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Soft-Sediment Deformation Features

Most sedimentary strata today, even when exposed at the earth's surface, are hard and brittle, because after deposition the sediment grains were cemented together, turning the soft sediment into hard rock. The processes are called diagenesis and lithification. In conventional geologic thinking, the layers of sedimentary strata in any given strata sequence, such as that exposed in the walls of the Grand Canyon, were deposited consecutively over millions of years, with the deposition of each conformable layer separated in time, perhaps also by millions of years. Diagenesis and lithification are also said to have perhaps taken millions of years, as chemicals in the water trapped between the sediment grains precipitate and crystallize to form the cement that binds the grains together. The strata sequence was then probably deformed, by being folded and faulted, probably millions of years after deposition finished and diagenesis and lithification had occurred, as has happened to the strata sequence in the Grand Canyon. Because in conventional geologic thinking deformation would thus have taken place after the sediment layers had already hardened into solid rocks, there should have been brittle failure of those rocks in response to the deformation.

It is known from experimental evidence that, under severe pressure and moderate temperature conditions, rocks can be made to deform and flow as if they were plastic, similar to modeling clay. However, when that happens, there is also evidence of the rocks being mineralogically and physically transformed, that is, metamorphosed. Nevertheless, many sedimentary strata sequences have not been so metamorphosed, and even though the strata are now brittle, they appear to have only suffered plastic deformation. The only way this could have occurred, without the tell-tale signs of metamorphism, is when the sediments were still soft after deposition, but prior to diagenesis and lithification. Yet even where the strata show compelling evidence of this having occurred, conventional geologic thinking discounts this evidence, because it automatically accepts the millions-of-years geologic timescale for the deposition of the sequences of sedimentary strata and their subsequent deformation.

On the other hand, this evidence of soft-sediment deformation is precisely what would be expected if the sedimentary sequences were rapidly deposited and then

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deformed in the year-long Genesis Flood, only thousands of years ago. Since the sediment layers at the base of strata sequences would generally have been deposited early in the Flood, then even if considerable thicknesses of other sediments were deposited on top of them, there would not have been the time or appropriate conditions for diagenesis and lithification to have fully occurred in the subsequent months of the Flood year, when deformation would have occurred while all the sedimentary strata were thus still soft and plastic.

This raises the question as to how long it takes for diagenesis and lithification of sediment layers to occur. Unfortunately, because there are a lot of variables involved, and each sediment layer experiences different conditions, there is no one specific answer. Important factors include the type of sediment, the amount of water in pore spaces, the type and amount of cement in solution, and the depth of burial (which determines the pressure and temperature conditions). If a sediment layer is buried deeply enough, then confining pressure will force the trapped water out of the pore spaces between the sediment grains, and the increased temperature will help precipitate the cement to bind the sediment grains together. Because conditions are unique to each sediment layer, in any particular strata sequence some sedimentary rock units are softer than others, while some may not have yet completely lithified, for one reason or another. Nevertheless, all sedimentary strata do become lithified, hard, and brittle, because under normal conditions sediments lithify relatively quickly, often in a matter of years, but at the most perhaps hundreds of years. Given ideal conditions, lithification can happen within days. The lithification process is somewhat analogous with a man-made mixture of gravel, sand, Portland cement, and water that lithifies to produce concrete, because the chemical present in the cement reacts with the water as the mixture dries. The process only takes hours to days.

A natural example of lithification illustrates how rapidly the process can occur. Following the explosive eruption of Mount St. Helens in Washington state on May 18, 1980, up to 600 feet (180 meters) of strata accumulated from the primary air blast, landslides, pyroclastic flows, mudflows and air falls.[1] The resultant strata, having been deposited catastrophically, appear essentially the same as other strata in the geologic record that are claimed to have been deposited over thousands and millions of years. After being deposited by the volcanic activity of Mount St. Helens, these sediment layers have subsequently not been subjected to optimum conditions for lithification, even suffering severe erosion as a result of a mudflow on March 19, 1982, eroding deeply into them to form a canyon system over 100 feet (30 meters) deep. Yet within five years of having been deposited, these sediment layers had been lithified sufficiently for them to support near-vertical cliffs in this canyon system. Thus, lithification can be a relatively rapid process, even at the earth's surface.

1 S. A. Austin, 1986, Mount St Helens and catastrophism, *Proceedings of the First International Conference on Creationism*, vol I, 3-9, Pittsburgh, PA: Creation Science Fellowship.

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Thus, once sediment layers become lithified, the resultant sedimentary rocks are extremely difficult to bend and deform without being broken and shattered. The rocks are hard and brittle, which is in stark contrast to their soft and plastic, more pliable, condition soon after sediment deposition, and prior to lithification. If deformation of a rock has occurred after its lithification, then the effects of the deformation on the mineral grains making up the rock can clearly be seen upon microscope examination. Many sedimentary strata sequences appear to have been deformed while the sediments were still soft and pliable, yet in conventional terms the sediments were deposited and supposedly lithified millions of years before deformation occurred. Thus, since lithification had occurred millions of years before deformation, the rocks were hardened when deformation occurred, and should have behaved in a brittle fashion. However, both at the macroscopic and microscopic scales, evidence implies plastic deformation has occurred when the sediments were still soft and pliable after deposition, thus challenging the claimed millions-of-years timeframe for the deposition of the sedimentary strata sequences and the subsequent deformation.

An excellent example of this soft-sediment deformation, which challenges the conventional timeframe for a sedimentary strata sequence, is found in the Grand Canyon area. The Grand Canyon itself has been carved through a 7,000-8,000 foot (2,150-3,450 meter) high plateau, and in the walls of the Canyon the sedimentary strata beneath the plateau are exposed. However, to the east, the same rock units that crop out at the rim of the Grand Canyon are found at a lower elevation. Indeed, some 250 miles (400 kilometers) to the east the same rock units are a mile or so (more than 1,600 meters) lower in elevation, so the plateau through which the Grand Canyon has been carved was uplifted to its current elevation by earth movements during tectonic adjustments of the earth's crust. In conventional terms, this is claimed to have occurred some 70 million years ago, during the Laramide Orogeny when the Rocky Mountains were also being formed. This pronounced elevation difference, due to uplift of what is known as the Kaibab Plateau, was achieved by upwarping in the eastern Grand Canyon, where the strata have been bent to form a fold structure called a monocline. The axis of the fold is called the East Kaibab Monocline, and its surface expression is a bending/folding of the Kaibab Limestone through an elevation difference of 3,000 feet (more than 900 meters). The fact that the Kaibab Limestone has been folded rather than altered indicates that it was still soft and pliable when the deformation occurred supposedly 70 million years ago. However, the Kaibab Limestone is supposed to be 250 million years old, more than enough time for it to have lithified in the claimed 180 million years since its deposition.

The other rock units in the sequence below the Kaibab Limestone have also been folded during this deformation event responsible for the Kaibab Upwarp, and the most extreme example is the Tapeats Sandstone at the base of the strata sequence. In the hinge zone of the monocline, the Tapeats Sandstone has been severely deformed, the internal layering being bent and twisted to be oriented almost

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vertically (Figure 51, page 1087). In conventional terms, the Tapeats Sandstone is claimed to be around 540 million years old, so that at least 470 million years had supposedly elapsed by the time of the Laramide Orogeny 70 million years ago. Since there was also at least 4,000 feet (1,200 meters) thickness of other sedimentary layers stacked on top of the Tapeats Sandstone for 180 million years (that is, after deposition of the Kaibab Limestone), there was ample time and sufficient confining overburden pressure to have resulted in the lithification of the Tapeats Sandstone by the time the deformation occurred. Thus, it would be expected that the lithified Tapeats Sandstone suffered brittle failure during deformation, if the millions of years are the correct time framework for these events.

However, the bending of the sandstone in the hinge area of the monocline does not show any sign of brittle failure (Figure 51), but instead the sandstone appears to have been in a soft, pliable condition when the bending occurred. Thus, lithification of the sandstone had not yet taken place, and therefore, there could not have been millions of years between deposition of the sandstone and the deformation event. Furthermore, close examination of the sandstone does not reveal any evidence of elongated sand grains, or of broken and recrystallized cement, both brittle deformation features that would be expected if the sandstone was fully lithified when the bending occurred. The Tapeats Sandstone obviously was thus still soft and pliable when the deformation occurred, even though the confining pressure of the overlying sediments must have compacted the sandy sediment, so the process of lithification had begun. There can't have been much time, therefore, between deposition of the Tapeats Sandstone, deposition of the overlying sediment layers, and then the deformation of the entire strata sequence.

It cannot be denied that if a rock is buried deeply, and thus experiences confining pressure from all directions surrounding it, then bending can occur in an otherwise brittle rock. Nevertheless, in a hard, lithified sandstone, such as the Tapeats Sandstone, such bending always results in elongated sand grains, and/or recrystallization of broken cement, neither of which has been found in the deformed Tapeats Sandstone in the Grand Canyon. There is a limit to how much strain (or deformation) a rock can endure under a given stress.[2] Deformation occurs when stress is applied to a rock, and if the stress is maintained at a constant level, the rock will continue to deform or "creep." If the rock experiences additional stress, it will suffer failure because it is brittle and will fracture. On the other hand, if a constant stress is maintained, at a value below that failure point, deformation will continue in most rocks, until a terminal value is reached where the rock will either become stable or will fracture. For most rocks there is a limit to the amount of creep that can occur over time, because they cannot undergo unlimited deformation, and will eventually rupture.

2 R. E. Goodman, 1980, *Introduction to Rock Mechanics*, New York: John Wiley and Sons, 74.

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In the example of the Tapeats Sandstone in the Grand Canyon, in the hinge area of the east Kaibab Monocline where the folding is greatest, the sandstone is bent at an approximate 90° within a distance of about 100 feet (30 meters). In the folding process, the sandstone in the outer half of the fold would have been under tension, while in the inside part of the fold the sandstone would have been under compression. Lithified rock is notoriously weak under tension, invariably failing by fracturing, yet at places within the hinge zone of the monocline, it can be seen that entire layers within the sandstone have thinned as they were stretched during bending. This is visible confirmation that the sandstone must have still been relatively soft and plastic under the stress of the deformation event, which must therefore have occurred soon after deposition of the sandstone, not 470 million years later. Lithified sandstone could otherwise have not withstood the amount of stretching involved in this folding, even under the confining pressures involved, because experimental work has demonstrated that lithified rock simply does not stretch and thin in the way observed in the Tapeats Sandstone. Thus, this observed soft-sediment deformation of the Tapeats Sandstone, in the hinge zone of the East Kaibab Monocline in the eastern Grand Canyon, is irrefutable testimony that the sequence of events, beginning with deposition of the Tapeats Sandstone and the overlying 1,200-meter-thick sedimentary strata sequence, followed by the deformation event that folded this strata sequence along this monocline during the uplift of the Kaibab Plateau, could not have occupied hundreds of millions of years, but rather an extremely short timeframe, which implies that deposition and deformation of this sedimentary strata sequence were catastrophic events.

Added powerful confirmation that this is the correct interpretation of the observed evidence is the faulting of the metamorphic rocks below the folded Tapeats Sandstone to Kaibab Limestone strata sequence along the East Kaibab Monocline. During the Kaibab Upwarp event, the same applied stress that stretched and thinned the Tapeats Sandstone as it was folded, caused fracturing and faulting of the schists and other metamorphic rocks in the basement complex directly underlying the Tapeats Sandstone. This implies that, by the time deposition of the Tapeats Sandstone-Kaibab Limestone sediments was occurring, these metamorphic rocks were hard and brittle, which in turn implies that sufficient time had previously elapsed for these rocks to have reached this condition. This is, therefore, consistent with their formation prior to the Genesis Flood, even dating back to the events of the Creation Week itself. Seismic studies have demonstrated that the fracturing of these brittle metamorphic rocks resulted in a vertical displacement of at least 5,000 feet (1,500 meters) along faults located underneath the East Kaibab monocline. Thus, while the previously hardened brittle metamorphic rocks in the basement complex were faulted by the deformation produced by the Kaibab Upwarp, the Tapeats Sandstone-Kaibab Limestone sedimentary sequence catastrophically deposited on top of the basement complex during the Flood was only folded, because the strata were still soft and pliable due to the upwarp occurring so soon after deposition that lithification had not fully taken place. However, the subsequent faulting with much less displacement, for example, along the Bright

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Angel Fault, which fractured and faulted the entire Tapeats Sandstone-Kaibab Limestone strata sequence, implies that the lithification of these sediments was soon completed after the major deformation of the Kaibab Upwarp.

This dramatic example of soft-sediment deformation in the Grand Canyon is definitely not unique, because there are almost countless other examples in other places where strata have been deformed while still soft and pliable. In the United States alone, both the Appalachian Mountains and the Rocky Mountains are full of such occurrences. Several examples in the Rocky Mountains are associated with the Ute Pass Fault, west of Colorado Springs.[3] The Front Range of the Rocky Mountains in Colorado was formed by large reverse faults, with vertical displacements of as much as 21,000 feet (6,400 meters). The very abrupt margin of the Front Range, with Pikes Peak (more than 14,000 feet or 4,250 meters elevation) on the west and Colorado Springs (6,000 feet or 1,830 meters elevation) on the east, is caused by the Ute Pass Fault, a prominent north-trending reverse fault more than 40 miles (64 km) in length. On the west side of the fault is the upthrown Pikes Peak granite and associated Precambrian metamorphic rocks, all sedimentary strata overlying them having been removed by erosion. On the east side of the Ute Pass Fault there are about 12,000 feet (3,650 meters) of Phanerozoic sedimentary strata overlying the Precambrian basement, so the vertical displacement on the fault is about 20,000 feet (6,100 meters). The Ute Pass Fault truncates, or folds, Cambrian to Cretaceous strata, so it must therefore be Cretaceous or post-Cretaceous. Field relationships confirm that all of the very intense deformation associated with the Ute Pass Fault is thus assignable to the Laramide Orogeny, which was responsible for the formation of the Rocky Mountains and for the uplift of the Kaibab Plateau in the Grand Canyon area.

Characteristic of the Ute Pass Fault is the intensity of folding of the strata on its east side, where there is an eroded remnant of an enormous monocline involving about two miles (more than 3 km) of structural relief. Approaching the flank of the Front Range, within three miles (almost 5 km) of the exposure of the Precambrian basement on the other side of the fault, the 14,000 feet (more than 4,200 meters) of sedimentary strata are bent into nearly vertical orientation. The Ute Pass Fault appears to be concealed at depth in the Precambrian basement, but this thick overlying sedimentary rock cover did not fault, and so must not have then been fully lithified. Instead, these sedimentary strata were plastically deformed by vertical displacement on the Ute Pass Fault to form this spectacular monocline.

Further evidence of soft-sediment deformation are the tight drag folds very close to the Ute Pass Fault, such as the very strong folding of the Fountain Formation

3 S. A. Austin and J. D. Morris, 1986, Tight folds and clastic dikes as evidence for rapid deposition and deformation of two very thick stratigraphic sequences, *Proceedings of the First International Conference on Creationism*, vol II, 3-15, R. E. Walsh, C. L. Brooks and R. S. Crowell, eds., Pittsburgh, PA: Creation Science Fellowship.

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sandstone in contact with the fault near Manitou Springs. The sandstone dips at 35°NE just 80 feet (24 meters) northeast of the Ute Pass Fault, but at the fault it is overturned and dips about 60°NW. This folding was caused by drag of the strata against the upthrown west side of the fault. Field observations clearly reveal that the sandstone was not able to transmit stress away from the fault, so was not internally faulted as it was folded, which is consistent with the strata being ductile and not solidly cemented when deformed. However, this Fountain Formation sandstone is Pennsylvanian-Permian, so in conventional terms it is regarded as 300 million years old, whereas the Laramide Orogeny is supposed to have occurred less than 70 million years ago. Therefore, how could this sandstone have remained ductile for those claimed 230 million years? That ductile flow was the mechanism for the tight drag folds has long been recognized from field observations of several outcrops on the Ute Pass Fault:

> These examples demonstrate that the drag effect in Fountain arkoses can be very local. The drag is accomplished with few visible fractures. The shape of the beds is apparently altered by ductile flow, that is, by small translation and rotation of individual grains of the arkoses and conglomerates.[4]

Translation and rotation of individual grains could be easily accomplished if the sandstone was not yet cemented when deformed. If the sandstone was cemented and fully lithified when Ute Pass Fault was formed, significant modifications to the shapes of individual grains within the sandstone due to the stress of the folding should now be observed. Furthermore, there should also have been significant faulting due to brittle failure.

Other soft-sediment deformation features that are even more significant are the clastic dikes of quartz sandstone associated with the Ute Pass Fault and many other reverse faults of the Front Range.[5] More than 200 sandstone dikes were mapped in one study alone, the dikes varying from a fraction of an inch to miles in length, from a fraction of an inch to 300 feet (over 90 meters) in width, and penetrating up to 1,000 feet (305 meters) or more through the surrounding bedrock, which is usually Precambrian basement (Pikes Peak granite or associated metamorphic rocks). The dikes occur most frequently on the upthrown (hanging wall) side of the Ute Pass Fault, within one mile (1.6 km) west of the fault, having been injected downwards from sandstone overlying the Precambrian basement (now eroded away) along extension fractures in the hanging wall of the convex-upward

4 J. C. Harms, 1965, Sandstone dikes and their relation to Laramide Faults and stress distribution in the southern Front Range, Colorado, *Geological Society of America Bulletin*, 76: 989.

5 W. Cross, 1894, Intrusive sandstone dikes in granite, *Geological Society of America Bulletin*, 5: 225-230; P. W. Vitanage, 1954, Sandstone dikes in the South Platte area, Colorado, *Journal of Geology*, 62: 493-500; G. R. Scott, 1963, Geology of the Kassler Quadrangle, *U.S. Geological Survey Professional Paper*, 421-B: 125pp; Harms, 1965, 981-1002; L. S. Kost, 1984, Paleomagnetic and petrographic study of sandstone dikes and the Cambrian Sawatch Sandstone, east flank of the southern Front Range, Colorado, University of Colorado, unpublished M.S. thesis, 173 pp.

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reverse fault. Virtually all the dikes strike parallel to the strike of the main reverse fault, and because of their coincidence with, and relationship to, the structures generated by the Laramide Orogeny, it is only reasonable to conclude that they are Laramide dikes. These sandstone dikes are remarkably uniform in composition, with greater than 90 percent quartz by volume, less than 5 percent feldspar, and less than 5 percent clay-size matrix. Xenoliths of granite from the wall-rock are common. Among investigators of these clastic dikes there is agreement that the Sawatch Sandstone (the Cambrian sandstone immediately overlying the basement) is the source. Not only is the Sawatch the closest sandstone to the dikes, but there is nearly identical compositional and textural similarity.

The evidence that the sand of the dikes was unconsolidated when injected has been widely recognized. There is little evidence of breakage of sand grains as if they were cemented before injection, and there is a lack of fine matrix, which would have formed from disaggregation of the sandstone had it been lithified. On the other hand, the long axes of granite xenoliths are oriented parallel to the dike walls, and the dikes themselves show laminated flow structures, with segregation of sand by size as if forcefully injected. Even dikes only a fraction of an inch wide are completely filled with sand, testimony to the great fluidity of the injected material.

Having agreed upon the source of the sand in these clastic dikes along the Ute Pass Fault, there is a divergence of opinion as to when their intrusion occurred. Of course, some investigators have recognized the fundamental impossibility of the Cambrian Sawatch Sandstone (supposedly 500 million years old) remaining unlithified while deeply buried for 430 million years until the Laramide Orogeny (assumed to be late Cretaceous about 70 million years ago or less). To avoid this obviously embarrassing problem, important field relationships are overlooked in order to suggest that the dikes were actually intruded in the Cambrian while the Sawatch Sandstone was unconsolidated. However, there is no evidence of tectonic movements in the Cambrian or Ordovician of a magnitude able to open up extension fractures hundreds of feet (tens of meters) wide along the Ute Pass Fault. Instead, the actual field data strongly support the Laramide intrusion of the dikes. The Laramide Orogeny was not only of sufficient magnitude to open up the large extension fractures, but the coincidence of the dikes along the Ute Pass Fault, a proven Laramide structure, cannot be accidental. Furthermore, one of these quartz sandstone bodies penetrates the Pennsylvanian-Permian Fountain Formation sandstone, so this dike cannot be Cambrian or Ordovician, but is related to the Laramide Ute Pass Fault.

In conclusion, it is abundantly clear that the total time required for deposition of the sequence of 14,000 feet (more than 4,200 meters) of sedimentary strata overlying the Precambrian basement, for regional flexing, for faulting, and for the development of the local deformation features, must have been less than the time it took for this entire thick sequence of soft sediments, complete with their

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contained water and mineral cement content, to lithify and completely harden to rock. This implies catastrophic deposition of these strata, and that tectonism immediately followed deposition before lithification of even the sand layer at the base of the 14,000-feet-(more than 4,200 meters) thick sequence of sediments. On the other hand, the conventional view is that this 14,000-feet-(more than 4,200 meters) thick sequence of strata along the Ute Pass Fault in Colorado accumulated from the Cambrian through to the Cretaceous, from supposedly 500 million years ago through to 70 million years ago, a total deposition time of some 430 or more million years. However, as amply demonstrated by the field observations of numerous investigators, there are numerous soft-sediment deformation features (monoclines, tight drag folds, and clastic dikes) among the strata along the fault which are associated with the Laramide Orogeny that supposedly occurred less than 70 million years ago, so how could this thick sequence of sediments escape lithification after deep burial through a duration of up to 430 million years? Without a doubt, the answer is that the evidence overwhelmingly supports the conclusion that the entire thick sequence of sediments was catastrophically deposited, and then immediately deformed, on a timescale consistent with the Genesis Flood, rather than the conventional view that claims deposition over 430 million years.

These two examples of soft-sediment deformation features that question the conventional claims of hundreds of millions of years for deposition of thick sequences of sedimentary strata should suffice. One or two such occurrences might be discounted as simply anomalies, but when there are numerous similar examples of soft-sediment deformation in many similarly deformed terrains all over the world, the overwhelming conclusion must be that the conventional timescale is wrong. The catastrophic deposition of these thick sequences of sedimentary strata was followed immediately by deformation before the sediments were lithified, on a timescale that must have been brief, because lithification can occur in only days or weeks. This is all consistent with the biblical account of the Genesis Flood.

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