those from which the initial grains were precipitated.

The Origin of Pebbles

The traditional interpretation of conglomerates is that these are simply lithified deposits of stones worn round by attrition. In other words, according to uniformitarian geologists, every rounded stone or pebble has been rolled around at the earth's surface in a stream or a beach at some time in the past.

That waters of streams and beaches do cause wearing of the surfaces of stones and pebbles was observed long ago, as we read "The waters wear the stones" in Job 14:19. The rounded cobbles and pebbles of conglomerates fall into streams that cross them, or are released by erosion of the shoreline by waves, and become further worn and smoothed by the action of the waters. The water itself does not smooth the stones, but vibrates and jostles the pebbles around, so they abrade each other. Only pebbles at the earth's surface can become worn in this manner, so for ancient pebbles buried in conglomerates to have been worn round would require enormous spans of time. But the pebbles of conglomerates may have been generated in a totally different environment.

Pebbles in sandstones and conglomerates may be abundant or sparsely distributed. Many conglomerates contain pebbles of a particular kind, such as quartz, or granite. In the Shawangunk Grit of the Catskill area of New York, some of the quartzite pebbles interpenetrate, indicating that the formation of this rock was not merely a matter of lithification of a detrital accumulation.

It is proposed that the formation of pebbles was subsequent to the formation of sandstones in which they occur. Pebble formation in the Shawangunk sandstone involved the initial deposition of cement from compaction fluids introduced into the sandstone. Cement was precipitated in discrete centers or nodules, rather than throughout the whole rock. Precipitation may have been initiated suddenly because of a change in stress conditions. Grains or crystals of quartz were cemented together, forming pebbles. The cement was precipitated in nodules having a shape which tended to minimize the surface area. This is analogous to recognized phenomena of concretion growth, which involves segregation of minerals into centers of precipitation. Finally, the pebbles were cemented by deposition of quartz or carbonate in the sand matrix, resulting in a quartz conglomerate.

The conglomerates of Catskill area increase in coarseness towards the folded and metamorphosed zone towards the east, suggesting that a more rapid uplift in that area, or the introduction of hot silica-rich fluids, or temperature effects may have been involved in the formation of pebbles. The mechanism of formation of rounded pebbles was evidently quite different from that which caused rounding of sand grains in other sandstones, since rounded quartzite pebbles are embedded in a matrix of angular quartz grains in the Catskill rocks.

Formation of Stratification

In previous articles the writer has suggested that the pattern of cross stratification, which characterizes many sandstones, may be of non-sedimentary origin.[22,23] Let us consider how this pattern may have originated in sandstones, in this environment of compaction of the sediment pile at the end of the Flood.

Alkaline fluids containing SiO_2 moving upwards through the sediment pile would precipitate silica as pressure decreased and as the pH was lowered because of CO_2 production. At some level in the pile, then, we would expect to find horizontal layers of quartz precipitated. Silica dissolved in fluids at elevated temperatures would precipitate at zones of lower pressure, where the fluids could vaporize. The silica may have been deposited either as quartz or as amorphous silica which soon became converted to quartz. The quartz deposited may have enlarged very tiny existing quartz particles which formed nuclei for grain growth and the formation of a granular framework in which the grains were in contact with one another may have altered the porosity of the rock, allowing fluids to flow more readily, thus causing more quartz to precipitate from fluids moving up to the zone of precipitation. The lower boundary of a sand layer formed in this way could thus become a surface at which more grains would form and so a pattern of stratification could develop, which would be a non-sedimentary one, characteristic of these sands and sandstones. A pattern such as this has been previously interpreted as a sedimentary one.

Non-sedimentary patterns of stratification have been recognized as possible results of diagenesis. Concretions in limestones and shales may occur in horizons of favorable pH and Eh values, which may not correspond with bedding planes. Botvinkina discussed examples of diagenetic stratification produced by processes of replacement and precipitation. He thought that the diagenetic form of stratification would correspond with the original stratification of a sediment. He wrote:[24]

> The phenomenon of diagenetic stratification may be called stratification, for although the strata form as a result of diagenesis, they are not accidentally distributed but appear in those places where the conditions for their formation were prepared during the process of sedimentation, the primary stratification serving as the starting point for the subsequent diagenetic change of the sediment and making it possible for the diagenetic stratum to replace a primary bed. For example, along either the upper or lower boundary of a bed conditions may exist which favor change; either the primary bed is enriched in some substance (organic matter, for example) which aids the chemical processes occurring in the bed, or the primary bed is more porous than the adjacent ones and thus the possibility is created for concentration in the pores of some substance, or the boundary between two beds serves as an impermeable surface and precipitation from solution is initiated in one of them, etc.

Chilingar and others stated that these diagenetic processes produce laminations that may be "very similar to those formed by ordinary detrital accumulations."[25]

Origin of Rippled Surfaces

Many sandstones contain rippled surfaces, the ripples being very well preserved. These are similar to ripples formed by currents on sand bars in rivers, or by waves on a beach. An explanation of the ripples in harmony with the proposed authigenic interpretation of sandstones is that they were formed by movements of fluids within sandstones during diagenesis. Upon the formation of a sandstone by quartz grain growth in successive layers, the greater permeability of the sandstone permitted flow of fluids entering the sand from adjacent strata. The flow direction may have been along horizontal planes as well as vertically.

Vortices of pore fluids could develop where there were variations in the flow velocity at different levels in the sandstones. If the rock was slightly more permeable along the plane of one of the laminations, pore fluid flow in that zone would be faster, possibly causing vortices in adjacent laminations which in turn would cause ripple development. The effects of vortices were preserved because the fluids were capable of precipitating and dissolving quartz or other cementing agents. This concept of a diagenetic origin for the rippled surfaces in sandstones is in harmony with Folk's analysis of ripple formation in various environments.[26]

Rippled surfaces generally are variable in both size of ripples and orientation, and these facts and their excellent preservation favor an explanation in terms of a diagenetic process rather than a sedimentary one.

Clastic Dolomites

The concept of authigenic sandstone formation outlined above requires that one of the common forms of stratification exhibited in sandstones be reinterpreted as a diagenetic form of lamination rather than a sedimentary one. This is supported by the fact that dolomitized limestones often exhibit a pattern of cross stratification like that of many quartz sandstones. The formation of dolomite in a limestone is generally interpreted as a diagenetic process. These cross stratified rocks, in which the "sand" is composed of rhombs of dolomite, are called "clastic dolomites."[27]

Describing these rocks, Williams and others wrote:[28]

> The clastic texture of calcarenites is not to be expected in dolomites, yet many dolomites contain rounded quartz grains presumably inherited from original calcarenites whose calcareous textures have been obliterated by dolomitization; in some of these rocks the quartz grains are disposed in cross-laminae, indicating that the original limestones were indeed deposited by currents.

The proposed alternative interpretation is that the patterns of cross strata were formed at the time of diagenesis, when the dolomite was formed. In certain cases, dolomitization causes an increase in porosity. High temperatures, high alkalinity and other parameters could be involved in the process of dolomitization.

The Underside of Sandstones

A quartz sandstone may thus have grown downwards as layers of quartz were deposited from fluids moving upwards from below. Patterns of cross stratification in sandstones record the successive surfaces of deposition at the sandstone-shale boundary as it moved downwards. As quartz was deposited, other minerals were dissolved or altered, existing grains were enlarged by overgrowths of quartz, and new grains were initiated. Lateral enlargement of the sand body and differential movements of the sand with respect to the underlying shales may have produced the grooves and chatter marks, called sole markings, which have been observed at many boundaries between sandstone and shale.

Major sandstones commonly appear to be nonconformable to the sediments they overlie. This would be expected from the nature of the process of sandstone formation outlined above. The underlying formations of mud, shale, or limestone, from which the fluids which supplied the silica for the growth of the sandstone were derived, would appear depleted in silica. Since the process of quartz precipitation proceeded at various rates, depending on the fluid supply rate, the shape of the surface of active precipitation would tend to develop irregular forms, such as channels and hollows. These have been interpreted as river channels, and as evidence of an erosional surface, or disconformity. Dott and Batten described such a surface below the St. Peter sandstone:[29]

> After extensive dolomite deposition for several million years, a widespread disconformity was produced over virtually the entire craton. The sea retreated completely from the craton at least to the marginal mobile belt areas and the interior was subjected to extensive erosion. Above the disconformity lies a very widespread pure quartz sandstone called the St. Peter. Stream channels were cut into the underlying dolomites and sandstones prior to the deposition of the sand.

A similar disconformity exists below the Oriskany sandstone in the eastern U.S., and disconformities typically occur below the sandstones of cyclothems. The new interpretation accounts for the apparent disconformities without recourse to several up and down movements of the earth's crust and episodes of erosion.

Multistory Sandstones

Sandstone formations display a tendency to reflect the geometry of other sandstones which they overlie. A sequence of sandstone layers, separated by layers of shale or limestone, may be thicker above areas where underlying sandstones are thicker, so that two or more lenses of sandstone may occur in vertical alignment. Such a sequence is called a multistory sandstone and is illustrated in Figure 2.

The uniformitarian interpretation requires that erosion was active immediately above a buried sand, and more sand was deposited in the depression. The hypothetical river, which eroded the upper channel, must have "remembered" the course of a preceding river, whose channel lay buried deep below. An example of a multistory sequence in the Permean rocks of north-central Texas extends through 1200 feet.[30]

These thick lenses of sandstone stacked vertically can be explained as follows. Once a sandstone body formed in the shale, the sand provided a conduit for fluids expelled during compaction. The process of sand formation by quartz grain growth was initiated below or above the first sand body, because of convergence of the flow to that region. The flow of pore fluids towards thicker sandstone layers (with higher permeability), where the pore fluid pressure gradient was greater, caused the development of thicker sandstone layers vertically aligned with previously formed lenses.

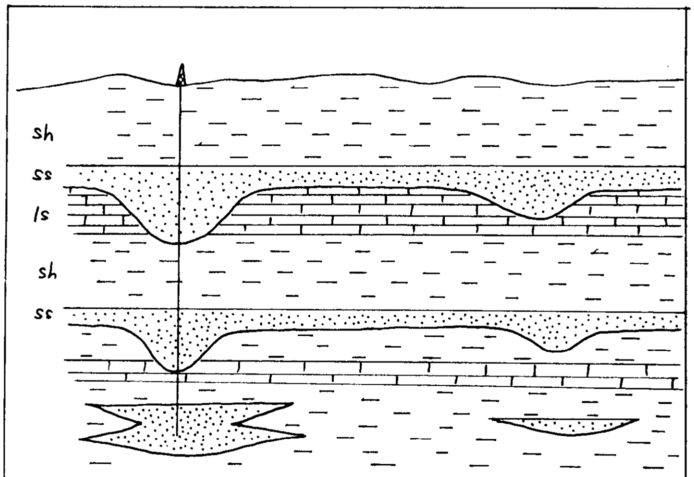

Figure 2. Diagram showing how multi-story sandstones occur in a sequence of shale, sandstones, and limestones. The vertical sequence of thick sandstone lenses provided a conduit for fluids escaping from the sediments when they were compacted. The symbols are: sh: shale, ss: sandstone, ls: limestone.

Sandstone Dikes

Faulting in sediments during uplift and compaction could provide conduits for the escape of pore fluids, the low pressure initiating deposition of quartz grains in the vicinity of the fault zone, thus forming vertical sandstone dikes, commonly called elastic dikes or neptunian dikes. These characteristically pinch and swell, so are not easily explained by infilling of cracks by sand, as has been proposed by uniformitarian geologists. The sand would have to be forced into cracks with such great pressures that the walls of the host rocks became dilated. The sand grains would probably be crushed long before the walls of the dikes became dilated. The facts about the sandstone dikes support the new interpretation of the origin of sandstone. Even the patterns of cross stratification, here interpreted as a diagenetic phenomenon, are present within some sandstone dikes. Patterns of vertical laminations resembling cross laminations within a sandstone dike were reported by Peterson?

At Clear Lake, near Espanola, Ontario, a group of sandstone dikes up to 30 feet thick occur in a carbonate siltstone. The dikes cut across the banded carbonate rock at a high angle. Some of the dikes contain a central band of coarse pebbles, as illustrated in Figure 3. The pebbles associated with sandstone in the dikes are easily accounted for in an authigenic interpretation, but how could they be explained in terms of the uniformitarian explanation, that the dikes were formed by injection of elastic material into fissures? Why would they arrange themselves in a central band within the dike? The features of sandstone dikes are anomalous in the traditional interpretation of the origin of sand, but these mysteries dissolve in the new explanation.

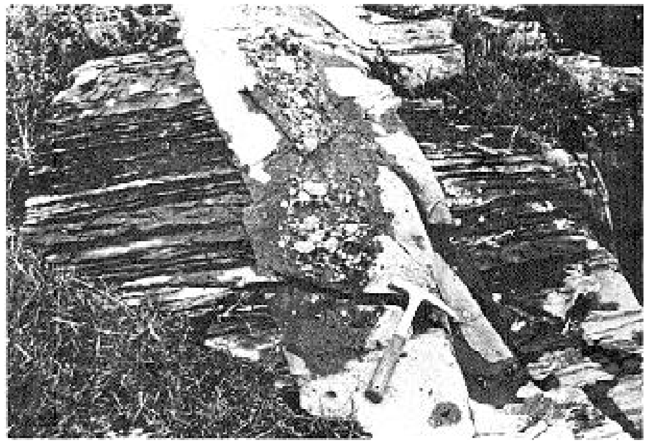

Figure 3. Portion of a sandstone dike containing a central band of quartz pebbles. The dark section of the dike is due to recent rain. The distribution of the pebbles seems anomalous in the interpretation of sandstone dikes as the product of injection of elastic material into fissures. The dike is on the shore of Clear Lake, about one mile south of Espanola, Ontario.

Preservation of Cross Strata

Analyses of pure quartz sandstones suggest that these are typically altered extensively by diagenesis, but these "mature" sandstones may have the patterns of cross stratification well preserved. In terms of the conventional interpretation of the pattern, this is enigmatic since the pattern is supposed to be formed during sedimentary deposition of the grains, and the diagenetic processes of grain growth and replacement, dissolution and emplacement of cement, and porosity reduction and compaction would all tend to obliterate rather than enhance original sedimentary patterns.

Metamorphism of rocks would also tend to destroy original sedimentary patterns, but cross strata have been reported in rocks that have undergone high grade metamorphism.[32] If the cross strata formed authigenically during metamorphism of the rocks, the presence of the pattern in high grade metamorphic rocks is not paradoxical.

Conclusion

In the context of sediment deposition in a world wide Flood and subsequent compaction of the sediment pile, the formation of sandstone authigenically by the formation of quartz grains and pebbles from expelled compaction fluids provides a plausible theory. These concepts are useful in accounting for many characteristic features of sandstones, their geometry, occurrence as dikes in other kinds of rock, and the presence of cross stratification in various contexts. These new concepts depend upon the uniqueness of the Flood and the consequently greater scale of associated processes of uplift of the sediments, compaction, and diagenesis.

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INSECTS INDICATE CREATION

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Received 9 August 1985; Revised 26 September 1985

Abstract

A Creation Research Society (CRS) insect collection has been started. Qualified workers are invited to participate in the identification of these specimens and other phases of entomological research. There are outstanding evidences for design in dragonflies, click beetles, springtails, and other insects. Insects simply appear in the fossil strata without indication of an evolutionary ancestry. The paleontology, physiology, and anatomy of insects are fields ready for creationist study.

A CRS Insect Collection

Baseline studies are needed of botanical, zoological, geological, and other scientific features at the CRS Grand Canyon Experiment Station (GCES), Paulden, Arizona. Collections of insects, plants, rocks, and other scientific specimens can be started for our laboratory facility when funds are available for its construction. Individual members can play important roles in these and other tasks. For an introduction to research possibilities at the GCES, consult Howe (1984). Insect research can also be performed at Grassland Experiment Station, Weatherford, Oklahoma from which a list of plants and animals has already been published—consult Hagberg and Smith (1983).

On July 10-13, 1985, insects at the GCES and nearby regions were collected and mounted. Several covered bait cups containing fruit or other foods were sunk to ground level along the southern edge of the GCES land and were periodically examined for insects (Figure 1). Insects were also netted out of milkweeds, thistles, and other plants flowering on the CRS land and at nearby Sullivan Lake, Paulden, Arizona.

Collections were made at night by using ultra-violet and fluorescent attractant lamps. Insects were mounted, labeled, and placed into families for future categor-

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