Tight Fold and Clastic Dikes as Evidence for Rapid Deposition and Deformation of Two Very Thick Stratigraphic Sequences

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Presented at the First International Conference on Creationism, Pittsburgh, Pennsylvania, August 4–9, 1986. Published in: Proceedings of the First International Conference on Creationism, *R.E. Walsh, C.L. Brooks & R.S. Crowell (Eds.), pp. 3–13, 1986.*

Abstract

Tight folds in 17,000 feet of Miocene to Pleistocene strata on the Split Mountain Fault in southern California indicate that Miocene or lower Pliocene sandstone remained in a non-lithified condition until folded in the late Pleistocene. Likewise, soft sediment deformation features (clastic dikes, tight drag folds, and intense monoclines) in 14,000 feet of Cambrian to Cretaceous strata on the Ute Pass Fault in Colorado argue that even the Cambrian strata were not lithified when the Front Range of the Rocky Mountains was uplifted in the late Cretaceous Laramide event. Evolutionists have assumed the California strata sequence involves about six million years between deposition and deformation. Furthermore, they have assumed the Colorado strata sequence involves up to 430 million years between deposition and deformation. How these two sedimentary sequences could escape lithification after deep burial for millions of years remains unexplained by evolutionists. On the other hand, creationists view this evidence that sedimentation and tectonics are concurrent as evidence for rapid deposition and deformation.

Keywords

Folds, Fault, Split Mountain, Sandstone, Soft Sediment Deformation, Stress, Creep, Front Range, Ute Pass, Clastic Dikes, Sand Injection, Rapid Deposition and Deformation

Introduction

Evolutionists and creationists have different views on the origin of sedimentary rock strata. Evolutionists, who uphold the uniformitarian doctrine of 19th century geologists, suppose that most sedimentary strata were deposited slowly over millions of years as the Earth evolved gradually to its present configuration. Creationists who uphold the catastrophist doctrine of Scripture propose that most sedimentary strata were deposited rapidly by Noah's Flood and that the total time span represented by sedimentary strata involves only thousands of years! Evidences for millions of years of deposition cited most frequently by evolutionists are radiometric dating and the supposed evolutionary succession of fossils in strata. Creationists, however, find the assumptions of radiometric dating objectionable and fault the logic behind evolution in the geologic column. Evidences for young age for strata frequently cited by creationists are the fiat Creation model of Scripture and the field evidences of rapid deposition of sedimentary strata. Evolutionists, however, reject the authority of Scripture and argue that some sedimentary strata indicate slow accumulation.

Attempts to determine the correct interpretation of sedimentary strata have been hindered by certain non-scientific and unproductive tendencies of both evolutionists and creationists. In their response to creationists, evolutionists frequently cite philosophical and cosmological arguments for why the radiometric dating assumptions must be accepted. Evolutionists reply frequently to the failure of fossils to demonstrate large-scale, slow evolution by arguing that more complete collecting in the future will reveal the transitional forms that have not yet been found. Because of the entrance of "neocatastrophist" concepts into geology, many evolutionists are now willing to concede that most sedimentary strata formed rapidly, but insist that long periods of time are required by bedding planes and unconformities between strata where the evidence of long ages was never deposited or has been eroded away. These philosophical or *ad hoc* arguments lack the empirical support of scientific data and remain weak. Many observers notice that scientists should be more interested in explaining what *has* been found in defending their assumptions or in explaining what *has not* been found.

Likewise, creationists have not always responded to the criticism of evolutionists with scientific evidence which fully supports their view of strata. When confronted with evolutionists' claims of great periods of time between strata, creationists have countered by providing specific cases where evidences of great time are lacking, and have argued inductively that *every* bedding plane and *all* unconformities show the same. Such arguments for universal negatives require a measure of omniscience where creationists should correctly approach the subject with caution. In countering evolutionists' claims that an individual stratum indicates slow deposition, creationists are required to undertake laborious investigations to reinterpret the individual stratum. After the reinterpretation of the specific stratum is complete, another problem for creationists may be dispelled, another evidence of catastrophism may be recognized, but the creationist notion that the entire strata record represents thousands of years remains to be defended. Furthermore, the reinterpretation of individual strata problems often favors the neocatastrophist position as well as that of the creationist. A stronger scientific case needs to be made for the creationist view of the strata record.

Long Ages or Rapid Deposition? A Geologic Test

We propose that a scientific test be devised to determine which of the two views of strata fits the data best. Such a test should be acceptable to both creationists and evolutionists. We propose that the relationship between sedimentation and tectonics be studied to evaluate the styles of deformation which are superimposed on very thick stratigraphic sequences. Creationists would predict that at many times and locations the tectonic processes were deforming sediments which had only shortly before been deposited with little time for cementation to occur. This deformation, whether it be faulting, folding, or injection, should provide evidence that the sediment was deformed while in an unlithified, plastic, or ductile condition. Because creationists regard thick sequences of strata as rapidly deposited, this style of deformation would be predicted to be superimposed on strata measuring thousands of feet in thickness.

Evolutionists on the other hand assume great periods of time are interposed between deposition and deformation, the two processes being generally consecutive, not concurrent. Because great thickness of strata are viewed as accumulated over long ages, there should have been time to lithify with mineral cements, and evolutionists would predict that thick strata sequences were deformed when the strata were in a lithified, brittle, or elastic condition. Specific types of fault and fold features which would be predicted by evolutionists should contrast strongly with those predicted by creationists.

In this paper we intend to demonstrate two examples of soft sediment deformation in very thick sequences of strata. The two examples illustrate the incompatibility of the data with evolutionary, uniformitarian and even neocatastrophist frameworks. In both cases the vast ages concept assigned to the strata and their deformation are shown to be incorrect. The two examples are not atypical, and we continue to investigate other areas where similar features exist.

Split Mountain Fault, Eastern San Diego County, California

Location of Fault

A spectacular exposure of a very thick stratigraphic sequence occurs at Split Mountain in Anza-Borrego Desert State Park in eastern San Diego County, California. The area is readily accessible by unimproved road from the town of Ocotillo Wells (intersection of Highway 78 and Split Mountain Road) which is 10 miles to the north. The 400-feet-high cliffs of the Split Mountain Gorge and slopes up to 1,000 feet high facing Fish Creek expose the core of a northwest-trending anticline. The gorge itself, as the name correctly implies, is the expression of a north-northeast trending normal fault. The southwest limb of the anticline dips homoclinally to the southwest at 20° and exposes more than 17,000 feet of strata from the gorge through Carrizo Badlands to the village of Canebrake.

Stratigraphy

The stratigraphy of the Tertiary strata in the Split Mountain area is described by several geologists (Dibblee, 1954; Kerr, Pappjohn, & Peterson, 1979; Woodward, 1963, 1974). The mechanics of deposition of these strata and identification of their source areas are outside the scope of this investigation but would make an excellent supplementary defense for catastrophism. The stratigraphic section consists of what geologists have identified as the pre-Tertiary crystalline basement complex of granitic and metamorphic rocks overlain nonconformably by what are called Tertiary rocks composed of very thick strata of arkosic sandstone, sedimentary boulder conglomerate, sedimentary boulder breccia, mudstone, and siltstone.

Beginning at the lowest strata formation in Split Mountain at the core of the anticline and proceeding out the southwest limb we encounter over 17,000 feet of strata in the anticlinal fold. Directly overlying the pre-Tertiary granitic basement rock is the Anza Formation composed of granitic boulder and pebble conglomerate with arkosic sandstone beds. The Anza Formation is up to 1,800 feet thick in the core of Split Mountain Anticline and is assigned to the Miocene Series (Kerr et al., 1979; Robinson & Threet, 1974; Woodard, 1974).

The Split Mountain Formation directly overlies the Anza and consists of a lower sedimentary boulder breccia unit (locally overlain by gypsum), a middle marine turbidite sandstone unit and an upper boulder breccia unit composed of chaotic and poorly bedded granitic and metamorphic boulders, some over 100 feet in length. Spectacular exposures of the Split Mountain Formation occur in the gorge where the formation is 1,000 feet thick with more than half of its thickness comprised of arkosic turbidite sandstone. The Split Mountain Formation has been assigned to the Miocene Series by Dibblee (1954), Strand (1962), and Woodward (1974). More recently the strata that compose the Split Mountain Formation have been attributed to both the upper Miocene and lower Pliocene by Robinson & Threet (1974) and by Kerr et al. (1979). The "middle marine sandstone" is approximately the Miocene-Pliocene boundary according to Robinson & Threet, while Kerr et al. put the boundary just above the lower boulder breccia unit.

The Imperial Formation overlies the Split Mountain Formation and consists of 4,000 feet of sandstone and rhythmically bedded siltstone and mudstone with occasional layers rich in marine mollusk fossils. These strata, which form the part of the badlands which flank the southwest side of Split Mountain, have been assigned to the Pliocene Series by numerous workers.

The Palm Springs Formation overlies the Imperial Formation conformably and consists of mudstone, siltstone, and sandstone over 10,000 feet thick occurring on the western side of the Fish Creek drainage and comprising the primary formation of the Carrizo Badlands. These strata have been assigned to the Pleistocene Series by Woodard (1974) and Downs & White (1968). Terrestrial and marine fossils in the lower part of the formation are claimed by Downs & White to represent the Blancan to Irvingtonian interval of middle Pleistocene age.

Relationship of Anticline to Strata

The fact that the Anza, Split Mountain, Imperial, and Palm Springs Formations overlie each other conformably (without major evidence of disconformity or angular unconformity between) argues that regional folding did not occur until after the Palm Springs Formation was deposited (that is, until after the middle Pleistocene). We could imagine that 17,000 feet of strata accumulating near the margin of a fault-bounded basin experiencing continuous subsidence as the bottom of the basin remained very level.

After the deposition of the 17,000 feet of strata, the structural style changed drastically. What had been a down-faulted, flat-bottomed basin was turned into an uplifted and arched mountain forming the Split Mountain Anticline. About 17,000 feet of uplift must have occurred to expose the granitic basement in the axis of the anticline. The axis of the anticline now trends northwest-southeast through Split Mountain and plunges up to 15° toward the northwest. Typical dips on the northeast limb are 30° while dips average a little more than 20° on the southwest limb.

Relationship of Split Mountain Fault to Anticline and Strata

Robinson & Threet (1974) mapped the Split Mountain Fault trending north-northeast through Split Mountain on the southwest limb of the anticline. They mapped the fault as cutting the Anza, Split Mountain and Imperial Formations. Cross-section analysis of their field data clearly demonstrated to Robinson & Threet that the fault dips eastward at a high angle (70° average) and that the rock on the east moved down about 400 feet in relation to the rock on the west. Slickensides on the fault indicate dip-slip movement and Robinson & Threet correctly call it a normal fault. Field exposures indicate that the fault surface has upward concavity as the dip of the fault and degree of curvature decrease with depth.

Numerous north-northeast trending normal faults have been mapped by Robinson & Threet (1974), Woodard (1963, 1974) and the authors of this paper on the southwest limb of the Split Mountain Anticline. The largest fault parallel to the Split Mountain Fault is called the Salt Spring Fault and occurs about 1,000 feet to the west. The two faults appear to merge into one fault on the southwest flank of Split Mountain. Woodard (1974) mapped this fault south-southeastward from Split Mountain a distance of 7.3 miles where it intersects both the Imperial and Palm Springs Formations, including the uppermost Palm Springs. Thus, we would conclude from the field exposure of the fault that it is middle or late Pleistocene (not Pliocene or Miocene) postdating the Palm Springs Formation and the deposition of the entire 17,000 feet of strata.

The middle or late Pleistocene deformation which formed the Split Mountain Anticline would, therefore, be concurrent with the slip of the Split Mountain Fault. Indeed, there are strong structural and mechanical reasons for regarding the Split Mountain Fault to be associated with anticlinal flexing. Robinson & Threet (1974, p. 54) say:

> The north to north-northeast trending set of faults may be interpreted as extension fractures developed in connection with elongation of the Split Mountain Anticline in a west-east direction.

The anticlinal extension fault interpretation for Pleistocene slip on the Split Mountain Fault is confirmed further by studies of the plunge of the Split Mountain Anticline. On the east side of the fault the anticline plunges over 15° to the west, while on the west side the plunge is more gentle. The change in plunge occurs at the fault and must be caused by rotation of the rock on the east on the concave-upward fault surface.

Details of Split Mountain Fault

Every observer, regardless of eduction, is struck with awe and wonder upon viewing the Split Mountain Fault and the unusual deformation features associated with it. The most frequently observed portion of the fault is about three-quarters of the way through the mountain (center of the west half of section section 36).

Figure 1 is a cross-section perpendicular to the fault showing at this location the deformation to the Split Mountain Formation. The concave-upward nature of the lowest fault surface in field exposure implies that the fault flattens out with depth, and further implies that physical separation of hanging wall from footwall must have occurred as about 400 feet of vertical slip occurred on the fault. The gap or mismatch of hanging wall and footwall produced a long trench-like hole into which secondary faulting allowed overlying material to fall or flow. Into this hole fell the upper boulder breccia of the Split Mountain Formation. The rock on both sides of the fault is the middle marine sandstone

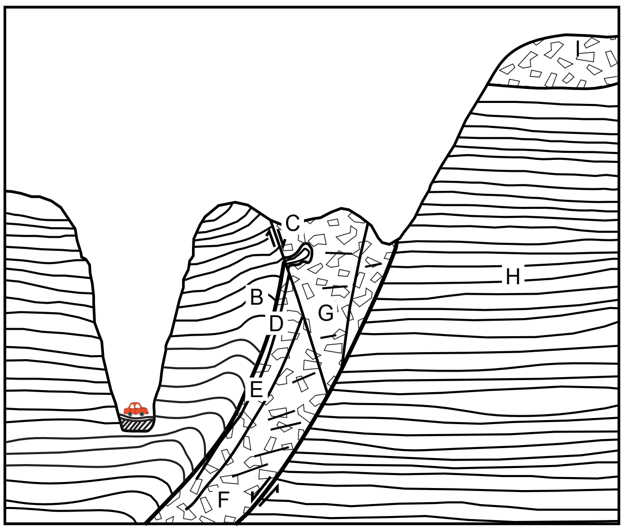

Figure 1. Cross-section of the Split Mountain Fault drawn perpendicular to the plane of the fault. A large volume of sedimentary boulder breccia slipped down into the hole created by slip on the concave upward normal fault. Zones labeled by letter are explained blow. Automobile in gorge provides scale.

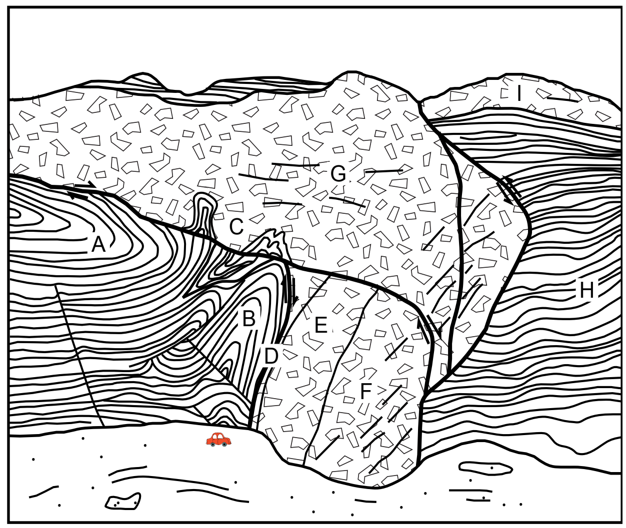

Figure 2. Overview from east side of Split Mountain Gorge of cliff and slope of the west side of the gorge showing numerous soft sediment deformation features associated with the fault. Zones labeled by letter are explained below. Automobile at base of cliff provides scale.

Zone A—Overturned strata of "middle marine sandstone." The force of impact from downdrop of fault block G pushed horizontally against the unlithified sandstone overturning the strata. Zone A is part of the hanging wall of fault.

Zone B—Underturned strata of "middle marine sandstone." Drag caused by rapid fall of block F severely disrupted zones D and E, and underturned the unlithified sandstone strata producing the spectacular fold shown in more detail in Figure 3. Zone B is part of the hanging wall of the fault.

Zone C—Mushroomlike masses of sandstone intruded into the boulder breccia. Between zones A and B the sandstone was neither overturned nor underturned, but was injected into the downfaulted block G. Individual sandstone strata in the intruded masses have very severe plastic deformation.

Zone D—Mixed zone of sand and boulders. Intense shearing of the downfaulted block F against the hanging wall disrupted both sand and boulders producing the mixing of materials. The sandgrains and boulders were certainly solid when deformation occurred but, because of their ease of mixing, could not have been lithified as part of their respective rock types (sandstone and boulder breccia) at the time of faulting.

Zone E—Sheared boulder breccia. Shearing of downfaulted block F against the hanging wall destroyed remnant bedding, rotated individual boulders, and homogenized the constituents of the boulder breccia.

Zone F—First downfaulted block of boulder breccia. The hole into which block F fell becomes narrower downward, which produced a "room problem" and deformation of zones B, D, and E. Block F has inclined remnant bedding inherited from its original layer at the elevation of stratum I.

Zone G—Second downfaulted block of boulder breccia. The wider part of the hole above block F was filled by fall of a second larger block which deformed zones A and C. Remnant bedding exists in block G.

Zone H—Slightly deformed "middle marine sandstone" forming the footwall of the fault.

Zone I—Undisturbed sedimentary boulder breccia overlying the "middle marine sandstone."

of the Split Mountain Formation which immediately underlies it.

Figure 2 is a drawing of the cliff and slope of the west side of the gorge viewed from high on the slope of the east side of the gorge. The fall of the boulder breccia into the gap along the fault was evidently rapid, producing a great variety of deformational features delineated as zones and described with Figures 1 and 2. Detail of part of the fold is shown in Figure 3. The remnant bedding of the middle marine sandstone is in places tightly folded, overturned, inverted, and injected, but rarely broken by secondary faulting as might be expected if the beds were in a rigid, elastic state. The data require that the beds had not yet had time to harden into rock, and that they deformed while still in a fresh, plastic state, if the folding was indeed rapid.

Rapid emplacement of the boulder breccia is demanded by the presence of a highly sheared, fine-grained zone immediately underlying and/or adjacent to the overhanging fault, remnant bedding of the boulder layer having been broken on impact, and the fact that an instantaneously created fault gap will not stand empty in the subsurface.

Figure 3. Detailed view of spectacular underturned fold in hanging wall of the Split Mount Fault. Zone B comprises most of the photo with zone C at the top and zones D and E at the right.

Evidence for Soft Sediment Deformation

Numerous arguments in favour of soft sediment deformation can be marshalled.

1. **Non-transference of stress.** The beds were insufficiently rigid to transfer the stress of impact any great distance away from the fault. The major deformation is restricted to the 30 feet nearest the fault.
2. **Different directions of folding.** The boulder breccia rapidly filled an irregular hole, causing no unified stress pattern. The surrounding beds deformed in an irregular sense. The rock material was not sufficiently strong to allow a unified stress field to develop.
3. **Degree of folding**. Rock is notoriously weak in tension, and above the neutral axis, all folded material is in tension. The rocks here have been folded as much as 180° within 15 feet. Tension would have developed sufficient to cause fracture had the rock been in an elastic phase.
4. **Thickening and thinning**. As the beds folded, they flowed rather than fractured. In places, individual beds are now twice as thick as they were originally and in other places, they nearly pinch out. Figure 3 shows considerable thickening of beds in the axis of the fold.
5. **Fracturing as space problem**. The rupture of beds which did take place was not generally in areas where excessive stress was expected. Rather, it appears the material fractured due to space requirements. In places, drag folding occurred along these rupture zones.
6. **Injected masses**. Above the main area of folding, masses of sandstone are incorporated into the slumped boulder breccia (zone C in Figures 1 and 2). Bedding remains recognizable, and is severely folded into mushroom shapes. This material was deformed as it was trapped in the falling boulder breccia, and folded through a 270° arc during slumping.
7. **Sheared and mixed zones below overhanging fault**. The matrix of the boulder breccia could not allow such intense reorganization if it was lithified at the time of faulting. Zones D and E were plastic when sheared.

Implications of Creep

Of special importance is the tension developed in strata of Figure 3 over 180° of folding and thinning of beds, all with no fracture. Could this deformation be the time-dependent result of constant loading (that is, creep)? Contrary to the statements of many uniformitarians, creep in brittle rock cannot continue indefinitely without fracture. The curve shown in Figure 4 is known as a **complete** stress-strain curve, developed by servo-controlled stress-

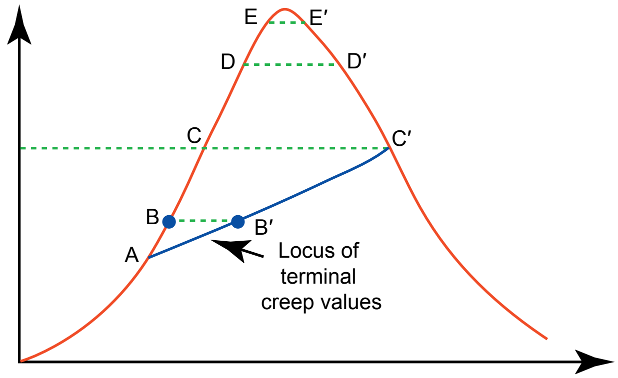

Figure 4. A complete stress-strain curve showing the limits of time-dependent strain on rock (after Goodman, 1980, p. 74).

strain experiments which do not allow the material to rupture. These tests consist frequently of many thousands of cycles over years of real time, and are thought to yield ultimate creep limits. Such a curve has not been generated for the various layers at Split Mountain, but the one shown can be considered qualitatively representative of these beds. As can be seen loading below a certain limit A does not result in creep at all. Loading between A and C results in limited creep only (for example, loading at level B results in strain BB′, after which creep is arrested). Line A B′B′ represents the locus of limiting creep values. Loading above C (at points D or E) results in creep which leads to failure (at points D′ and E′). There is no loading which results in indefinite creep without failure.

In view of the fact that extensive deformation cannot occur **slowly** in rigid rock, nor, as everyone agrees, can extensive deformation occur **rapidly** in rigid rock, therefore the deformations seen at Split Mountain must have occurred when the material was in a soft, plastic state.

Ute Pass Fault west of Colorado Springs, Colorado

Location and General Features

The Front Range of the Rocky Mountains of Colorado was formed by large reverse faults which in one place has 21,000 feet of vertical slip. The very abrupt margin of the Front Range with Pikes Peak (over 14,000 feet elevation) on the west and Colorado Springs (6,000 feet elevation) on the east is caused by Ute Pass Fault, a prominent north-trending reverse fault more than 40 miles in length. On the west side of the fault is the upthrown Pikes Peak granite and associated Precambrian metamorphic rocks with all sedimentary strata removed by erosion. On the east side of the Ute Pass Fault are the flat lying strata thousands of feet thick which are typical of the plains in eastern Colorado. On the south, the Ute Pass Fault dies out into a narrow monocline.

A generalized cross-section of the Ute Pass Fault is shown in Figure 5. According to field study conducted by Harms (1965), the Ute Pass Fault dips steeply westward near the surface, then becomes near vertical with increasing depth. According to stratigraphic data assembled for the Phanerozoic rocks on the east side of the Ute Pass Fault, about 12,000 feet of strata underlie Colorado Springs (Mitchell, 1955), with Precambrian basement occurring at an elevation of about 6,000 feet below sea level. Because the adjacent Precambrian basement on the west side of Ute Pass Fault occurs up to 14,000 feet above sea level, about 20,000 feet of vertical displacement is indicated southwest of Colorado Springs on the east flank of Cheyenne Mountain.

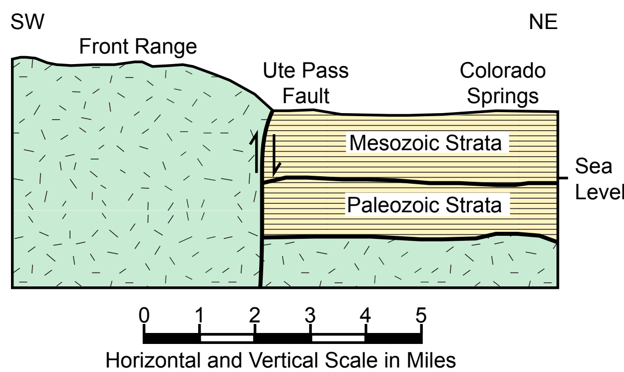

Figure 5. Cross-section of Ute Pass Fault southwest of Colorado Springs, Colorado. Precambrian basement rocks have been uplifted many thousands of feet on the west side of the fault.

Stratigraphy and Age of Faulting

The thick strata section to the east of the Front Range in the Colorado Springs area is summarized by Mitchell (1955), Scott & Wobus (1973), and Trimble & Machette (1979). The measured sections of Mitchell includes 5,700 feet of Paleozoic strata, 8,700 feet of Mesozoic strata, and 2,300 feet of Cenozoic strata. The quartzose Sawatch Sandstone (Cambrian) directly overlies the Precambrian basement. Also of importance in relation to the Ute Pass Fault is the very thick, arkosic Fountain Formation (Pennsylvanian and Permian).

The Ute Pass Fault truncates or folds strata assigned from Cambrian to Cretaceous, and therefore must be Cretaceous or post-Cretaceous. The Laramide Orogeny has been recognized to be the main deformational event and is assigned an age of Cretaceous to Oligocene (Harms, 1965). There was also a time of structural instability assigned to the Mississippian-Pennsylvanian boundary with the associated Fountain formation. The thin and extensive lower Paleozoic quartzose sandstones and carbonates are evidence of great structural stability. Judging from the field relationships of the Ute Pass Fault, nearly all the deformation is Laramide, with all of the very intense deformation assignable as Laramide.

Monoclines and Tight Drag Folding on the Ute Pass Fault

One of the most interesting characteristics of the Ute Pass Fault is the intensity of folding of the strata on the east side of the fault. The southern termination of the Ute Pass Fault where it is crossed by Little Fountain Creek is the eroded remnant of an enormous monocline involving about two miles of structural relief. As the strata approach the flank of the Front Range within three miles of the exposure of Precambrian basement, 14,000 feet of strata are flexed into nearly vertical orientation. It would appear that the Ute Pass Fault is concealed at depth in the Precambrian basement but that the overlying sedimentary rock cover was not solidified and able to fault. Instead the strata were plastically deformed by vertical displacement on the Ute Pass Fault to form this incredible monocline.

Evidence of soft sediment deformation can be seen also in tight drag folds very close to the Ute Pass Fault. Figure 6 shows how the red arkosic sandstone of the Fountain Formation is very strongly folded in contact with the fault near Manitou Springs. The Fountain bedding dips at 35°NE just 80 feet northeast of the Ute Pass Fault, but at the fault the sandstone is overturned and dips about 60°SW. This folding was caused by drag of the strata against the upthrown west side of the fault. The observations show that the sandstone was not able to transmit stress away from the fault and was not internally faulted as it was folded, which is consistent with the notion that the strata were ductile and not solidly cemented when deformed. The only problem is that the strata are assigned an age of 300 million years while the Laramide Orogeny is regarded as less than 70 million years. How could the material remain ductile for 230 million years?

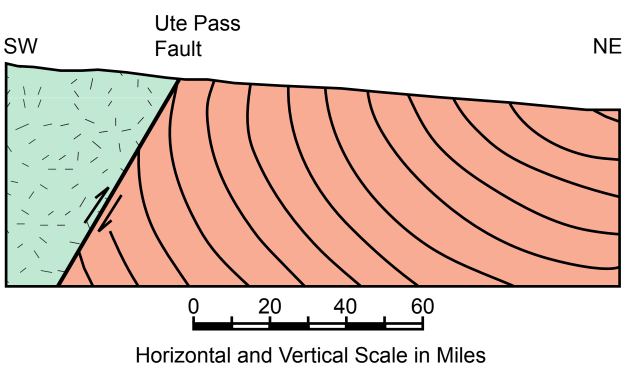

Figure 6. Cross-section of Ute Pass Fault one mile southeast of Manitou Springs, Colorado. Pikes Peak granite on southwest side of fault has been upthrown thousands of feet to deform Fountain Formation, arkosic sandstone strata. The intensity of drag folding dies out dramatically within several tens of feet northeast of the fault.

Ductile flow as the mechanism for tight drag folds was recognized by John Harms after study of several outcrops on the Ute Pass Fault (Harms, 1965, p. 989):

> 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.

The translation and rotation of individual grains could be easily accomplished if the sediment was not yet cemented when deformed. If it was cemented, we would expect significant modifications to the shapes of individual grains due to the stress of folding. We could also expect significant faulting as indicated by Figure 4.

Clastic Dikes Along the Ute Pass Fault

Among the most talked about soft sediment deformation features along the Ute Pass Fault are the clastic dikes of quartzose sandstone found associated with this fault and many other reverse faults of the Front Range (Crosby, 1897; Cross, 1894; Harms, 1965; Kost, 1984; Scott, 1963; Vitanage, 1954). Over 200 sandstone dikes were mapped by Harms. The dikes vary from a fraction of an inch to miles in length, from a fraction of an inch to 300 feet in width, and penetrate up to 1,000 feet or more through the surrounding bedrock which is almost always the 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 west of the fault. Harms interprets the sandstone dikes to have been injected from sandstone overlying the Precambrian basement along extension fractures in the hanging wall of the convex-upward reverse fault. Virtually all the dikes mapped have strike parallel to the strike of the main reverse fault, and because of their coincidence with the Laramide structure would be reasonable Laramide dikes.

Although the clastic dikes are variable in dimension, they are remarkably uniform in composition. They are greater than 90% quartz by volume, less than 5% feldspar, and less than 5% clay-size matrix. Xenoliths of granite from the wall rock are common. Hematite cement is abundant and imparts a red or purple coloration to the dikes. Among investigators of these clastic dikes there is agreement that the Sawatch Sandstone (the Cambrian strata just above 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.

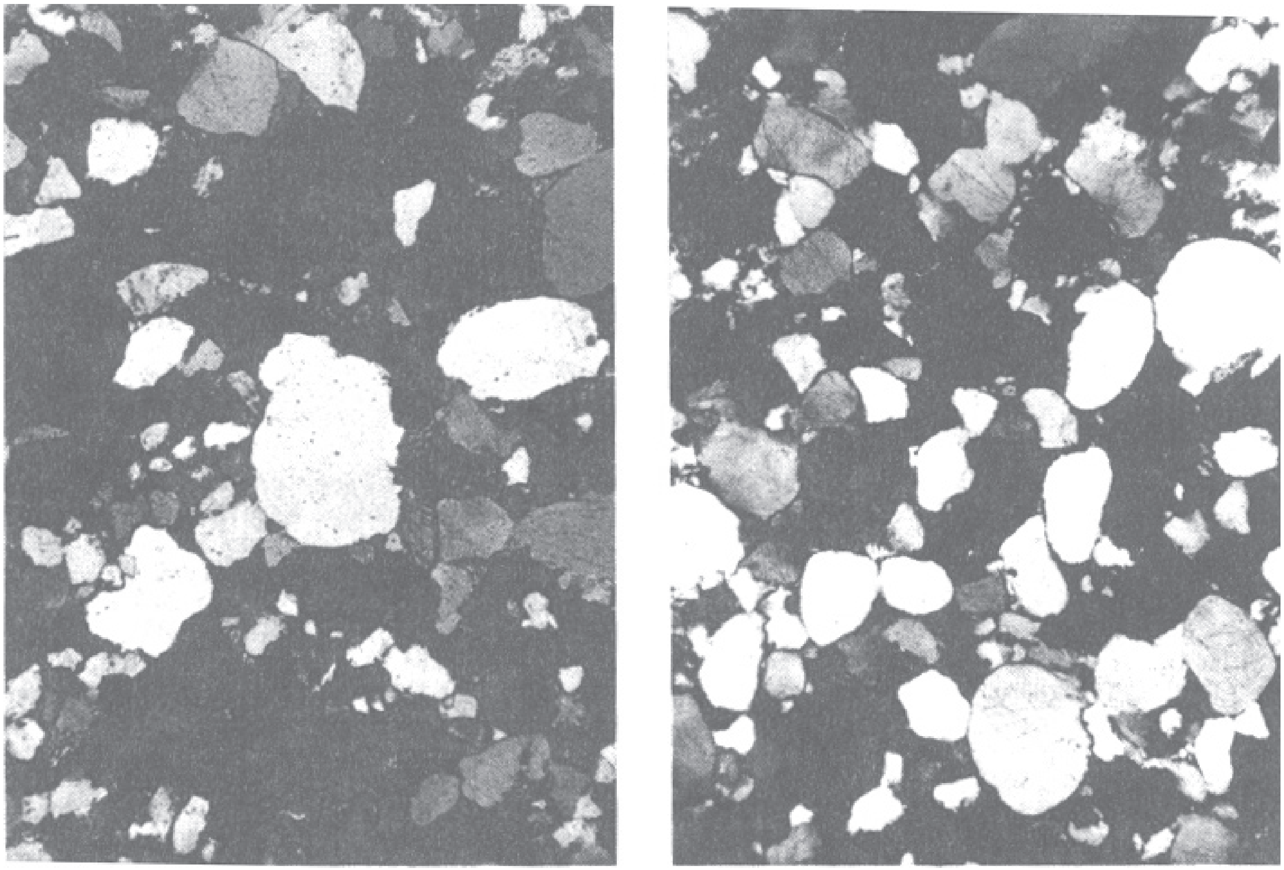

Figure 7. Microscopic views comparing typical Sawatch Sandstone (left) with typical clastic dike (right) from Ute Pass Fault. Thin sections of sandstones were photographed using crossed polarizers. The width of field in each specimen is 4 mm.
Left photo—Sawatch Sandstone from Manitou Springs, Colorado. Grains are more than 90% quartz. Cement is dolomite. Note the presence of more clay-size and silt-size particles than in the clastic dike.
Right photo—Clastic dike from Crystola Creek south of Woodland Park, Colorado. The sand from dike, also dominated by quartz, usually has better sorting and rounding and less clay-size matrix than the Sawatch Sandstone. Hematite cement is common. The grain boundaries are not fractured as would be expected if the dike was formed by mechanical disaggregations of a lithified sandstone source bed.

Evidence for Unconsolidated Sand Injection

The evidence that the sand of the dikes was unconsolidated when injected has been recognized by many workers (Cross, 1894; Harms, 1965; Kost, 1984; Scott, 1963; Vitanage, 1954). There is little evidence of breakage of sand grains as if they are cemented before injection, and there is a lack of fine matrix which would form from disaggregation of rock. Instead, the long axes of granite xenoliths are oriented parallel to dike walls and the dikes themselves show laminated flow structures with segregation of sand by size as if forcefully injected. Evidence of great fluidity of the injected material is seen in dikes only a fraction of an inch wide completely filled with sand.

Figure 7 compares the Cambrian Sawatch sandstone to a Ute Pass Fault clastic dike. Lack of breakage of quartz grains and less matrix are characteristic of the dike indicating fluid injection.

Evidence for Laramide Injection of Dikes

Among investigators of the clastic dikes along the Ute Pass Fault there is divergence of opinion as to when intrusion occurred. Some workers (Kost, 1984; Scott, 1963; Vitanage, 1954) recognize the fundamental impossibility of keeping the Sawatch Sandstone (assumed Cambrian age of 500 million years) unlithified and deeply buried for 430 million years until the Laramide Orogeny (assumed late Cretaceous age of 70 million years or less). These workers tend to negate the important field relationships and suggest that the dikes were actually intruded in the Cambrian while the Sawatch Sandstone was unconsolidated. Evidence of Cambrian or Ordovician tectonics of a magnitude able to open up extension fractures hundreds of feet wide, however, has not been found on the Ute Pass Fault.

The actual field data strongly supports the Laramide intrusion of the dikes. The Laramide event 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 as Harms (1965) correctly claims. Scott and Wobus (1973) have mapped a quartzose sandstone body one mile west of Manitou Springs on the east side of the Ute Pass Fault which penetrates Fountain arkosic sandstone (assigned to Pennsylvanian and Permian systems). In this case the dike cannot be Cambrian or Ordovician, and would be naturally assigned to the Laramide.

Conclusion

A geologic test of creationist and evolutionist views of strata was conducted on the Split Mountain Fault with 17,000 feet of associated strata in California and the Ute Pass Fault with 14,000 feet of associated strata in Colorado. The total time required for deposition of each sequence of strata, for regional flexing, for faulting, and for development of local deformation features must be less than the time it takes soft sediment, complete with necessary water and mineral cement, to harden into rock. The data support the creationist view that deposition of strata and tectonism are concurrent, not consecutive.

The conventional dating assigned to the lowest Pliocene middle marine sandstone of the Split Mountain Formation assumes an age of about 7 million years. The age assigned to the soft-sediment deformation is middle or late Pleistocene, just several hundred thousand years ago in the conventional dating of evolutionists. How could the sediments escape lithification after deep burial over a duration assumed to be 6 million years?

Evolutionists regard 14,000 feet of strata along the Ute Pass Fault in Colorado as accumulating from the Cambrian (assumed age of 500 million years) through the Cretaceous (assumed age of 70 million years). Yet among the strata along the fault are soft sediment deformation features (monoclines, tight drag folds, and clastic dikes) which are associated with Laramide Orogeny (assumed age less than 70 million years). How can sediments escape lithification after deep burial through a duration up to 430 million years? The answer to these questions is to discard the assumption of millions of years.

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Discussions

This paper does present two field studies which would argue for deposition of large, layered formations before any part of it lithified or became cemented into what is normally thought of as a rock. If solid consolidation or cementation occur **necessarily** within thousands of years, then, yes, the examples are discordant with the million year depositional model. But, although the authors entitle their introduction: "Long Ages or Rapid Deposition?—A Geologic Test," by that they merely mean a test for the idea of deposition over millions of years, not a test for rapid deposition.

In the entire paper there is only one sentence referring to microscopic study of the extent of granite cementation **before** deformation, for instance, cementation which was fractured by the sand grains separating and moving with respect to each other. That is a critical set of observations, one easily made, but one left undone. The question remains: How cemented were the grains? Concurrent deposition and deformation would imply a total lack of cementation before deformation, even though additional cementation may have occurred since then.

Another major consideration to be aware of is the mechanical behavior of sediment under elevated temperatures and pressures. Rock which is strong and rigid at atmospheric conditions may flow under conditions of deep burial, especially if the deformation is relatively slow, and the grains relatively uncemented. It is important to note in one field case the material is described as "unlithified under deep burial" conditions. In the other field case, depth of burial at the time of deformation is left unaddressed.

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This paper demonstrates only that in some cases sediments remain unconsolidated prior to and during deformation. It does not demonstrate recency of sedimentation or tectonism. Although time may be a necessary condition for the cementation of most sediments, it is not a sufficient condition. Time alone does not guarantee that appropriate physico-chemical conditions for cementation will occur. Witness the unconsolidated Gulf coastal plain sediments or very poorly consolidated St. Peter and Navajo sandstones. Moreover, what of the possibility of a previously existing cement having been dissolved?

More to the point, how does one account for abundant evidences of deformation of consolidated rock, for example, the deformed fossils, deformed oolites, vein-filled extension and shear fractures, so common in the Appalachians, within a very short time frame given our knowledge of the chemistry of cements?

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Closure

Our purpose in presenting the paper was to contrast some expectations concerning the stratigraphic record which would be predicted by old-earth evolutionists and young-earth creationists. We selected the topic of deformation structures in sedimentary rocks because the subject has not been addressed in creationist works, and seemed to us to be very worthy of study. We tried to formulate predictions which would allow testing of the evolutionist and creationist views on strata. Evolutionists, who assume millions of years within stratigraphic sequences, would expect brittle deformation features to dominate in sedimentary rocks, while creationists, who assume thousands of years within stratigraphic sequences, would expect plastic deformation features. We carefully studied two very thick stratigraphic sequences and presented numerous evidences for plastic deformation.

Both reviewers of our paper subscribe to long ages for strata, but, to our astonishment, seem to agree with our main point that soft sediment deformation features occur in the two very thick stratigraphic sequences we studied. Dr. DeVilbiss says our two field areas "… argue for deposition of large, layered formations before any part of it lithified or became cemented into what is normally thought of as a rock." Dr. Young is less forthright, but notes that our data demonstrates "… sediments remain unconsolidated prior to and during deformation." We thought it would be harder to convince our critics!

Those who assume great ages for strata have problems explaining how these two thick stratigraphic sequences remained non-lithified. In the case of the 17,000 feet of Split Mountain strata, we are asked to assume that no significant degree of lithification occurred for a minimum of six million years, while the strata were deeply buried at high temperature and high pressure, and where interstitial fluids rich in dissolved minerals could migrate and deposit cement. Then, after uplift and removal from the ideal cementation environment in the latest thousands of years (certainly much less than a million years in evolutionary thinking), the present brittle character of the rocks was acquired. The time discrepancy is even more of a problem in the case of the 14,000 feet of strata on the Ute Pass Fault. We are asked to believe that nonlithified sediment existed for 430 million years through deep burial, repeated transgressions, regressions, and orogenies, and, in spite of abundant deposition of lime sediments and flow of carbonate ground waters.

Dr. Young is correct in noting that time alone is not a necessary condition for cementation to occur. However, he and other advocates of great age between deposition and tectonics must assume great pressure and temperature as well. Pressure increases on the order of 1 psi per foot depth through sediment, and temperature increases at approximately 1 °C per

100 feet depth (sufficient time for adjustment to geothermal gradient before deformation is granted by Drs. DeVilbiss and Young, but not necessarily by advocates of young age). Therefore, Drs. DeVilbiss and Young would be obliged to admit that temperatures approaching 200 °C and pressures of 15,000 psi were sustained by clastic and carbonate sediments for millions of years **without** cementation!

Cementation of sediment can occur by four mechanisms: (a) pressure solution of grain boundaries, (b) recrystallization of clays, (c) infiltration and precipitation from moving interstitial fluids, and (d) ion diffusion and precipitation through stationary interstitial fluids. Each of these mechanisms could produce significant cementation for the temperature, pressure and time assumed by evolutionists. The advocate of millions of years duration between deposition and tectonics must explain what presented cementation from occurring in the presence of these conditions and mechanisms. The creationist has no such problem, as long times are not assumed.

Dr. Young's mention of the poorly cemented Gulf Coast sediment is a special case that does not apply to our examples. The Gulf Coast sediment has low geothermal gradient, while the Rocky Mountain and Southern California rocks have high geothermal gradients. The argument of Dr. Young concerning the poorly cemented St. Peter and Navajo sandstones is, quite frankly, a "straw man." Where deeply buried, these sandstone **are** well cemented and have worn out thousands of drill bits. Only in the near surface environment, where weathering by solutions has removed much of the original cement, is the sandstone poorly consolidated.

Our work shows that creationist predictions concerning the relationship between sedimentation, tectonics and cementation more closely correspond to reality than do evolutionist predictions. We invite evolutionists to explain our data better than we can.

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