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Scott H. Rugg
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**DETACHMENT FAULTS IN THE SOUTHWESTERN UNITED STATES - EVIDENCE
FOR A SHORT AND CATASTROPHIC TERTIARY PERIOD**

Scott H. Rugg M.S.
Engineering Science Applications
8534 Commerce Avenue, Suite B
San Diego, CA 92121

ABSTRACT

Low-angle mid-Tertiary detachment faults (gravity slides) within the southwestern United States are best understood as developing very rapidly (<100 years) within a catastrophic framework. This is supported by the example of modern and ancient gravity slides which occur very rapidly (within seconds, minutes, or days) and are usually initiated by catastrophic events such as earthquakes. Evolutionists believe that detachment faulting and related geologic events occurred over a period of 10 to 20 million years. However, the basic principles of rock mechanics reveal that upper-plate movement is impossible under docile uniformitarian conditions. Movement was assisted by large and frequent earthquakes which provided both lateral and horizontal forces to overcome the restraining forces against movement due to friction and cohesion. Studies indicate that rapid basement warping, extensive dike emplacement, volcanism, and hydrothermal mineralization occurred contemporaneous with detachment faulting due to a high heat flow rate within the earth's crust. Thick deposits of coarse grained sediments and megabreccias also indicate rapid uplift, erosion, and deposition. This reveals that an unparalleled amount of seismic energy was released at this time. The rapid development of detachment terrane indicates that the Tertiary period was similar to the latter stages of Noah's Flood as the "mountains rose" and "valleys sank down" and was significantly shorter than the millions of years assigned under the uniformitarian model.

INTRODUCTION

Thousands of gravity induced landslides occur each year around the world. They range in size from several thousand square meters to several square kilometers and are most often initiated during other catastrophic events such as torrential rain storms, earthquakes or volcanic eruptions. Movement is nearly always rapid; occurring within several seconds, minutes, or days.

Ancient landslides have also been identified throughout the world. These "old" landslides are usually several orders of magnitude larger than modern landslides. The conventional uniformitarian view concerning ancient landslides, is that movement occurred slowly (several centimeters per year) over a period of several millions of years. This view is a contradiction of the uniformitarian doctrine that "the present is the key to the past," since it is clear from experience that landslides occur rapidly and not slowly.

Not all have swallowed the "slow slide" pill. William G. Pierce has eloquently argued that the Heart Mountain Detachment (ancient Tertiary gravity slide) in Wyoming was a cataclysmic event. This interpretation displeases his fellow uniformitarian geologists because other synchronous (coeval) geologic events associated with movement, such as erosion, sedimentation, and accumulation of several hundred meters of volcanic deposits, would have occurred during the same time frame as the cataclysmic sliding.

Many of these ancient landslides (Tertiary detachment faults) have been identified in western North America, in a region west of the Rockies, stretching from the Canadian border of the United States into Sonora, Mexico (Figure 1). Recent intensive study has been focused within the region surrounding the Colorado River which includes southeastern California, southwestern Arizona, and southern Nevada. Nearly every mountain range within this region has been affected by detachment faulting (Figure 2).

In this paper, we intend to show that the most tenable explanation for detachment faulting in the southwestern United States is that it occurred rapidly (within minutes, days, or years) in response to other catastrophic events, under conditions similar to those which would have been present during Noah's flood. It will be shown that other synchronous geologic events such as erosion, sedimentation, hydrothermal mineralization, and basement warping also occurred rapidly during development of detachment terrane. This catastrophic scenario is also supported by historic and ancient examples of landsliding which were clearly catastrophic and by the basic principles of rock mechanics.

GENERAL DESCRIPTION OF DETACHMENT FAULTED TERRANE

A detachment fault (low-angle normal fault, denudational fault, decollement, or gravity fault) is a nearly horizontal surface which separates a detached and displaced upper-plate allochthon from a lower-plate autochthon. Peter Misch (1960), who first closely studied these faults within the Great Basin region of the western United States, attributed upper-plate movement to compressional forces (thrusting). However, it was soon determined that the upper-plate had actually been distended, which made it clear that movement was accomplished by tensional forces and not compression (Anderson, 1971). The total amount of upper-plate distention ranges up to 50 to 100 percent (Spencer, 1985) and possibly as high as 400 percent in some areas (Lister et al., 1986).

Nearly every mountain range within the region extending west of the Colorado Plateau to the San Andreas fault, from Death Valley and southern Nevada to Sonora, Mexico (Colorado River borderland) has been affected by detachment faulting. It is believed that this event initiated at the beginning of the late Oligocene and continued through mid-Miocene time (10 to 20 million years). The detachment surface is a regional feature with lateral upper-plate displacement ranging from a few kilometers to as much as 50 to 80 kilometers (Reynolds and Spencer, 1985; Stewart, 1983). The direction of transport has generally been toward the northeast, but a few areas exhibit westward directed upper-plate transport. The fault has been deformed into a sinuous configuration of antiforms and synforms by lower-plate warping which occurred during detachment faulting. Present slopes on the detachment surface range from horizontal to 60° (Berg et al., 1982). Prior to warping, the surface was a gently sloping feature of probably less than 5°.

The upper-plate consists of a combination of Tertiary volcanic and sedimentary rocks and Mesozoic and Precambrian crystalline rocks. In many mountain ranges, the upper-plate consists almost exclusively of the Tertiary rocks. The structure of the upper-plate is characterized by high-angle curved normal faults (listric faults) which flatten at depth and merge into the basal detachment surface (refer to Figure 3). This has resulted in the formation of an imbricated system of parallel half-graben blocks. During distention, the half-graben blocks underwent rotation, resulting in bedding structure which dips in a direction opposite the transport direction of the upper-plate.

The lower-plate is composed of Mesozoic and Precambrian metamorphic and crystalline rocks. The lower-plate is generally arched upward which has caused deformation of the detachment surface. In some ranges, the lower-plate has a foliation (mylonization) which is truncated by the detachment surface.

In a few mountain ranges, several stacked series of detachment faults have been identified (John and Howard, 1982). Other ranges however, do not exhibit any signs of the regional detachment surface (Dahm, 1983).

Several mechanisms have been proposed to account for wide-scale distention exhibited in the upper-plate. Some have attributed distention to a pure shear model related to a crustal spreading at depth, which has caused decoupling of the upper-plate with little or no gravity sliding occurring. However, widespread displacement of the upper-plate can only be accommodated by large-scale transport (Reynolds and Spencer, 1985) of which gravity sliding had to play a primary role (Seager, 1970; Shackelford, 1975; Davis et al., 1979).

GEOLOGIC EVENTS COEVAL WITH DETACHMENT FAULTING

Sedimentation/Erosion

The upper-plate is composed of a high percentage of Tertiary volcanic and sedimentary rocks. The sedimentary rocks are characterized by high energy deposits including fanglomerates, volcanoclastic rocks, conglomerates, arkosic sandstones, siltstones, boulder breccias, and megabreccias with clasts as large as 6 meters in diameter (Pike and Hansen, 1982). They are over one kilometer thick in some areas and are often interbedded or intertongued with volcanic flows (Teel and Frost, 1982). In the Trigo Mountains, volcanoclastic beds up to 20 meters thick are interbedded with volcanic flows within the lower section of the upper-plate and exhibit sharp bedding contacts (Rugg, 1986). The interbedding of the coarse grain sedimentary rocks and volcanic flows reveals that deposition was extremely rapid and continuous, with no time for erosion, and took place in hot water several hundreds of meters deep.

Within the Whipple, Chemehuevi, Copper, and Kofa Mountains, the sedimentary bedding has a consistent increase in dip down-section within the rotated upper-plate half-graben blocks. This structural configuration, known as growth faulting (see right side of Figure 3), demonstrates that upper-plate movement occurred contemporaneous with deposition of the sedimentary rocks (Frost, 1979).

Most of the sedimentary clasts have been derived from the area that they have been deposited. Within the Chemehuevi Mountains, the composition of the clasts change up-section in conformance with progressive unroofing of different zones of lower-plate basement rock lithology (Miller and John, 1988). This pattern is additional confirmation of coeval sedimentation, erosion, and detachment faulting. Surely, this would have required a tremendous amount of rapidly moving water to transport and lay down all the thick deposits of coarse grained sediments.

Hydrothermal Mineralization

Identifying detachment terrane has taken on economic significance because of the relationship between the detachment fault and a variety of hydrothermally mineralized deposits. Faulting has resulted in the development of a breccia zone up to a hundred meters thick. This fractured zone has provided an excellent conduit for the transport of hot mineralizing fluids and the deposition of large ore bodies along the detachment fault and within thinner breccia zones associated with the upper-plate listric faults.

Spencer and Welty (1986) have shown that hydrothermal mineralization in the Buckskin-Rawhide-Whipple Mountains area was continuous with detachment faulting. They found several generations of mineralized deposits at different depths within the upper-plate. These deposits could only have been formed by movement passed a mineralizing interface. Bartley and Glazner (1985) also confer that mineralization was synchronous with upper-plate movement. They believe that the hydrothermal fluids may have played a key role in accommodating upper-plate movement due to the buoyant effects of inferred high fluid pressures within the detachment zone.

Lower-Plate Warping

The borderland region of the Colorado River has been deformed into a system of roughly parallel arches and basins aligned with their major axis in a northeast-southwest direction (Otton and Dokka, 1981). The amplitudes of these features range up to 2 kilometers with axial lengths on the order of 20 kilometers or more. In several areas, a superimposed set of nearly perpendicular northwest trending folds have further deformed the northeast trending folds into dome shaped features (Cameron and Frost, 1981).

It appears that folding is related to warping of the metamorphic and crystalline basement rocks during a highly ductile phase of the lower-plate. Cameron and Frost (1981) indicate that the regional antiformal/synformal character of the detachment surface developed in response to this large scale basement folding and occurred simultaneously with detachment faulting. Spencer (1984) suggests that uplifting of the lower-plate resulted from isostatic rebound due to upper-plate movement which unroofed and exposed vast areas of basement rock. He believes that the warping occurred rapidly during a period of very low flexural rigidity of the basement rocks, which suggests a high heat flow rate during this time. Spencer and Welty (1986) indicate that the geothermal gradient at this time was greater than 100# C/km. Undoubtedly, there would have been a tremendous amount of seismic energy release during uplifting of the basement rock material. Little consideration has been given to the effects of this seismic energy release and the development of detachment terrane.

Dike Emplacement

Dike swarms are extensive and occur within many of the mountain ranges of the Colorado River borderland, particularly in the northern region of this area in the Homer, Sacramento, and Newberry Mountains (Spencer, 1985). In some regions, the dikes are so numerous that they compose over 40% of the total surface outcrops. The dikes typically dip very steeply and are oriented in a northwest-southeast configuration, however, east-west and north-south trending swarms have also been identified. The composition of the dikes (rhyolite to andesite) is similar to the composition of the Tertiary volcanic flows within this region, indicating that dike fissure flow may have been the source for many of the volcanic flow deposits. The Castle Dome Mountains, where some of the most remarkable dike swarms within the United States are found (Logan and Hirsch, 1982), have also been identified by Gutmann (1981) as an ancient caldera from which exuded much of the volcanic rocks for this region.

The dike swarms are primarily concentrated within lower-plate crystalline rocks. However, dikes have also been observed penetrating the detachment surface in a few isolated areas (Spencer 1985). This pattern reveals that the majority of dike emplacement occurred just prior to movement of the upper-plate and continued at a lesser amount during and after upper-plate movement. It appears that dike emplacement was facilitated by concave upward flexure (warping) of the lower-plate (Spencer, 1985). This relationship also establishes a genetic link between dike emplacement, lower-plate warping, and a high heat flow rate.

Additional Geologic Observations

The Tertiary period was unparalleled in the amount of volcanic activity which occurred. This

activity indicates that the vast amount of water which also occupied this region was significantly warmer than present day oceans. Nutting (1984) demonstrated that sedimentary red beds indicate a hydrothermal depositional environment. A thick sequence of chaotic Tertiary red beds occur directly below and in conformable contact with volcanic deposits within the Trigo Peaks and Dome Rock Mountains region (Dahm, 1983), indicating the presence of hydrothermal waters in this region during deposition. This "hot" water could have also been the source for the mineralizing fluids which were present during detachment faulting.

The majority of the basalt flows in this region are nearly flat-lying which indicates that detachment faulting had nearly ceased by the time basaltic volcanism initiated. Basaltic volcanism is not as energetic as the rhyolitic/andesitic volcanism associated with detachment faulting. Rhyolitic/andesitic volcanism is associated with explosive eruptions like that of Mount Saint Helens. The close link between the cessation of detachment faulting at the close of explosive rhyolitic/andesitic volcanism would indicate that movement of the upper-plate was facilitated by tremendous energy release during volcanism.

PROBLEMS RELATED TO LOW-ANGLE GRAVITY SLIDING

Before a landslide can occur, the sum of the driving forces, which act with movement, must exceed the sum of the restraining forces, which act against movement. The primary driving force for landsliding is gravity. This force decreases from a maximum in a vertical orientation to zero along a horizontal plane. The restraining forces are those resulting from the internal friction and cohesive strength of the rock material. Most rock and soil material have an internal friction angle of approximately 33°. This means that under cohesionless conditions, gravity sliding can only occur on surfaces greater than 33° (called the angle of repose). This is why dry beach sand, which is cohesionless, cannot form slope faces of in excess of 33°. However, all rock and most soil have significant cohesion which is why slope faces greater than the angle of repose can develop.

These basic principles of rock mechanics have caused considerable controversy among geologists for decades because most ancient detachment surfaces slope significantly less (<5°) than the angle of repose. Therefore, it would be impossible for the small lateral component of gravitational forces acting along the slide plane to overcome the forces acting against movement due to friction and cohesion. This indicates that there had to be another type of driving force. However, little consideration has been given to what this force was, because of the imposition of uniformitarian philosophy.

In attempting to resolve this problem, Hubbert and Rubey (1959) asserted that high pore-fluid pressures developed within the detachment zone which caused the upper-plate to float, thus voiding the forces due to friction and allowing sliding to occur on any surface over 0°. Their model is based on two assumptions: 1) the cohesion factor was equal to zero; and 2) high pore-fluid pressures could be maintained for millions of years. Hsu (1969) has pointed out that the cohesion value would be a significant factor, requiring tremendous forces to overcome. Therefore, there would have to have been a significant lateral force to initiate a detachment surface. Here again however, gravity alone could not account for that total force.

Hubbert's and Rubey's second assumption is also highly questionable. The main detachment surface as well as faults and fractures which would develop within the upper-plate would provide excellent conduits for the rapid release of pore pressure. Guth (1982) has also shown that the phenomena of rock hydrofracture would cause a rapid reduction of high pore pressure within confining layers. This shows that the assumption of high pore-fluid pressures being maintained over periods of millions of years is unlikely.

EFFECTS OF HIGH GROUND ACCELERATIONS

The effects of high ground accelerations from catastrophic seismic events has been given little consideration in the role of detachment faulting. Large earthquakes can generate both horizontal and vertical ground accelerations significantly greater than 1g. These seismic forces would have several effects: 1) they would cause fracturing of the rock material, thus reducing the restraining forces due to cohesion in the upper-plate; 2) they would assist upper-plate movement by providing laterally directed seismic forces; and 3) they would reduce the frictional forces by providing vertically directed components of seismic ground accelerations that would act in opposition to gravity. Under these conditions upper-plate movement would occur very rapidly.

To initiate detachment faulting the earthquakes would have to have been much larger and frequent than modern earthquakes. Earthquake generated upper-plate movement would be similar to the movement of objects that vibrate down a very slightly sloping board surface when it is smoothed with a vibratory sander.

It is clear that during Tertiary detachment faulting, an unparalleled amount of seismic energy was released due to volcanism, rapid basement warping and other forms of faulting. In fact, we have seen that cessation of detachment faulting occurred during a transition to a much lower seismically active period. This shows the clear relationship between detachment faulting and intense periods of seismic activity.

It is also interesting to note that in many ranges, the detachment surface occurs only at the contact between Tertiary rocks and the crystalline basement material. This suggests a plane of low shear strength at the contact, which indicates that movement probably occurred directly after deposition of the upper-plate, before cohesion to the lower-plate could occur and not after millions of years had passed.

EXAMPLES OF CATASTROPHIC DETACHMENT FAULTING

Heart Mountain Detachment

Heart Mountain is located in the northwest corner of the state of Wyoming. Dake (1918) was the first to recognize a low-angle (as low as 2#) fault at the base of Heart Mountain, which he identified as an overthrust. William G. Pierce, who has worked in the Heart Mountain region since the mid 1930's, reinterpreted this fault in 1957 as a "detachment thrust" which had broken loose along a basal shear plane and moved over long distances probably by gravity gliding. The area of sliding encompasses over 3400 square kilometers with a break-away zone of 105 kilometers in length. The upper-plate broke up into over 50 blocks which moved southeast over distances ranging up to 50 kilometers. The largest upper-plate block is over 8 kilometers wide. Extensive study in this area later led Pierce (1979) to conclude that movement was a rapid event related to "cataclysmic" phenomena. Cataclysmic implies that movement would have occurred within a time frame of several days or hours, or possibly as short as several minutes.

Pierce proposed that upper-plate movement was initiated by a catastrophic earthquake with vertical ground accelerations approaching 1g, which caused separation and gravity assisted downslope sliding of the upper-plate carbonate material. Rapid movement is supported by the presence of slide generated carbonate breccia (calci-breccia) injected as clastic dikes into the base of several of the detachment blocks. The injection of the dikes could only occur as a result of rapid lithostatic loading of the thick volcanic cover (Wapiti Formation) which encases many of the detached blocks. The calci-breccia material also occurs along the surface of the detachment ramp below the detached blocks and below the Wapiti Formation where it was deposited directly on unroofed sections of the detachment ramp. This clearly indicates rapid deposition of the Wapiti Formation soon after upper-plate movement, before erosion of the exposed calci-breccia on the detachment ramp could take place.

This author asserts that the initiation of volcanism and the earthquake that induced upper-plate movement were related events. This implies that the entire sequence of events probably occurred within several days. Field relationships also indicate that a conglomerate deposit developed in the time frame between movement and accumulation of the Wapiti Formation. This indicates that very rapid erosional and depositional processes were in operation during these events.

Turnagain Heights Landslide

On March 27, 1964, an earthquake estimated as high as 8.75 Richter magnitude rocked northern Alaska. Over 50,000 square miles of Alaska was tilted at new attitudes as a result of dynamically induced subsidence (Hansen, 1975; Hansen et al., 1966). The quake caused thousands of avalanches and rock slides. The most disastrous effects were in the upscale residential development of Turnagain Heights. The damages were caused by two landslides which merged and engulfed a total area of 130 acres within a period of less than 2 minutes. The slide moved seaward with a maximum lateral slippage estimated at two-thirds of a kilometer down a failure slope of 2.2# (Voight, 1973). The slide took place retrogressively starting at an unrestrained bluff face and failed landward with a headward regression of approximately 400 meters. The landslide was broken into numerous half-graben blocks which exhibited both rotational and translational movement. Separation occurred along a low shear strength clay layer.

Many of the upper-plate features observed at Turnagain Heights are identical to features observed in Tertiary detachment terrane. The most obvious are the development of rotated half-graben blocks, curved upper-plate fault surfaces which merge into the basal detachment surface, and upper-plate distention. The Turnagain Heights landslide is one of many examples of large catastrophic failures initiated by seismic activity. Most importantly, this landslide has established a connection between catastrophic seismic events and gravity sliding down very low sloping detachment surfaces, similar to those observed in the southwest United States.

The example of Heart Mountain has also shown the connection between ancient detachment faulting, volcanism, and earthquake activity. A dramatic increase in the rates of erosional and

depositional processes has also been demonstrated by this example.

CONCLUSIONS

The resolution of the movement problem along low-angle detachment faults lies in the consideration of the strong and frequent seismic events which were occurring contemporaneous with upper-plate movement. The effects of the seismic energy release would provide an additional driving force to overcome the restraining forces against movement due to friction and cohesion and would lessen the effects of friction by countering vertical components of gravitational acceleration with vertical components of seismic ground acceleration. Earthquake induced landslides are common events which occur almost daily and on a significantly larger scale during ancient past. This has been demonstrated by the examples of Heart Mountain and Turnagain Heights.

The Tertiary period within the southwestern United States was a time of colossal release of tectonic and seismic energy. This was caused by a very high heat flow rate which resulted in basement warping, explosive volcanism, and rapid erosion and sedimentation as the mountains rose out of the water. Basement warping and volcanism would also have been accompanied by large and frequent earthquakes. This allowed for an immense amount of geologic work to be accomplished over a very short period of time. The character of the sedimentary rocks within this region is also clear testimony to the cataclysmic events which occurred during the Tertiary period. The existence of interbedded sediments and volcanic rocks is evidence for rapid continuous deposition in a hot deep body of water. This indicates hydrothermal mineralization was also ongoing at this time.

Under uniformitarian conditions, the energy released during the Tertiary period is spread out over millions of years with geologic events separated by large gaps of time. This geologic environment is relatively docile and innocuous and is not much different from what we see today. Sufficient geologic power is not available to accomplish the work needed to account for the highly energetic geologic events of the Tertiary period. However, if the Tertiary period were only a few hundred or thousands of years long, the geologic power to do work would have been dramatically greater. Under these conditions, the geologic events are closely spaced in time and have a direct cause and effect relationship with one another, being individual interrelated parts of one overall geologic phenomena. Also, the power available to do work is at a level necessary to accomplish detachment faulting and related catastrophic events.

Rapid mountain building and vast quantities of turbulent hot water were the primary agents in the geologic development of this region. This is clearly indicative of the latter stages of Noah's flood when the land surface emerged from the flood waters. This event would have required tremendous amounts of energy to accomplish and would have been accompanied by explosive volcanism and violent earthquakes beyond modern day comparison. The seismic generated forces from this event would have been sufficient to cause sliding on the scale of Heart Mountain and the detachment terrane within the southwestern United States.

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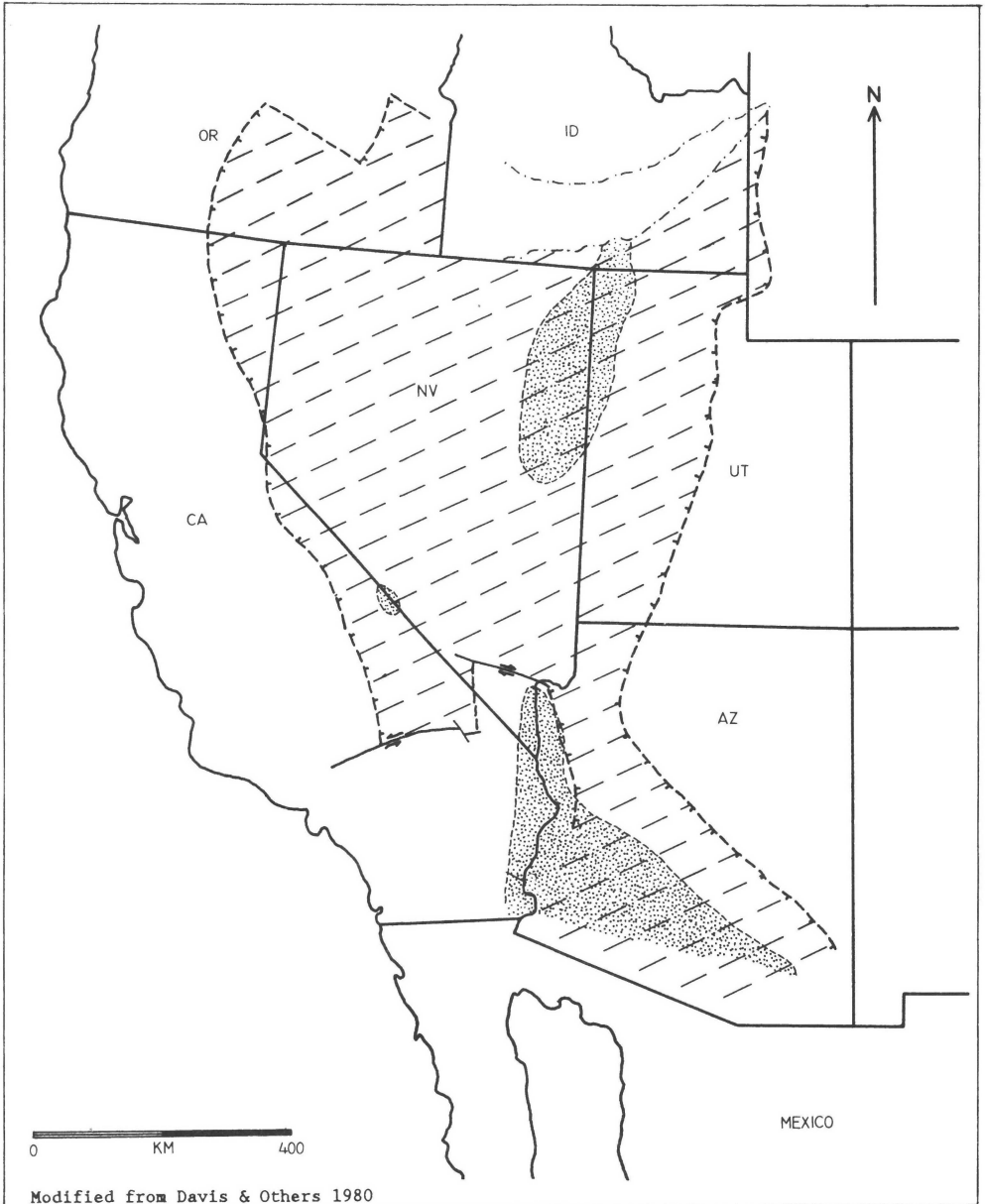


Figure 1

Map of Western United States Showing Region of Tertiary Extensional Tectonism (indicated by diagonal pattern). Stippled pattern indicates areas affected by detachment faulting.

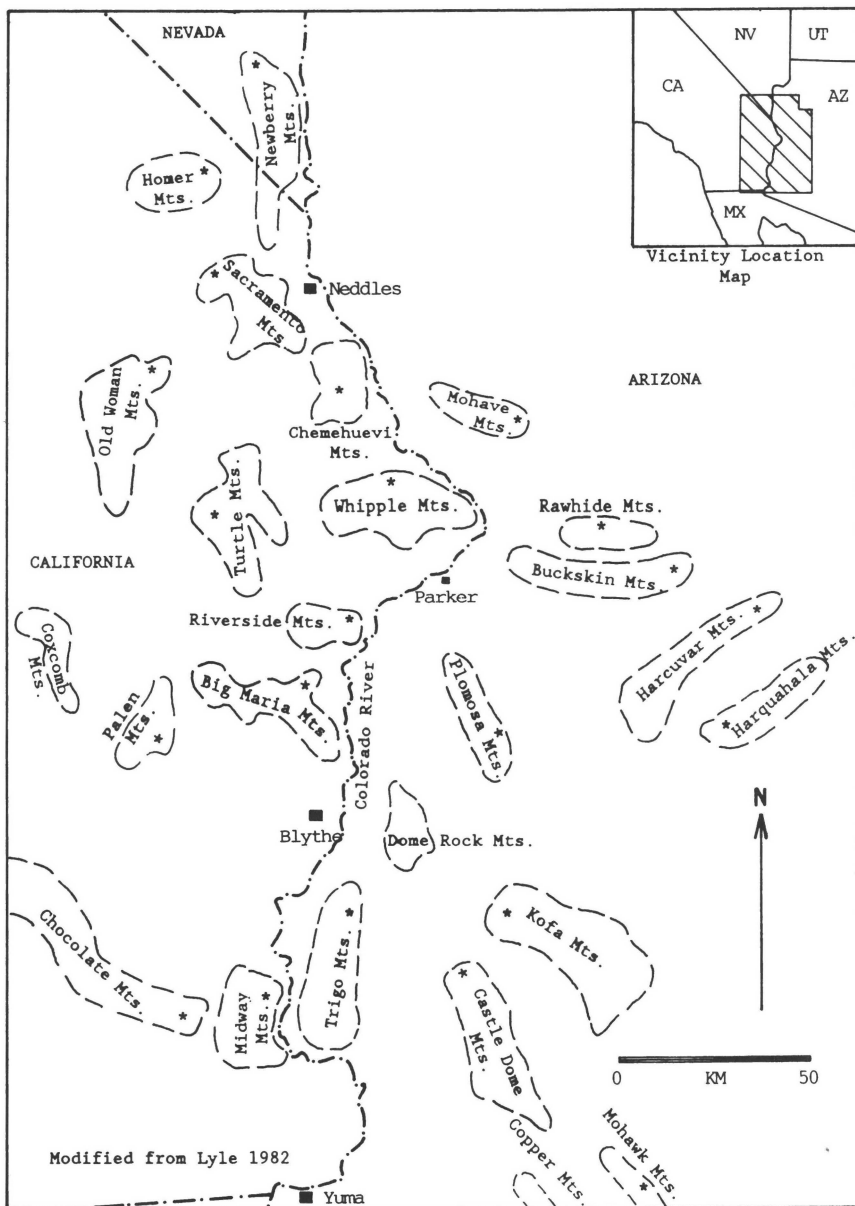


Figure 2

Index Map of Mountain Ranges in Detachment Terrane of the Colorado River Borderland. (* - indicates those ranges where a detachment fault has been recognized)

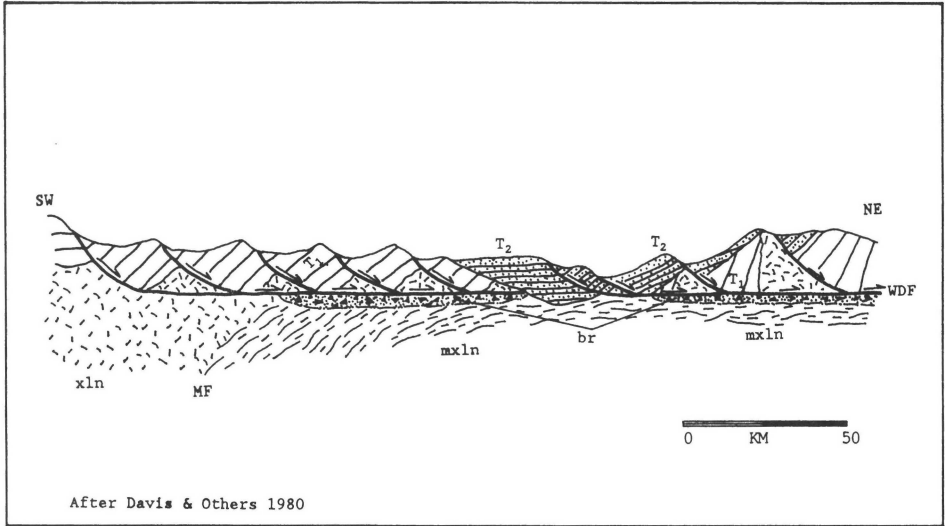


Figure 3

Diagrammatic Cross-section Showing Two Phases of Rotational (listric) Normal Faulting Associated with Low-angle Detachment Faulting Along the Whipple Detachment Fault (WDF), Whipple Mountains, Arizona. Upper-plate movement was toward the northeast. Inclined bedding has resulted from northeast rotation of the upper-plate half-graben blocks. Note the growth nature of the faults at the northeast side of the section indicating that upper-plate movement and deposition were contemporaneous. T₁ = Gene Canyon sedimentary and volcanic rocks; T₂ = Copper Basin sedimentary and volcanic rocks; MF = mylonitic front; xln = intrusive rocks; mxln = mylonitic equivalents of xln; br = tectonic breccia.

DISCUSSION

The geologic evidence for detachment faults is compelling and needs to be explained by current tectonic models. Mr. Rugg has shown why uniformitarian tectonic models fail to explain detachment-faulted terranes. Catastrophic tectonic models are needed. The enormous size of the detachment terranes of southeastern California and western Arizona argue for a regional catastrophic cause. The analogy of detachment faults to the Turnagain Heights Landslide (Alaska, 1964) makes catastrophic detachment faulting very believable. We need small-scale modern examples to help us reason in the colossal scale required by the evidence. The author is to be commended for his valuable addition to creationist research.

Steven A. Austin, Ph.D.
Santee, California

The arguments provided by Mr. Rugg do not adequately support his conclusions. The main conclusion is that the detachment faults in the southwestern U.S. are evidence for a short and catastrophic Tertiary period which characterized the latter stages of Noah's Flood.

The author reasons that these detachment faults resulted from frequent earthquakes (of a magnitude larger than we observe today) which were associated with explosive volcanos composed of rhyolite and andesite. Repeated tremors would cause large blocks of earth to slide along a fault plane.

Here are some difficulties with such reasoning:

1. In the Tertiary strata of S.W. United States there are numerous examples of non-explosive, quiet lava flows composed of rhyolite and andesite which are far from any volcano, while in the same region there are many examples of highly explosive volcanos composed of basalt.
2. Most earthquakes, and the largest earthquakes in the world today, are related to fault movement, not volcanos.
3. Detachment faults come in many sizes and shapes and are the result of numerous factors, only one of which is earthquakes.
4. Much of the Tertiary strata found throughout the world is characterized by a quiet, non-catastrophic environment. This is much different than the author's Tertiary model for S.W. United States.
5. To cause such large detachment faults, the author postulates much larger volcano-related earthquakes than seismologists have recorded in recent history.

Uniformitarianism says that the present is a key to the past. Its principles set the guidelines for geologic research. Mr. Rugg seems to waiver between uniformitarian principles and his own guidelines, whichever suit his purpose. Claiming that "explosive volcanism and violent earthquakes beyond modern day comparison" isn't playing by the rules and most geologists won't accept that kind of speculation as convincing evidence.

Kirk W. McCabe, M.S.
Pittsburgh, Pennsylvania

Mr. Rugg has presented an interesting hypothesis concerning the origin of detachment faulting. However, he seems to bump the two very different types of detachment faulting into the same category. The extensional type of detachment faulting shown in figure 3, as a relatively newly identified phenomenon. In this type of detachment faulting, older rocks are not moved on top of younger strata. In the previously identified style, compressive forces are required to explain the crustal shortening observed, since the rocks are piled upon top of each other rather than being spread out.

It would also be nice if Mr. Rugg had presented detailed calculations that reasonable seismic energy released could provide the mechanical energy necessary to initiate movement.

Glenn R. Morton, M.S.
Dallas, Texas

CLOSURE

Mr. McCabe has erroneously characterized the scope of my model for detachment faulting in the southwestern United States by implying that the sole seismic energy source for initiating upper-plate movement is volcanism. A proper reading of the paper clearly indicates that seismicity from volcanism is only one component of an intensely energetic tectonic phase. Other events occurring at this time were extensive dike emplacement, high heat flow and several thousands of feet of basement warping. The sum of these events would have undoubtedly been accompanied by an immense release of seismic energy by both magma displacement and faulting. I would also like to point out that this region is cut by a multitude of high-angle Tertiary faults.

Although "much" of the worldwide Tertiary strata may apparently indicate a "quiet, non-catastrophic environment", much of the strata is also clearly indicative of a catastrophic environment. Although I cannot take the space here to expound on this, I will say that the rock record in the southwestern United States, of which my paper was limited, is clearly indicative of highly energetic catastrophic processes.

I hope I made no misrepresentations; my paper was not intended to be a standard uniformitarian exegesis. Therefore, I thought I was not required to follow its rules. Mr. McCabe seems to believe that uniformitarianism is a scientific fact as indicated by his statement that "Its principles set the guidelines for geologic research". Uniformitarianism is only one theory used to interpret the body of geologic data. Catastrophism is another theory used to do the same. I wasn't there to see it happen and neither was Mr. McCabe.

It is correct that detachment terrane in the southwestern United States is of extensional origin which is dissimilar to the compressional origin of overthrust faults. However, many detachment faults were previously identified as overthrust faults because of their location and similar fault configuration. This was the case for the Heart Mountain detachment which William G. Pierce has shown to have been a cataclysmic gravity slide unrelated to compressional tectonics.

It should be noted that due to the similarity in fault configuration (nearly horizontal fault surface) between extensional detachment faults and overthrusts, the mechanical problems associated with upper-plate movement in both cases is nearly identical. The difference being the type forces required to initiate and maintain movement.

Scott H. Rugg, M.S.

