The pre-Flood/Flood Boundary: As Defined in Grand Canyon, Arizona and eastern Mojave Desert, California

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Abstract

The singular events which occurred at the initiation of the Flood should have produced a geologic signature with at least five characteristics: (a) a mechanical-erosional discontinuity (ED) identified by regional structural analysis—probably the most significant unconformity in any given area; (b) a time or age discontinuity (AD) identified by coarse sediments above the erosional unconformity containing lithified fragments of various sedimentary units found below the unconfomrity; (c) a tectonic discontinuity (TD), found at the erosional unconformity, distinguished by substantial regional tectonic disruption, especially at pre-Flood continental margins; (d) a sedimentary discontinuity (SD) consisting of a thick, fining-upward, clastic-to-chemical strata megasequence of regional to inter-regional extent defined at its based by a significant onlap unconformity; (e) a paleontological discontinuity (PD) marked by an increase in abundance of fossils and the first appearance of abundant plant, animal, and/or fungal fossils.

In Grand Canyon of Arizona one of the most significant regional unconformities (ED) is found at or near the top of the Chuar Group. Associated with the unconformity is the Sixtymile Formation—a tectonic-sedimentary unit dominated by breccia with large clasts (TD) from the formations below it (AD). The Sixtymile Formation occurs at the bottom of a thick, regionally extensive series of strata called the Sauk Sequence, consisting of the fining-upward clastics, capped by carbonates (SD). Only low-abundance microfossils are known below the unconformity, whereas undisputed animal fossils occur only above the Sixtymile Formation, and there in great abundance (PD). We believe, therefore, that the Sixtymile Formation is the oldest preserved Flood deposit in Grand Canyon of Arizona.

In the eastern Mojave Desert region of California, the Kingston Peak Formation is a very thick, regionally extensive clastic unit containing gigantic breccia clasts (TD) from the formations below it (AD). Associated with the formation is one of the region's most prominent unconformities (ED). The Kingston Peak Formation is also the lowermost of a very thick, regionally extensive, transgressive, fining-upward, clastic-to-carbonate megasequence (SD) known as the Sauk Sequence. Only low-abundance microfossils are known from the Kingston Peak Formation and below, whereas common animal fossils are only found in rocks above the formation (PD). We believe, therefore, that the Kingston Peak Formation signals the beginning of the Flood in the Mojave region of California and should be correlated with the Sixtymile Formation of Grand Canyon or Arizona.

Keywords

Flood Model, Pre-Flood/Flood Boundary, Sedimentation, Sedimentary Rocks, Strata, Stratigraphy, Time, Tectonics, Erosion, Paleontology, Fossils, Discontinuity, Unconformity, Southwestern United States, Grand Canyon, Mojave Desert, Precambrian, Cambrian, Paleozoic, Megasequence, Continental Margin, Ocean Flood, Submarine Megaslide, Gravitational Collapse, Megabreccia, Megaclast, Diamictite

Introduction

Broad, theoretical studies are common in creationist geology (for example, Nelson, 1931; Price, 1923; Whitcomb & Morris, 1961). Theoretical studies are important, but they need to be substantially buttressed with empirical studies. In the process of applying theoretical concepts to actual data, poor theories can be rejected and better theories can be improved. The creationist literature has too few empirical studies to test the proposed theories. A general example of this phenomenon arises with the definition of the pre-Flood/Flood boundary in the stratigraphic column. As reviewed by Austin & Wise (in prep.), a number of (theoretical) pre-Flood/

Flood boundary definitions have been introduced in creationist literature. Each definition fails when applied to actual stratigraphic sequences. Some of the definitions are too ill-defined to be applicable to any geologic section; others, though successful in many localities, fail to define the boundary everywhere.

Revisions and additions to the previous criteria are proposed by Austin & Wise (in prep.). This paper will review those criteria, discuss their applicability to the strata in Mojave Desert, California and Grand Canyon, Arizona, and, finally, propose the potential applicability of these criteria worldwide.

Suggested pre-Flood/Flood Boundary Criteria

According to Austin & Wise (in prep.) the pre-Flood/Flood boundary should be associated with five geologic discontinuities. The five criteria are briefly summarized as follows:

1. **A Mechanical-Erosional Discontinuity (ED).** Energized by global tectonic activity, the early Flood waters may have caused some of the most substantial mechanical erosion in earth history. As a result, when seeking the pre-Flood/Flood boundary in a particular stratigraphic section, regional structural analysis should be undertaken to identify the most significant regional, mechanical-erosional unconformities. The pre-Flood/Flood boundary is likely to correspond to the most substantial (or one of the most substantial) of these unconformities.
2. **A Time or Age Discontinuity (AD).** At any moment in the Flood, pre-Flood sediments will have had more than two orders of magnitude more time for lithification than any sediments formed earlier in the Flood. Among Flood-generated conglomerates, those containing clasts of pre-Flood sediments would then be expected to be more common, thicker, of broader areal extent, and/or coarser than those containing clasts of Flood-generated sediments. Because later Flood deposition would bury pre-Flood source rocks, conglomerates with pre-Flood clasts are more likely to have been produced very early in Flood deposition in a given area. As a result, when seeking the pre-Flood/Flood boundary in a particular stratigraphic section, one should identify the conglomerates with clasts of underlying sedimentary units. Those conglomeratic units associated with the dominant mechanical-erosional unconformities in a region are likely candidates for the oldest preserved deposits of the Flood in that section.
3. **A Tectonic Discontinuity (TD).** The unparalleled magnitude of tectonism in the first moments of the Flood should leave a distinctive tectonic signature in many places across the planet. Furthermore, the rapid plate motion suggested by Austin et al.'s Flood model (1994) may leave the early Flood tectonism uniquely associated with few volcanics. As a result, when seeking the pre-Flood/Flood boundary in a particular stratigraphic section, one should search for evidences of tectonic disturbance in the region (for example, rapid changes in sedimentary thickness, conglomerates, breccias, megaclasts, megaslides, and detachment faulting). The dominant mechanical-erosional unconformities of a region which are associated with the greatest amount of tectonic disturbance are likely candidates for the pre-Flood/Flood boundary in that region.
4. **A Sedimentary Discontinuity (SD).** As the waters deepened at any given locality, earliest Flood erosion gave way to deposition. Waning energies would be expected to drop a megasequence of fining-upward clastics capped by chemical sediments (TST to HST in sequence stratigraphic terms). Given the unparalleled energies and the global extent of these early Flood waters, regional studies should reveal a transgressive megasequence as the largest such sequence in the stratigraphic column, and should contain sedimentary units identifiable regionally to inter-regionally. As a result, when seeking the pre-Flood/Flood boundary in a particular stratigraphic section, one should identify sedimentary sequences on a local and regional scale. The dominant, fining-upward, transgressive, clastic-to-chemical sedimentary megasequence setting atop a dominant, mechanical-erosional onlap unconformity is likely to represent the first sediments of the Flood in that region.
5. **A Paleontological Discontinuity (PD).** Under normal taphonomic conditions, probability of fossilization is proportional to rate of sedimentation. Compared to the rapid deposition during the Flood. The slow deposition in the pre-Flood world would have made fossilization of plant, animal, and fungal remains unlikely. Also, it is very likely that the initial erosion of the Flood destroyed or reworked virtually all of the fossils which were present in pre-Flood sediments. Consequently, below the pre-Flood/Flood boundary, sediments capable of preserving fossils might, at best, contain only traces of the most abundant and easily fossilized life forms—bacterial, algal, and protist fossils—and probably in very low abundance. Plant, animal, and fungal fossils might be expected to be found in high abundance only above the pre-Flood/Flood boundary. As a result, when seeking the pre-Flood/Flood boundary in a particular stratigraphic section, one should study the regional paleontology and note the abundance and taxonomic composition of fossils in each of the units. The dominant

mechanical-erosional unconformity which has at most uncommon fossils below and abundant plant, animal, and fungal fossil only above, is likely to represent the initial erosional event of the Flood in that region.

Rather than relying upon one criterion, the greatest strength of this analysis comes when all the criteria are used simultaneously on a particular stratigraphic section. This means that defining the pre-Flood/Flood boundary only becomes possible with a stratigraphic, structural, and paleontological analysis of the region in which the section is found. The dominant, regionally defined, mechanical, erosional unconformity (a) underlying the clastic unit which incorporates the highest proposal of lithified clasts from below the boundary, (b) associated with the greatest amount of tectonic disturbance, (c) directly underlying the most dominant clastic-to-chemical sedimentary megasequence with regionally deposited sediments, and (d) underlain by low-abundance fossils of microorganisms, and overlain by high-abundance fossils of macroorganisms, can be confidently defined as the pre-Flood/Flood boundary in that region. If the geology of a region does not permit the use of any one or more of these criteria, the strength of the conclusion is lessened. If a boundary is well established in one region, correlation with other regions nearby should add strength to tentative boundary identifications in nearby areas.

Applied pre-Flood/Flood Boundary Criteria

Grand Canyon

At least 13,600 feet of Precambrian (Ford, 1990; Hendricks & Stevenson, 1990) and 4,000 feet of Paleozoic (Austin 1994a, 1994b) strata are found in Grand Canyon. Most interformational contacts are gradational, intertonguing, or at worst, paraconformable (Austin). Of the ten boundaries with direct evidence of mechanical erosion, seven are not likely to have cut any more than 500 feet into underlying formations (Austin & Wise, in prep.). The three remaining unconformities occur in association with the Precambrian and Cambrian strata of Figure 1. In Grand Canyon the sub-Unkar Group unconformity (Figure 1) has less than 150 feet of local relief (Hendricks & Stevenson). The actual depth of erosion must have been at least an order of magnitude greater. On the sub-Sixtymile unconformity, up to 230 feet of erosion is indicated by lithologic studies (Elston, 1979; Ford). The limited exposure of the Sixtymile Formation (invisible at the scale of Figure 1), and the great thickness of the underlying Kwangunt Formation, make determination of actual depth of erosion impossible. The sub-Tapeats unconformity ("The Great Unconformity" of Figure 1) is observed to have up to 300 feet of local relief (Austin). It also locally cross-cuts every sedimentary formation of the underlying 13,600 feet of Precambrian strata, and even the crystalline basement below. The most significant, direct, regional evidence of mechanical erosion in Grand Canyon is associated with The Great Unconformity. It is also possible that the sub-Sixtymile and the sub-Unkar unconformities could have been associated with comparable mechanical erosion.

In the entire Grand Canyon sequence there are just four stratigraphic horizons associated with significant evidence of a time discontinuity. The sub-Unkar unconformity separates high-temperature-generated metamorphic and igneous rocks below from sedimentary rocks above. The crystalline granitic rocks seem to have had time to cool before the unconformity was formed and subsequent deposition began. At the base of the Surprise Canyon Formation is a pebble-to-cobble, locally boulder, conglomerate with clasts of chert and limestone from the Redwall Limestone below it (Beus, 1990). The breccia of the Sixtymile Formation contains clasts of the underlying Kwagunt Formation of the Chuar Group, some of which are 130 feet in length (Elston, 1979; Ford, 1990). The base of the Tapeats Sandstone locally contains clasts eroded from the Shinumo Quartzite (a formation of the Unkar Group) which are up to 15 feet in diameter (Austin 1994a, 1994b). The dominant mechanical-erosional unconformities associated with the most substantial evidence of time discontinuity are the sub-Unkar, sub-Sixtymile, and the sub-Tapeats unconformities.

Thus far, evidence of four tectonic intervals can be found in the Grand Canyon sequence: (a) at least 200 feet of fault displacement during deposition of the Shinumo Quartzite to account for convolute bedding (Austin 1994a, 1994b), and variations in formation thickness (Sears, 1990); (b) at least 650 feet of fault displacement during deposition of the Nankoweap Formation to explain depositional features (Ford, 1990); (c) approximately 2,300 feet of fault displacement during the Cretaceous to explain the folding and faulting of pre-Cretaceous formations (Sears); and (d) up to 20,000 feet (Sears) of fault displacement after the deposition of the Chuar Group sediments to account for deformation of all Unkar and Chuar formations (Grand Canyon Supergroup in Figure 1), and possibly to explain the breccias and large (130 foot) clasts of the Sixtymile Formation (Elston, 1979; Elston & McKee, 1982). It may be that the uppermost Precambrian event also generated many of the major faults in Grand Canyon, including those utilized in the Cretaceous tectonic event. The most profound tectonic discontinuity in the Grand Canyon strata sequence is associated with the sub-Sixtymile and/or the sub-Tapeats unconformities.

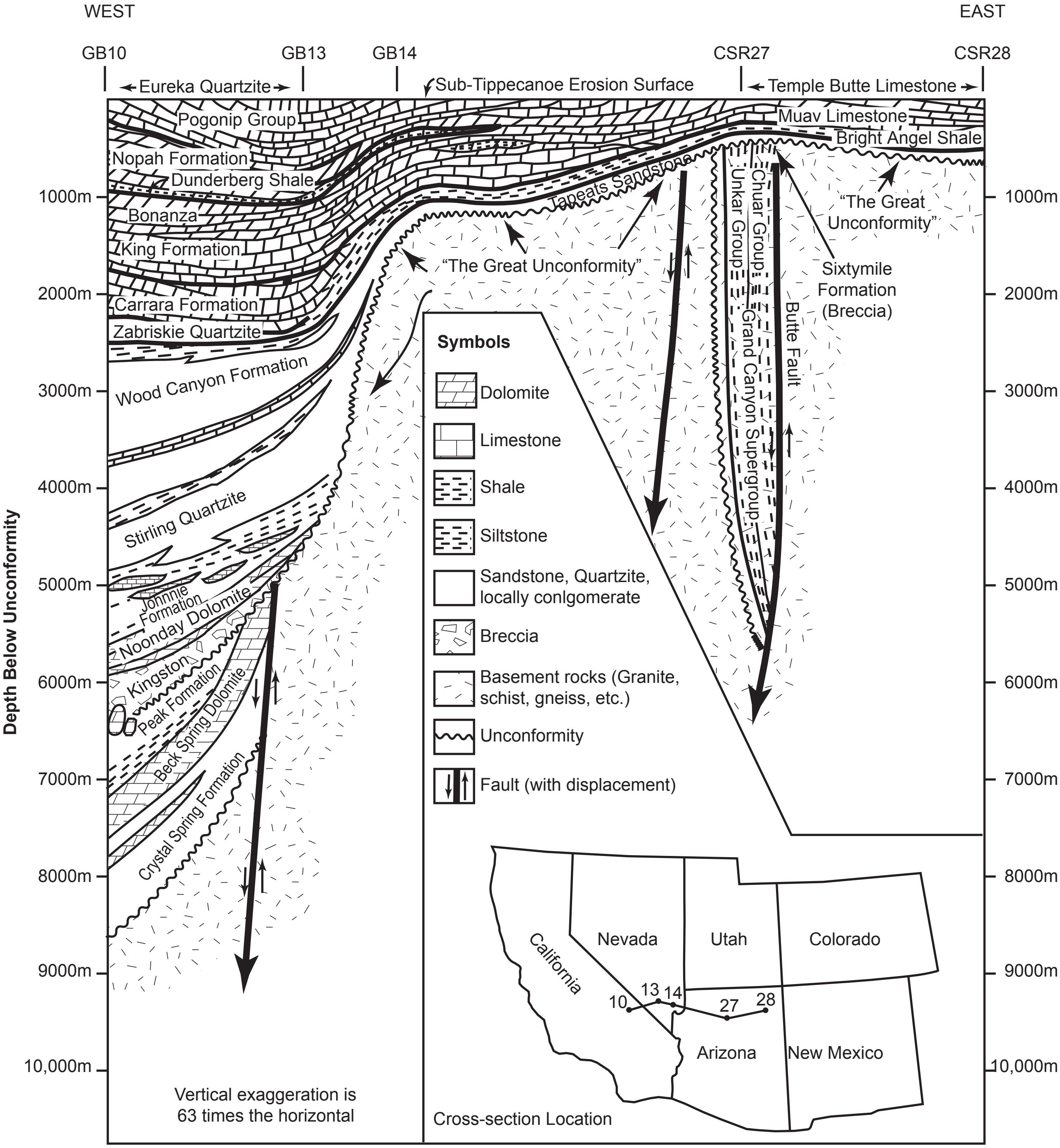

Figure 1. Paleogeologic cross-section of the southwestern United States showing the stratigraphic relationships of the uppermost Precambrian and the lowest Paleozoic strata. The cross-section indicates the original continuity of strata of the Sauk Sequence (for example, the unconformity-bounded Kingston Peak Formation through Pogonip Group). The Sauk Sequence is separated from the pre-Sauk strata by an onlap unconformity of regional extent (The Great Unconformity). The pre-Sauk strata sequence in the eastern Mojave Desert (California) is the Crystal Spring and Beck Spring Formations, and some of the lower beds of the Kingston Peak Formations. The pre-Sauk strata sequence in Grand Canyon (Arizona) is the Grand Canyon Supergroup (the formations of the Unkar through Chuar Groups). The cross-section shows the sub-Tippecaneo erosion surface at the top as a level datum, and the diagram, therefore, emphasizes the enormous topographic relief on the sub-Sauk onlap unconformity (The Great Unconformity). Cross-cutting, faulting, tilting, and megaclasts in the diagram provide evidence of tremendous tectonic disruption of pre-Sauk rocks beneath the unconformity. (The diagram was created primarily from generalized COSUNA strata columns published by the American Association of Petroleum Geologists.)

Most of the unconformities of Grand Canyon lack a complete fining-upward megasequence. Above the sub-Unkar nonconformity is found the Bass Limestone and the Hakatai Shale. Above the Hakatai/Shinumo unconformity is the fining-upward sequence of Shinumo Quartzite and Dox Formation. Above the Unkar/Nankoweap unconformity are the clastics of the Nankoweap Formation, and above the Nankoweap/Chuar unconformity are the fine clastics and carbonates of the Galeros and Kwangunt Formations. Above the sub-Sixtymile unconformity, however, are the very coarse breccias of the Sixtymile Formation, followed by the Tapeats Sandstone, the Bright Angel Shale, the silty carbonates of the Muav Formation, and the thin-bedded carbonates of the unclassified dolomites. This fining-upward, clastic-to-carbonate megasequence (Figure 1) in the western Grand Canyon is over 2,000 feet thick, and its base represents a sedimentary discontinuity associated with the sub-Sixtymile unconformity where it is exposed and The Great Unconformity elsewhere. That fining-upward sequence has been referred to as the Sauk Sequence on the North American continent. The sequence sits on an onlap unconformity of continental scale.

The paleontology of the Unkar Group includes possible stromatolites (Ford & Breed, 1976; Hendricks & Stevenson, 1990), and possible cyanophyte microfossils (Ford & Breed, 1976). Fossils of the Chuar Group include possible stromatolites (Ford & Breed, 1973; Hendricks & Stevenson), *Chuaria*, a probable algae (Ford & Breed, 1973, 1976; Hendricks & Stevenson), microscope acritarchs (Hendricks & Stevenson), melanocyrillids (Bloeser, 1985), and probable cyanophytes (Ford & Breed, 1976; Pierce & Cloud, 1979). In the Upper Tapeats Sandstone, several types of trace fossils (Middleton and Elliott, 1990), evidence animal life. Typical Lower Paleozoic fossils are found in abundance in the Bright Angel Shale and above (Middleton & Elliott). The paleontological discontinuity of abundance occurs somewhere between the base of the Sixtymile Formation and the base of the Bright Angel Shale. The micro-/macro-fossil discontinuity is somewhere between the base of the Sixtymile Formation and the middle Tapeats Sandstone. Thus, the sub-Sixtymile unconformity and/or The Great Unconformity is associated with the paleontological discontinuity of abundance and micro-/macro-erosional discontinuity in the sequence.

Mojave Desert

The eastern Mojave Desert contains nearly 20,000 feet of Precambrian (Miller, Wright, & Troxel, 1981; Pierce & Cloud, 1979), and about 23,000 feet of Paleozoic (Norris & Webb, 1990) sediments. The Upper Precambrian to Lower Paleozoic strata are shown in Figure 1. Only four Lower Paleozoic or Precambrian inter-formational boundaries have substantial evidence of mechanical erosion: (a) the nonconformity below the Pahrump Group (Crystal Spring, Beck Spring, and Kingston Peak formations in Figure 1) cuts an unknown distance into crystalline rocks. Yet, because each of the three Pahrump Group formations (up to a total of 20,000 feet thickness) lies somewhere on crystalline basement (Austin & Wise, in prep.) it is likely that the unconformity surface has many thousands of feet of relief (Labotka & Albee, 1977); (b) the base of the Kingston Peak Formation is locally conformable with the underlying Beck Spring Dolomite (Labotka & Albee; Miller, 1985; Miller et al). Elsewhere, it crosscuts all the 7,000 or so feet of underlying sediments and an undetermined distance into the underlying crystalline rocks (Labotka & Albee; Miller, 1985; Miller et al.); (c) the mid-Kingston Peak unconformity has an observed relief of more than 115 m in 600 m lateral distance (Miller, 1985; 1987). Enclosed clasts of pre-Pahrump gneiss (Miller, 1985; 1987) imply it may cut through all of the nearly 8,500 feet of sediment stratigraphically below it; and (d) although the Noonday is occasionally conformable with the upper Kingston Peak Formation (Miller, 1985; Miller et al), it is usually an unconformity (Miller, 1985; 1987; Miller et al; Pierce & Cloud) with up to 300 m of observed relief (Cloud, Licari, Wright, & Troxel, 1969). It also crosscuts all the 10,000 or so feet of the Pahrump Group beneath as well as unknown distance into the crystalline rocks below (Miller, 1985; 1987). Any one of these unconformities—that below the Pahrump Group and those within, below, and above the Kingston Peak Formation—vie for the most substantial mechanical-erosional discontinuities in this section.

In Precambrian and Paleozoic strata of Mojave Desert, three substantial boulder conglomerates or breccias occur—each containing clasts of all underlying formations: (a) a conglomerate at the base of the Crystal Spring Formation (Hunt & Mabey, 1966); (b) a thick series of conglomerates and breccias in the Kingston Peak Formation (Cloud et al, 1969; Horodyski & Mankiewicz, 1990; Labotka & Albee, 1977; Miller, 1985: 1987; Miller et al, 1981; Stewart, 1970; Troxel, 1969; Walker, Klepacki, & Burchfield, 1986); and (c) a conglomerate or breccia in the basal portion of the Noonday Dolomite (Williams, Wright, & Troxel, 1956; Wright, Williams, & Troxel, 1984). Localized fault-associated lithification might account for some clasts—for example, Kingston Peak and Noonday Dolomite clasts, reported from the upper Kingston Peak (Miller, 1987) and the basal Noonday formations (Cloud et al; Wright et al). In contrast, the regionally distributed, thick deposits of the Kingston Peak Formation could not be entirely due to fault-associated lithification. The most substantial time discontinuities are associated with the Kingston Peak and sub-Pahrump unconformities.

Abrupt lateral changes in the thickness of the Kingston Peak Formation, and the vertical relief of the unconformity associated with it, are best explained by syndepositional faulting (Cloud et al., 1969; Miller, 1985, 1987; Miller et al, 1981). Megaclasts of lower formations up to 1,600 m long in the Kingston Peak Formation (Miller et al; Stewart, 1991; Troxel, McMackin, & Calzia, 1987; Troxel, Wright, Williams, & McMackin, 1984; Walker et al, 1986) and up to 15 m long in the basalt Noonday Dolomite (Cloud et al; Wright et al) also argue for syndepositional tectonism (Walker et al, 1986). The best evidence of pre-Cenozoic tectonic discontinuity is associated with the deposition of the Kingston Peak Formation and earliest Noonday Dolomite.

Separating crystalline from sedimentary rocks, the sub-Pahrump nonconformity represents a sedimentary discontinuity. The Crystal Spring Formation above that nonconformity is, broadly speaking, a fining-upward (conglomerate-sandstone-shale), clastic sequence. It is capped by a cherty dolomite (Hunt & Mabey, 1966), and the Beck Spring Dolomite. The breccia-dominated Kingston Peak Formation can similarly be seen as the lowermost and coarsest clastic unit in another regionally distributed (Palmer, 1971; Stewart, 1991) megasequence. This sequence (the Sauk Sequence) is terminated at its top by the carbonate-dominated Bonanza King Formation, Nopah Formation, and Pogonip Group (Figure 1). Whereas the Crystal Spring/Beck Spring megasequence is up to 6,500 feet thick (Miller et al, 1981), the Kingston-to-Pogonip megasequence exceeds 30,000 feet thickness in the western Mojave region (Miller et al; Norris & Webb, 1990; Pierce & Cloud, 1979). According to Stewart the Kingston Peak Formation and correlatives are the oldest deposits which are distributed in a manner similar to the Lower Paleozoic sediments. This would be expected if the Kingston Peak Formation is the lowest part of the same megasequence.

Stromatolites and microfossils are known from every formation from the Crystal Spring Formation through the Johnnie Formation ((Austin & Wise, in prep.). Macrofossils of Tommotian affinity have been reported from the Johnnie (Ford & Breed, 1973) and the Stirling (Pierce & Cloud, 1979). From the lower Wood Canyon Formation, Ediacaran (Horodyski, 1991) pteropod (Diehl, 1976), and trace fossils (Diehl; Prave, Fedo, & Cooper, 1991) are known. From the upper Wood Canyon upward, Lower Cambrian invertebrates are found in high abundance (Diehl; Mount, Hunt, Greene, & Dienger, 1991; Palmer, 1971; Stewart, 1970). The paleontological discontinuity in abundance appears to occur somewhere within the middle Wood Canyon Formation. With only one possible microfossil found between the sub-Noonday unconformity and the upper Johnnie Formation (in the lower Johnnie Formation [Pierce & Cloud, 1979]), and only a few reports of microfossils in the Kingston Peak Formation (Horodyski & Mankiewicz, 1990; Pierce & Cloud), preservability of body fossils has not been well demonstrated in that zone. As a result, the paleontological micro-/macro-fossil discontinuity can only be said to lie somewhere between the basal Kingston Peak and upper Johnnie Formations. Any of the unconformities associated with the Kingston Peak Formation would be within this micro-/macro-fossil discontinuity.

Combining all five pre-Flood/Flood boundary criteria, an intra-Kingston Peak unconformity is the most likely location for the pre-Flood/Flood boundary in the Mojave region. This would identify the Kingston Peak Formation as containing the oldest preserved sediments of the Flood in this area. This intra-Kingston Peak unconformity is associated with a profound time discontinuity, lies directly below the most substantial evidence of tectonic activity, and occurs at the base of the most substantial fining-upward megasequence. It is also one of the most significant mechanical-erosional unconformities in the region, and lies below the paleontological discontinuity of abundance and somewhere within the range of the micro-/macro-fossil transition.

Grand Canyon/Mojave Correlation

Several correlations between Grand Canyon and the eastern Mojave strengthen the proposed equivalence of the Kingston Peak and Sixtymile Formations (see Figure 1): (a) both stratigraphic columns are nonconformably lying atop gneisses, schists, and granitic intrusives; (b) two disabase sills in the Crystal Spring Formation of Mojave are positionally and mineralogically similar to two diabase sills in the Bass Limestone of Grand Canyon (Walker et al, 1986); (c) microfossils found in the Pahrump Group of Mojave are similar to microfossils found in the Chuar Group of Grand Canyon (Pierce & Cloud, 1979), especially the vasiform melanocyrillids in the Kwagunt Formation of Grand Canyon and the Beck Spring Dolomite of Mojave (Bloeser, 1985; Horodyski, 1987); (d) stromatolites similar to *Baicalia* and *Stratifera* are found in both the Galeros Formation of Grand Canyon (Ford & Breed, 1973) and the Beck Spring Dolomite of Mojave (Marian & Osborne, 1992); (e) The Sixtymile and Kingston Peak Formations both contain very coarse breccias with very large clasts of local provenance (Walker et al); (f) similar marine invertebrate fossils are found in the Paleozoic rocks (for example, *Cruziana* in the Tapeats Sandstone and

Bright Angel Shale of Grand Canyon and the Wood Canyon Formation and Zabriski Quartzite of Mojave (Prave et al, 1991); *Olenellus* and *Glossopleura* trilobites in the Bright Angel Shale of Grand Canyon, and upper Wood Canyon and Carrara Formations of Mojave (Mount, Hunt, Greene, & Dienger, 1991; Palmer, 1971); and (g) the Tapeats Sandstone of Grand Canyon is equivalent lithostratigraphically to the Wood Canyon Formation of Mojave (Fedo & Prave, 1991).

Conclusion and Discussion

It has been common to assign the pre-Flood/Flood boundary to the Precambrian/Cambrian boundary. In the eastern Mojave, where the Precambrian/Cambrian boundary is gradational and unassociated with an unconformity, these definitions fail to produce an unambiguous pre-Flood/Flood boundary. In contrast, the five criteria of (Austin and Wise, in prep.) will be sufficient to define the pre-Flood/Flood boundary worldwide.

Traditionally interpreted as a glacial deposit, we suggest that the Kingston Peak Formation be re-evaluated as a submarine landslide deposit. First, Cambrian paleomagnetics (Mount et al, 1991), Wood Canyon archaeocyathids (Mount et al, Stewart, 1970), Kingston Peak oncolites (Pierce & Cloud, 1979), oolites (Tucker, 1986), and carbonates (Labotka & Albee, 1977; Miller, 1985; Miller et al, 1981; Tucker) suggest a low-latitude, warm water, position for this area during the deposition of the Kingston Peak Formation. This is an improbable glacial environment. Second, faceted and striated boulders and possibly the lonestones claimed from the Kingston Peak Formation (Labotka & Albee; Miller; Miller et al) can be produced in conditions of catastrophic mass movement (Crowell, 1963; Schermerhorn, 1974). Third, pillow lavas (Labotka & Albee; Miller; Miller et al) and ripple marks throughout the formation (Miller; Troxel, 1967) indicate subaqueous deposition. Fourth, dish structures, inverse- to normal-graded beds, turbidites, flame structures, and convolute lamination indicate not just subaqueous, but also rapid deposition (Crowell; Miller; Miller et al; Troxel; Troxel et al, 1985; Walker et al., 1986). We believe that these features of the Kingston Peak Formation can be better explained as a submarine landslide deposit than as a glacial deposit.

The Kingston Peak Formation is only one of many Upper Precambrian diamictites thought to be glaciogenic. Commonly associated with low-latitude indicators (Miller, 1985, 1987 Schermerhorn, 1974) these deposits may also have to be re-evaluated as non-galciogenic. Being coarse conglomerates, they automatically represent a time discontinuity and substantial mechanical erosion. If a clastic sequence is above them, they are likely to define the base of a coarsening upward megasequence. Commonly deposited during tectonic disturbances (Miller, 1985; Schermerhorn), they seem to be associated with tectonic discontinuities. Typically found immediately below sediments containing Ediacaran organisms, they are likely to be associated with the micro-/macro-fossil paleontological discontinuity as well. We suspect upon re-evaluation that most of the Upper Precambrian diamictites will likely be understood to represent the first Flood sediments wherever they are found.

Based upon the sediment deposited atop the sub-Pahrump nonconformity in east Mojave (Austin & Wise, in press; Prave et al, 1991), the easternmost portion of Mojave near the California/Nevada border was the location of a substantial change in the dip of basement rocks. We suggest that the change in dip may represent the shelf break on the pre-Flood cratonic margin—with pre-Flood, basaltic ocean floor somewhere to the west, and pre-Flood shallow, continental shelf to the east (Figure 2, top diagram). We believe that the Kingston Peak Formation, which is only found to the west, and, thus, down the slope of this break, represents lithified shelf material which was disrupted and collapsed down that slope (Figure 2, bottom diagram). Olistostromes, turbidites, as well as common slump folds and soft-sediment deformation (Walker et al, 1986) seem to argue for rapid deposition by gravitational slumping on a sloping continental margin. Our proposal is that the disruption of pre-Flood sedimentary rocks occurred due to violent earthquake activity—probably that associated with the initiation of ocean plate subduction (see Austin et al, 1994). (Figure 2, bottom diagram). If this is so, we would expect to see the same phenomenon along most of the world's pre-Flood cratonic margin. If we are to interpret such strata as submarine megaslide deposits, then the linearity of Upper Precambrian diamictites of western North America (Miller, 1985; Stewart, 1991) may define the edge of the pre-Flood craton. We would suggest that worldwide application of the five criteria of Austin and Wise (in prep.) should permit an improvement in our understanding of pre-Flood geology and geography and earliest Flood dynamics.

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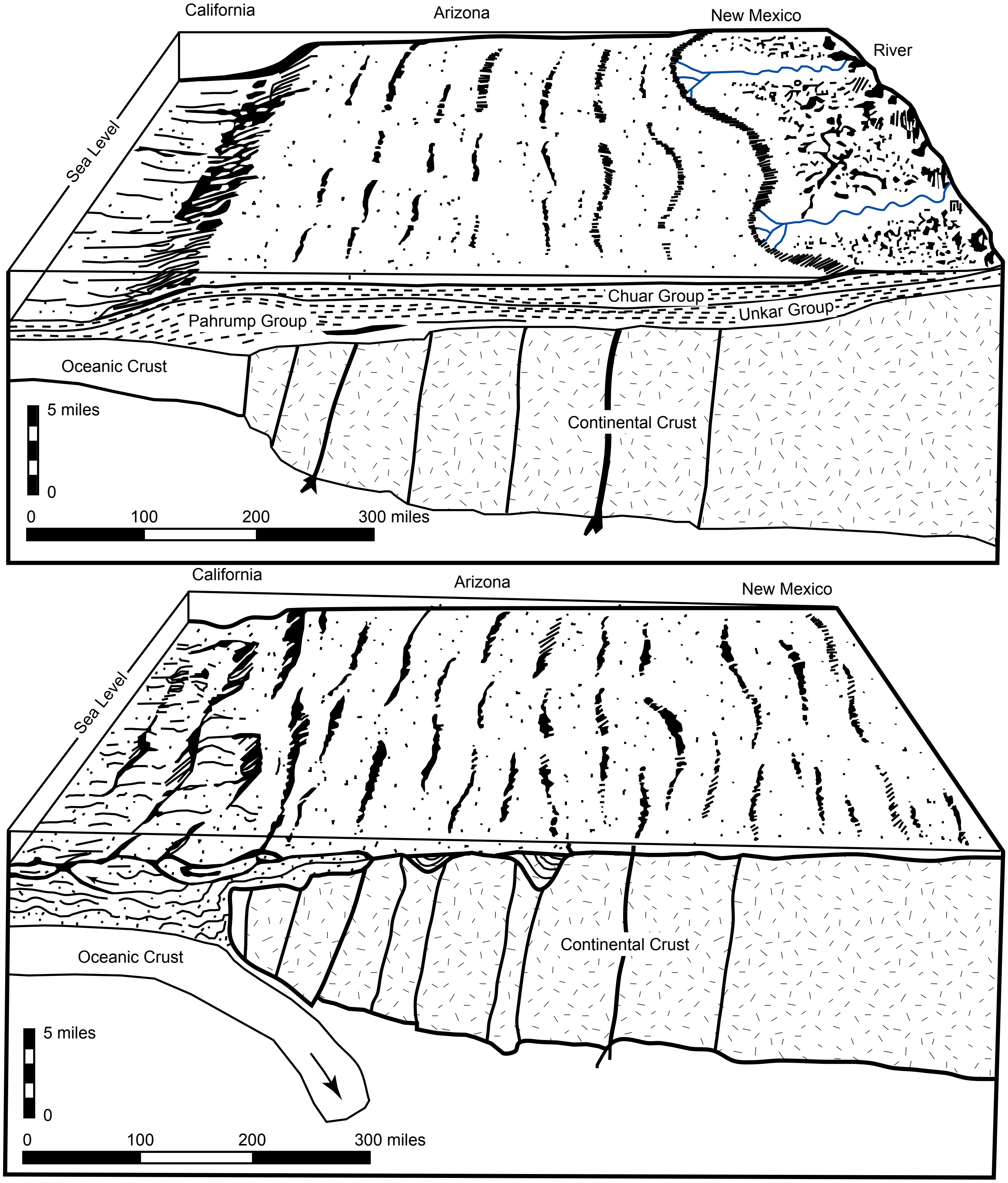

Figure 2. A tectonic-sedimentary model for the beginning of the Flood in the southwestern United States.
Top diagram: The continental margin the day before the Flood began suggesting how the ocean deepened westward. Thick pre-Flood sediments had accumulated on the continental margin.
Bottom diagram: Early in the Flood the continental margin was deformed in response to oceanic crust subduction. The oceanic crust in California was subducted causing the continental crust to be flexed, allowing Flood waters to invade the continent. The upper continental crust especially was in tension creating listric faults, rotated upper-crustal blocks (for example, Grand Canyon Supergroup), and the gravitationl collapse of the sedimentary strata on the continental margin (for example, the Kingston Peak Formation). The Kingston Peak and Sixtymile Formations are evidence of the initiation of the enormous tectonic event. With the invasion of the ocean, strata of the Sauk Sequence (Figure 1) were deposited over the disrupted continental margin.

Flood boundary within strata of the southwestern United States. Institute for Creation Research, Santee, California: ICR Technical Monograph.

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