The Geology of the Oklahoma Basement

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Abstract

The basement in Oklahoma consists of igneous rocks, mostly granitic, whose surface is a profound erosional discontinuity overlain by marine sediments. Basement deforming tectonism was active in the southern part of the state forming the Southern Oklahoma Aulacogen, which is commonly interpreted as a Cambrian rift. This feature contains thick sequences of bimodal igneous rocks with unusual sheet granites. The lithologic and erosional discontinuities that mark the transition from the igneous crust to overlying Paleozoic marine sediments probably represents the pre-Flood boundary, and the tectonism of the Southern Oklahoma Aulacogen may reflect activity at the onset of the Flood in the southern midcontinent.

Introduction

The success of creationist geology will depend on the integration of modern geological data, currently obscured by multiple layers of uniformitarian interpretation, into a framework consistent with biblical history. Progress has been slowed by the regrettable practice of prematurely building grand explanatory models absent sufficient data, and the need exists for a more measured approach. The task is challenging. Catastrophists are few, uniformitarians many. We must work against a flood of contrary interpretations, understanding that the uniformitarian paradigm provides a path of least resistance in assimilating and publishing new information. In addition to these obvious hurdles, creationists must subject themselves to more restrictive interpretive constraints (Reed and Froede, 1997). For example, vertical successions of strata must be integrated (in a short time frame); there is no luxury of millions of years of erosion or nondeposition to account for an apparent discontinuity inserted between two formations of quite different properties. An important initial consideration in effectively reworking geological data is the determination of an appropriate scale of study. I believe that work done on basinal to regional scale can provide optimum progress as long as the goal of interpretive continuity is maintained from one project to another (Reed, 2000; 2002c; 2003; 2004). This approach is applied here: to follow the data logically, this series will begin with the basement and work stratigraphically upwards to the present day surface for the state of Oklahoma.

In almost all of the state, the basement is covered by deformed sedimentary sequences that form the present day geologic provinces of Oklahoma (Figure 1). The thickest sedimentary sequences are offset by exposed basement at the juxtaposed Wichita Uplift and Anadarko Basin in Southwestern Oklahoma. The most complexly deformed strata are found in the southeastern Oklahoma Ouachita overthrust province. Northern Oklahoma's basement is covered by relatively thin undeformed sediments. In each province, the extent, direction, and timing of basement tectonics are a crucial influence on the overlying strata.

> Knowledge of the basement is fundamental to understanding the evolution and geological history of a region. The way the "cover" has interacted with its substrate, the basement, determines to a large degree how the geological processes of the Earth's surface and upper few kilometers of the crust unfold. Fluid flow through the upper crust (formation of petroleum reservoirs, ore deposits, regional-scale aquifers, etc.) is ultimately almost always tied to basement-cover interactions. (Gilbert, 2002, p. 31).

One advantage of studying Oklahoma geology is the large amount of published information available. Base-

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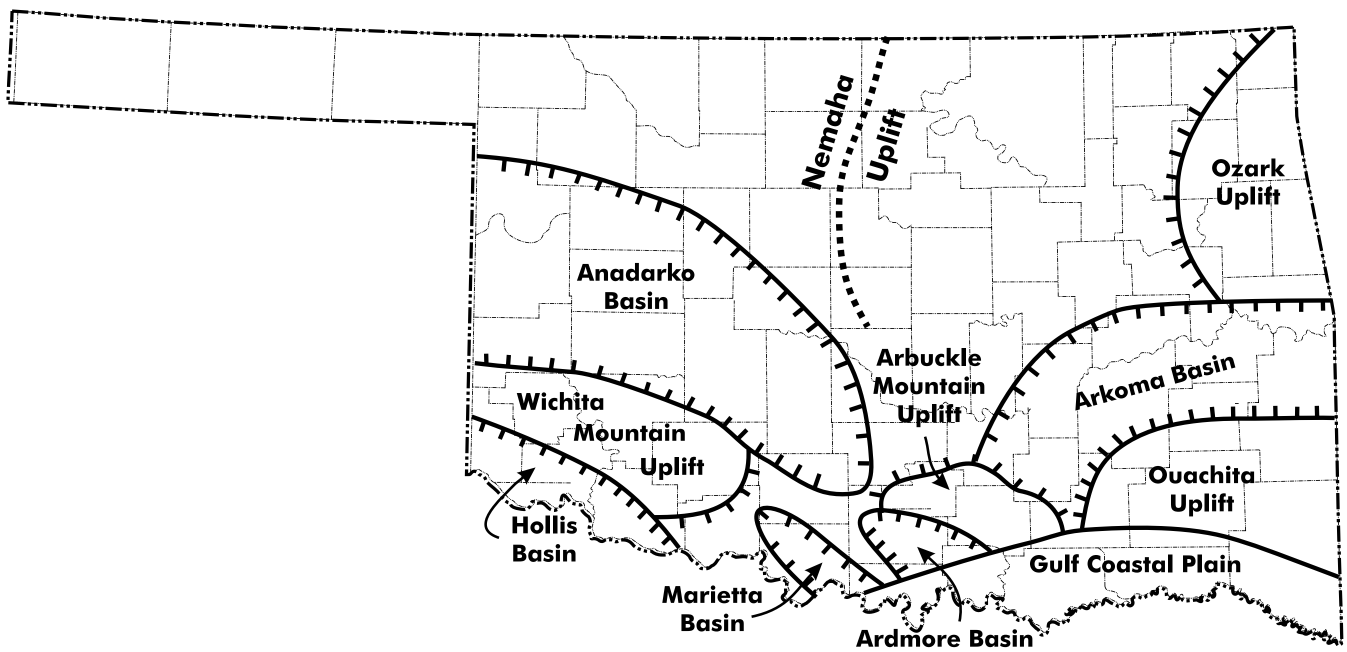

Figure 1. Geologic provinces of Oklahoma. Modified from Northcutt and Campbell (1995).

ment rocks have been extensively investigated in outcrop, geophysically (seismic, gravity, magnetic, and well logs), and in cores. A mature oil and gas industry has fueled many of these studies, and much information is available from the Oklahoma Geological Survey http://www.ogs.ou.edu/. Of the more than 260,000 oil and gas wells completed in Oklahoma, many have penetrated into basement rock. Outcrops exist in several locations in southwestern Oklahoma (see http://www.ogs.ou.edu/education/intgeol/2precam.htm) and have been extensively studied.

> In Oklahoma, two well-known geologic windows, the Arbuckles and the Wichitas, expose for study key aspects of the basement of the Midcontinent. (Gilbert, 2002, p. 31)

Outcrops in northeastern Oklahoma are limited to exposures of the Spavinaw Granite in five hills in Mayes County (Denison, 1981).

This paper will address the geology of the Oklahoma basement by first describing it in context; the basement of the midcontinent region. Then it will describe the various basement provinces and terranes present beneath the state and offer an interpretation of those features in the context of the Genesis account.

Geology of the Midcontinent Basement

Some knowledge of the surrounding regional Precambrian[1] basement helps to place the features of the Oklahoma basement in context. Detailed information of the midcontinent basement is available in Reed (1993). Uniformitarian interpretations of the basement appear to rest on two fundamental assumptions: (1) the existence of joined crustal terranes of distinct origin and history, defined primarily by isotopic dating, and (2) plate tectonics. The extent to which such interpretations might prove useful to creationists, I leave to the reader.

Topographically, the basement surface in the midcontinent dips to the south from surface exposures in Minnesota and Wisconsin (where exposed basement extends even farther north and east to the Canadian Shield) to deeply buried rocks in the Anadarko-Arkoma-Ardmore basins at the north boundary of the Wichita uplift and Ouachita thrusts (Sims, 1990). Depth to crystalline rock in the Anadarko Basin ranges up to ~12,000 m (~40,000 ft) (Dutton et al., 1982; Johnson et al., 1989). This south-dipping surface is interrupted by cratonic basins (e.g., Illinois, Michigan, Salina-Forest City), most of which supposedly formed during the Paleozoic.

There are many uniformitarian studies interpreting the early history of the midcontinent Precambrian crust. Increasing acquisition of geophysical data has revealed a structural complexity not previously expected. Protero-

[1] The use of uniformitarian stratigraphic names is used for convenience of reference only. No age information should be inferred.

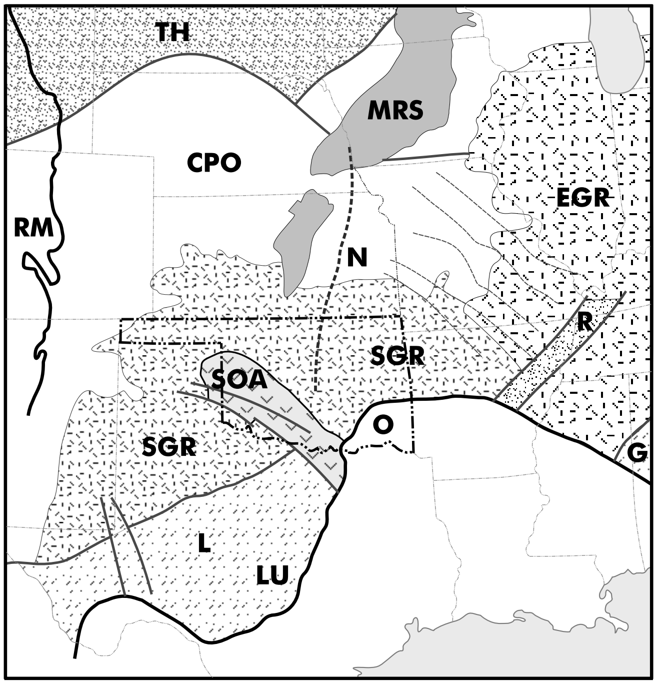

Figure 2. Basement provinces of the North American Midcontinent. RM = Rocky Mountains; TH = Trans-Hudson provinces; G = Grenville Province; L = Llano Province; LU = Llano Uplift; SOA = Southern Oklahoma Aulacogen; CPO = Central Plains Orogen; MRS = Mid-continent Rift System; SGR = Southern Granite Rhyolite Province; EGR = Eastern Granite Rhyolite Province; R = Reelfoot Rift.

zoic fold and fault zones indicate an episode of extension that fractured the craton into tectonic blocks that would later serve as zones of weakness for Phanerozoic inversion, transpression, and transtensional faulting (Marshak and Paulsen, 1996; Marshak et al., 2000). Thomas and Baars (1995) connected many of these into a proposed line of fault systems and associated sedimentary basins extending from the Bahamas to the Olympic Peninsula. They noted three specific periods of activity: >1 Ga; at the Precambrian-Cambrian boundary, and during the late Paleozoic to early Mesozoic. Kinsland (1995) proposed an 800-km (500-mi) slip transform fault running from Florida to Montana based on a perceived offset of anomalies in the national gravity map. Although details differ, most uniformitarians agree that Precambrian history saw the gradual development of the continent by accretion during the Archean and Proterozoic, based on isotopic dates (Van Schmus et al., 1993; 1996) and inferred plate tectonic history.

Geologists have classified basement rocks into several regional provinces (Figure 2). Basement rocks in the southern midcontinent include the Southern and Eastern granite-rhyolite provinces and the Wichita Magmatic Province. Sm-Nd age dates (Van Schmus et al., 1996) have led researchers to believe that much of the granite-rhyolite provinces existed as a veneer covering the older crust of the Central Plains orogen. The basement in Oklahoma is predominantly the Southern Granite-Rhyolite Province, a younger unit (1.37 Ga) of epizonal granite and rhyolite. Descriptions come from outcrops in northeastern Oklahoma, and from numerous wells drilled in Oklahoma, Missouri, Kansas, and Texas. Outcrop samples include granophyre (very finely crystalline granite), granite, granodiorite, and equivalent volcanic rocks. These rocks are chemically and petrographically similar to the Eastern Granite-Rhyolite Province, but are dated at a younger age than those 1.47 Ga rocks.

Oklahoma Basement Provinces

Three distinct basement provinces are recognized in Oklahoma: the Southern Granite Rhyolite Province, the Southern Oklahoma Aulacogen, and the Ouachitas (Gilbert, 2002). The basement beneath the Ouachitas (Figure 1) is poorly known, but currently considered transitional to the Gulf of Mexico. While it is significant to the tectonic history of the region (late Paleozoic deformation in the state is tied to Ouachita thrusting) discussion of the Ouachita Province is best left to another paper. The terranes of the Southern Granite-Rhyolite Province are somewhat better known and those of the Southern Oklahoma Aulacogen have been intensely studied for many years due to the economic importance of the geology in southern Oklahoma. Thus, the bulk of this paper will focus on the Southern Oklahoma Aulacogen, but the reader should remember that this emphasis is driven by data.

Southern Granite-Rhyolite Province

An extensive petrographic, isotopic, and geochemical study (Dennison, 1981) using numerous cores from wells spread over 64,000 km^2 (25,000 mi^2) subdivided the Southern Granite-Rhyolite Province basement in northeastern Oklahoma into four distinct rock units and three terranes. The basement over much of this area is less than 1,000 m (3,000 ft) below ground surface, with outcrops occurring in only one small area near Spavinaw, Oklahoma. Relief on top of the basement surface (Figure 3) is significant, up as much as ~450 m (1,500 ft) in one township (Denison, 1981). Significant well control has allowed the identification of four major rock units (Figure 4), composed of rhyolite porphyry and its equivalent tuff (~65%), metarhyolite (~33%), and minor andesite (~2%).

Denison (1981) identified and mapped (Figure 4) four

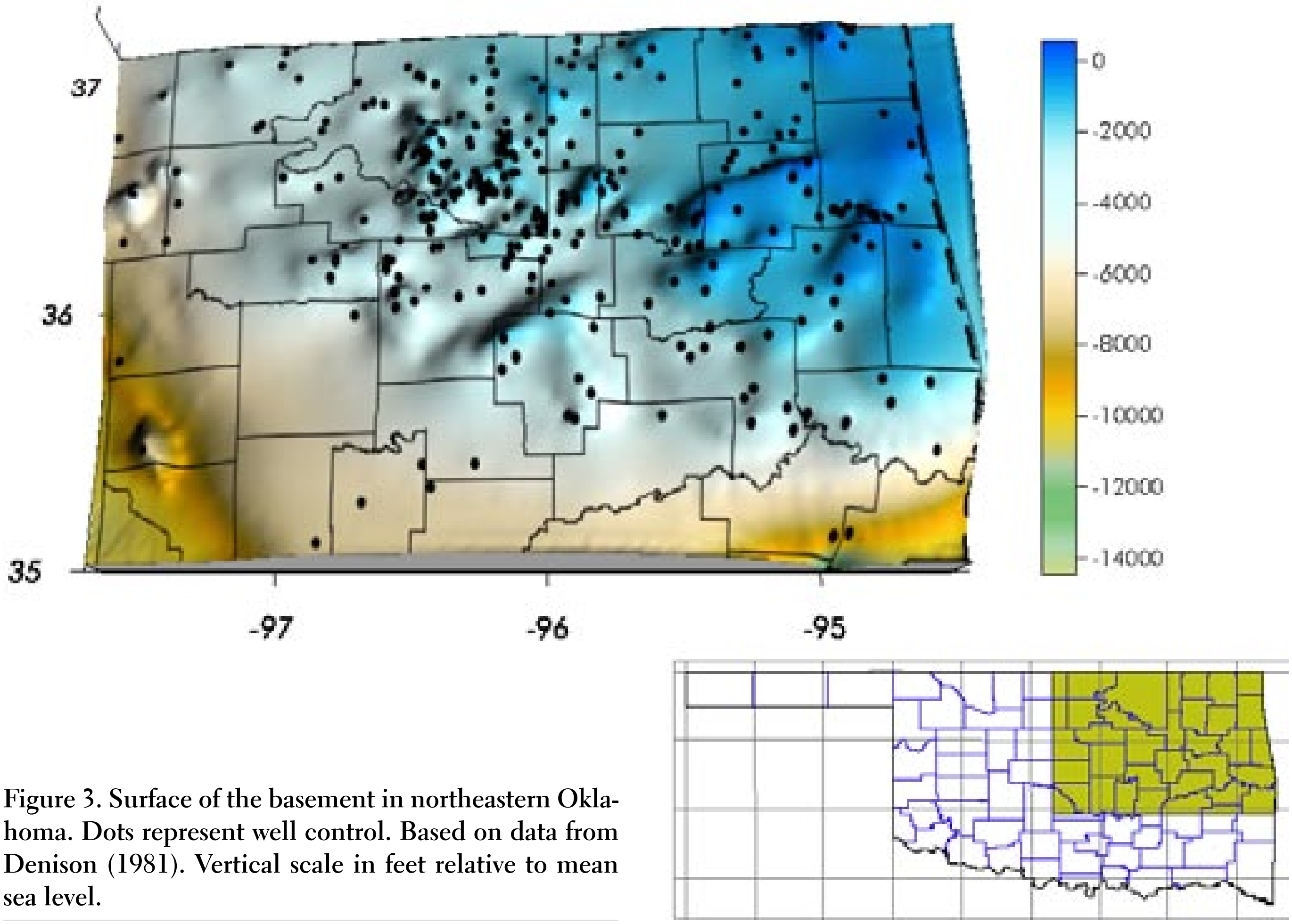

Figure 3. Surface of the basement in northeastern Oklahoma. Dots represent well control. Based on data from Denison (1981). Vertical scale in feet relative to mean sea level.

major rock units in northeastern Oklahoma (the historical interpretations are his).

Washington Volcanic Group. The Washington Volcanic Group is named for Washington County, and consists of rhyolites and a band of metarhyolite adjacent to the Central Oklahoma Granite. The greatest known thickness is 145 m (475 ft), based on well penetration, but the rhyolite is thought to achieve a much greater thickness. The metarhyolite has been converted to hornfels (high-temperature, low-pressure metamorphic rock of uniform grain size formed by contact metamorphism), but the 56 km (35 mi) width of the band argues against contact metamorphism. Regional metamorphism would be needed to alter such a large unit, but the rocks show no evidence of high pressure, shearing, or high water content.

Spavinaw Granite Group. The Spavinaw Granite Group was named for granite that outcrops in five small hills in Mayes County that is remarkably similar to a wide band of granite covering 19,000 km^2 (7,300 mi^2) (Figure 4). Denison (1981) notes that there is greater uniformity in the Spavinaw Granite than in the much smaller Wichita granite bodies in southwestern Oklahoma, which suggests that it is a single sill, although it is considered by many to be too large for one sill. The Spavinaw Granite is classified as a micrographic granite porphyry.

Osage Microgranite. The Osage Microgranite is an extremely homogeneous circular intrusion of ~830 km^2 (~320 mi^2) in central Osage County. The rock has a distinctive texture; quartz phenocrysts are shaped like spicules (rods). As Denison (1981, p. 16) noted: "Only a special intrusive process could have caused a distinct rock type to be so uniform petrographically over such a wide area." Because of the petrographic uniformity, Denison interpreted the Osage body as a thin sill intruded into rhyolite which was later eroded away. However, he notes that there are no contact effects in the surrounding rhyolite.

Central Oklahoma Granite Group. The Central Oklahoma Granite Group is a mesozonal granite with slightly younger isotopic dates than the other three. Its petrography led Denison (1981) to conclude that it

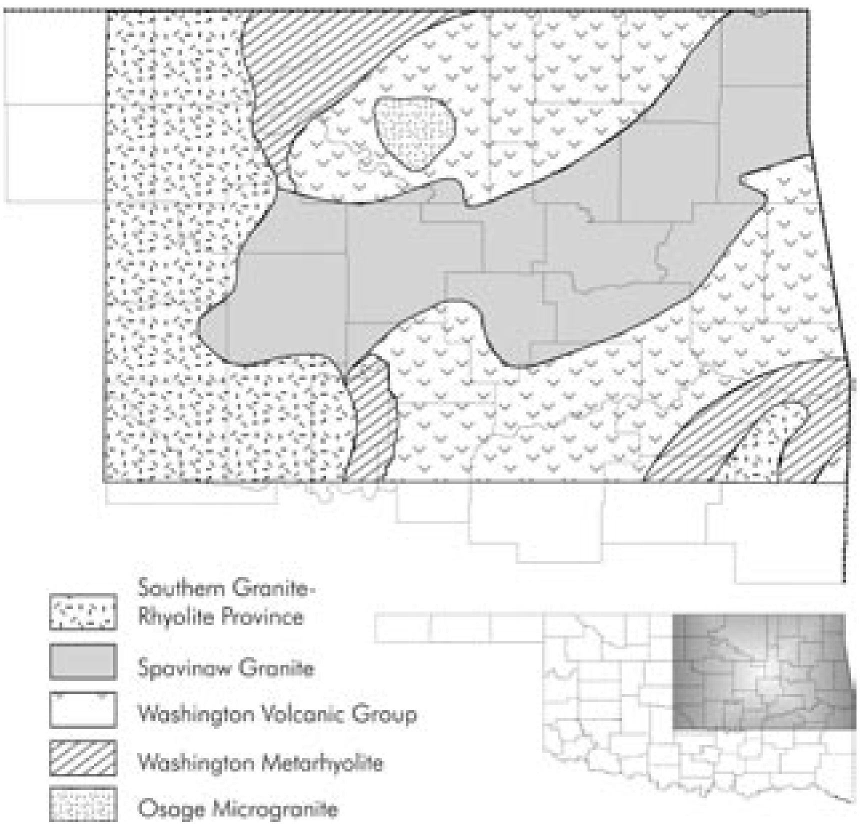

Figure 4. Basement lithologies in northeastern Oklahoma. Modified from Denison (1981).

was a composite of multiple batholiths that had been emplaced at greater depths than the Northeast Province rocks and subsequently eroded more deeply than those rocks. It is considered to be the youngest of the northeastern Oklahoma basement units since the Washington volcanics have been metamorphosed at their contact with the Central Oklahoma Granite Group.

The structure of the northeast basement is dominated by the Spavinaw Arch, coincident with the trend of the Spavinaw Granite (Figure 4). Denison (1981) assumed that rhyolite (presently mapped to both the north and south of the granite) once covered the Spavinaw Granite and was later eroded as the arch was uplifted. Structural evidence is not sufficient to determine whether the arch formed by folding or faulting. Areas to the north and south of the Spavinaw Arch with Washington Group rhyolite are interpreted as basement synclines. Likewise, the Nemaha Uplift is interpreted as having been active prior to Cambrian sedimentation because rhyolite is absent on that structure. Denison (1981) suggests that Paleozoic movement was a reactivation of earlier basement structuring.

Denison (1981) notes several contrasts between the basement in northeastern Oklahoma and southwestern Oklahoma. The southwestern rocks are richer in silica, and have basalt and diabase dikes that are absent in the northeast. All of the northeast basement units have been isotopically dated at ~1,280 Ma (Denison, 1981). Because they are considered a shallow veneer over unknown deeper rocks, they are considered less eroded than surrounding rocks.

Southern Oklahoma Aulacogen

The Southern Oklahoma Aulacogen (SOA) is defined as "the rift of apparent Cambrian age which now trends WNW from about the Dallas area to the Amarillo area." (Gilbert and McConnell, 1991, p. 110). It includes the southernmost part of the present-day Anadarko Basin (the deepest sedimentary trough in North America), the Ardmore and Marietta basins, the Arbuckle uplift and the Wichita uplift (Northcutt et al., 2001; Figure 1). It was first named by Shatski (1946), but the name, "Southern Oklahoma Geosyncline" was also used for many years (Lindsay and Koskelin, 1991). "Aulacogen" is a tectonic term for any deep sedimentary basin believed to be a failed arm of a triple junction. Aulacogens are usually fault bounded and show multiple cycles of movement and sedimentation. In spite of the plate tectonic, uniformitarian connotations, "Southern Oklahoma Aulacogen" is the most commonly used term in the literature and will be used throughout this paper descriptively, without implying any plate tectonic or uniformitarian interpretation.

Gilbert and McConnell (1991) note five ways in which the extent of the SOA has been identified (Figure 2). These include: (1) gravity and magnetic anomaly signatures, (2) the distribution of Cambrian basement based on isotopic dating, (3) the distribution of mafic basement rocks, (4) the distribution of faults and uplifts, and (5) thickening of Cambrian and Ordovician sediments into the SOA, approximately 3–4 times their cratonic thickness. All of these criteria are centered around the present day Wichita-Criner-Amarillo uplift. This implies that the mafic basement rocks comprised the rift fill, and later silicic volcanics overlapped the rift boundaries. Rock relationships suggest that the rift formed a half graben with most of its extension to the north. The only exposed boundary of the rift is

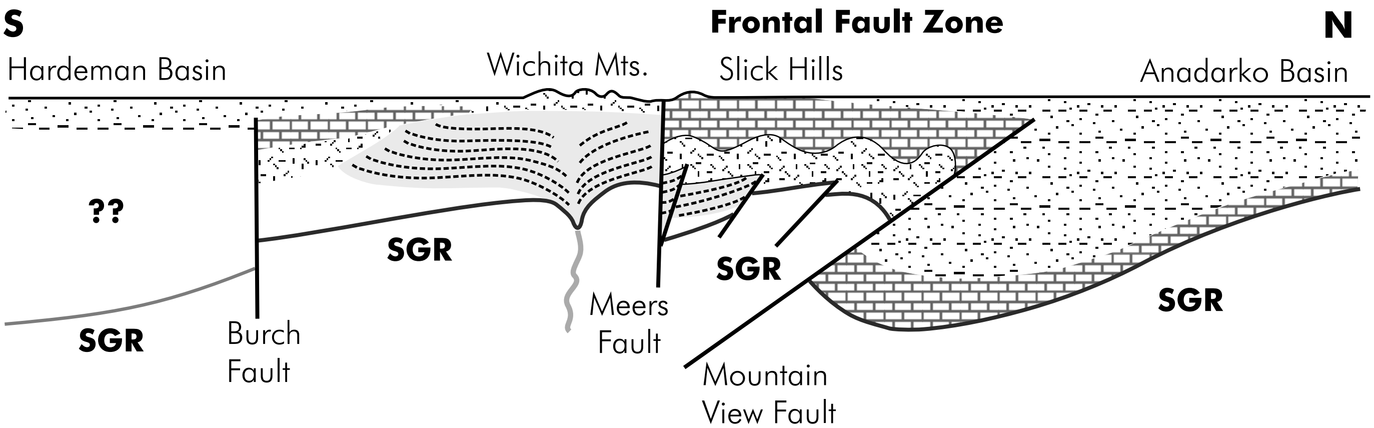

Figure 5. Schematic north-south cross section of the Anadarko Basin, Wichita Uplift, and Hardeman Basin. Modified from Gilbert and Denison (1993).

the Washita Valley Fault in the Arbuckle Mountains, which offsets Precambrian mesozonal granite outside the aulacogen with the Cambrian Carlton Rhyolite (Ham, 1973). Precambrian mesozonal granites (1,300–1,600 Ma) surround the SOA.

The SOA basement is exposed in outcrop in the western Arbuckles (Fay, 1989) and in the Wichita Mountains in a trend that extends ~100 km (62 mi) from Fort Sills, Oklahoma in the southeast to Granite, Oklahoma in the northwest. Outcrops are also exposed in the Slick Hills on the northeast side of Wichita Mountains, surrounded by a thin mantle of lower Permian sediments (Gilbert, 2002). The SOA trends N60°W (Donovan, 1995). The Wichita Mountains are an uplifted and broken crustal block that used to be the basement of the SOA and now form the southern boundary of the Anadarko Basin. The mechanical integrity of the block may be due to the strength of the igneous fill, underlain by dense mafic rocks such as the gabbros of the Glen Mountains Layered Complex.

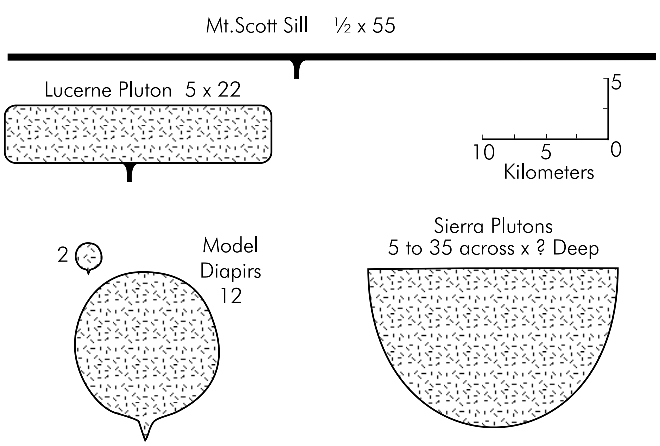

Figure 6. Dimensions of granitic plutons as compared to the Mount Scott sill in the Wichita Mountain Granite. Modified from Gilbert and Denison (1993).

Gilbert and McConnell (1991) cited the distribution, composition, and interrelationships of igneous fill of the SOA to infer its tectonic history prior to Paleozoic sedimentation. They noted that the timing between the igneous activity and the earliest marine sandstone was relatively short, based on isotopic dating of the granites. They concluded that the SOA was a rift with bimodal rocks filling its expanding volume. The lack of rift sediments contrasts sharply with many other known rifts, and Gilbert and McConnell (1991) speculate that this implies uplift prior to igneous activity. Crustal extension estimates have been made based on (1) fault geometry, (2) crustal thinning, and (3) mass-balance calculations. These estimates run between 5 and 21 km (3–13 mi), in the direction N30°E. (Gilbert and McConnell, 1991; Donovan, 1995).

Outcrop and geophysical evidence suggest that the mafic intrusions extend to the southern boundary of the SOA and are covered by a veneer of silicic rocks (Figure 5). The thickest parts of the Carlton Rhyolite are found in the less uplifted areas of the frontal fault zone. Extension in the SOA is based on structural and petrologic evidence. Rifting, magmatism, and erosion are all considered part of the formation of the SOA. The sheet nature of the granites (Figure 6) argues for extension because granite intrusions would probably be more equant in a compressional regime (Gilbert and McConnell, 1991).

Gilbert and Denison (1993) summarized the SOA and its igneous fill. Isotopic dating places the rift fill in the early Cambrian; the only igneous rocks of that era in the midcontinent. The igneous rocks are bimodal (mafic and felsic), similar to those of the Midcontinent Rift System.

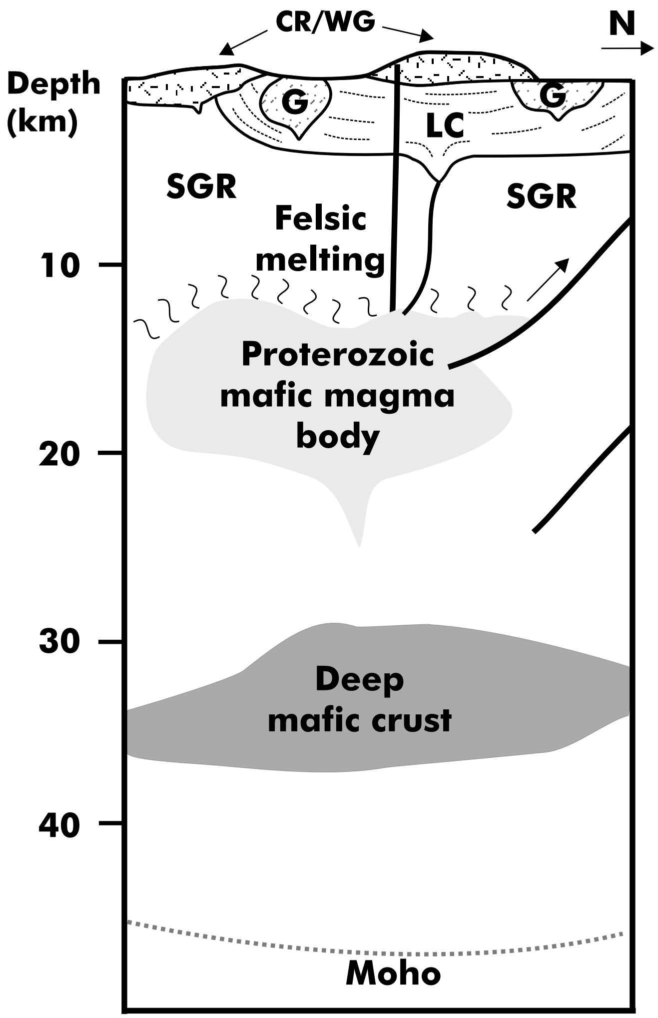

Figure 7. Diagram of crust beneath Wichita uplift showing effect of hypothesized deep crustal intrusion on both mafic and felsic igneous activity. Modified from Gilbert and Denison (1993).

They consist of sheet granites and rhyolite overlying a layered mafic complex and intruded gabbros. Late stage diabase dikes cut all of the other units. The only sediment associated with the SOA rifting is the Meers Quartzite, found above the mafic fill and overlain and metamorphosed by granite. Cambrian igneous rocks range up to 6,100 m (20,000 ft) thick on the Wichita Uplift and are considered to have ranged between 1,500–6,100 m (5,000–20,000 ft) in the deep basin (Johnson, 1989).

The Tillman Metasediment Group is considered by some to be pre-rift (Lindsay and Koskelin, 1991), but McBee (1995) believes that it postdates tectonism and preceded igneous activity. He speculates that Tillman sediments were deposited in the graben formed by the left lateral movement along the Muenster and Washita Valley faults. Rift fill units and their relative positions are shown in Figure 5. Although a variety of subdivisions have been made in the field, the SOA igneous rocks shown here are more broadly classified. Based on both field relationships and isotopic data, these units are presented from oldest to youngest.

Raggedy Mountain Gabbro Group

The Raggedy Mountain Gabbro Group includes the Glen Mountain Layered Complex and the Roosevelt Gabbros. The Glen Mountain Layered Complex is the oldest exposed Cambrian igneous unit and is believed to represent the onset of rifting. The complex is a layered anorthositic intrusion, with alternating layers of plagioclase and olivine. It is estimated to cover between 975 and 2,000 km^2 (375–975 mi^2) with 1–2 km (0.6–1.2 mi) of its vertical section exposed in outcrops. Some well-laminated layers imply seismicity during the intrusion (Gilbert and Denison, 1993). Cooper (1991) divided the Glen Mountain Layered Complex into three major cycles, representing individual magma pulses.

The Roosevelt Gabbro consists of several large cylindrical intrusions and numerous smaller dikes and sills into the Glen Mountain Layered Complex (Cooper, 1991). They have been observed in five small outcrops (the largest is 24 km^2 or 9 mi^2); as a large cylindrical intrusion; as dikes up to 3 m (10 ft) thick; and sills up to 60 m (200 ft) thick (Cooper, 1991). The gabbros were derived from hydrous tholeiitic liquids, with primary biotite and amphibole. The Glen Mountain Layered Complex is intruded by two sets of mafic dikes and the felsic Cold Springs intrusions, which include tonalite, granodiorite, and local granite as laccoliths and sills up to 70 m (225 ft) thick and 1.6–3.2 km (1–2 mi) across (Cooper, 1991). Cold Springs intrusions are common along preexisting sills and dikes.

Navajoe Mountain Basalt-Spilite Group

A poorly known basalt and spilite sequence that reaches a drilled thickness of 320 m (1,050 ft) (Ham, 1973), is considered an extrusive equivalent of the gabbroic intrusions. It is composed of spilitic basalts and tuffs. However, little is known about this unit at present.

The Carlton Rhyolite Group

The Carlton Rhyolite Group (locally called the Colbert Rhyolite in the Arbuckles) is known from five outcrops in the Wichita and Arbuckle Mountains. The lavas, pyroclastics and agglomerates were deposited on an unconformity on top of the gabbros of the Glen Mountain Layered Complex and the Roosevelt Gabbros. Exposures of the rhyolite cover ~260 km^2 (~100 mi^2) (Donovan and Stephenson, 1991). Donovan (1995) reported that 1,100 m (3,600 ft) of the Carlton Rhyolite is exposed in the Slick Hills region of the Wichita Mountains as a monotonous, thick-bedded sequence of lava and pyroclastic flows. However, the reported a maximum thickness of the Carlton is nearly 1,500 m (5,000 ft) (Ham, 1973), and Fay (1989) noted a drilled thickness of 1,370 m (4,500 ft) and an estimated thickness of 2,290 m (7,500 ft) for the equivalent Colbert Rhyolite at the top of the East Timbered Hills in the Arbuckle Mountains along Interstate 35. The rhyolite probably once covered nearly 39,000 km^2 (15,000 mi^2), although much of this was removed by later erosion (Denison, 1973). McBee (1995) attributed the Carlton Rhyolite and associated intrusives to the creation of a release bend graben formed by lateral slip along major faults.

The unconformity between the Carlton Rhyolite and Cambrian sediments shows significant relief with hills up to 300 m (1,000 ft) high. Donovan and Stephenson (1991) note that this relief implies rapid subsidence of the volcanics relative to the surrounding craton.

Wichita Granite Group

The Wichita Granite Group is a series of sheet granites (Gilbert, 2002), named for their geometry (Figure 6). The sheet style of the granites is determined from gravity anomalies, the apparent lateral extent of some of the granites (up to 55 km or 34 mi), regional subhorizontal granite body floors, abundant cooling columns, and evidence of quenching. Individual sill thickness ranges up to 0.5 km (1,640 ft). This geometry combined with the known high viscosity of granite magma suggests emplacement through fissures or faults instead of pipes, in turn implying intrusion during rifting. Although eleven different granites have been identified, the Mount Scott Granite is the most widespread, dated at 534 Ma (Gilbert, 2002). Chemically, these rocks are A-Type granites, characterized by low calcium, aluminum, mafic and feldspar trace elements; and high iron and potassium.

Uniformitarians agree that the granites were emplaced near the surface, beneath the Carlton Rhyolite, based on their granophyric texture, shallow crustal inclusions, and mineralogical indications of low pressure, high temperature conditions. The presence of rhyolite dikes indicates that erosion and/or block rotation occurred immediately after emplacement of granites because if the overburden had not been decreasing, the rhyolite dikes would have granitic texture (Gilbert and McConnell, 1991). Most granites are high-silica, hypersolvus, quartz-perthite rocks. Mafic constituents include hornblende, biotite, and magnetite. The melt depth has been estimated at 12–15 km (7.5–9.3 mi) (Gilbert and Denison, 1993) and granite source chemistry varied from west to east, based on changes in their silica content.

Minor Igneous Rocks

A variety of hybrid igneous rocks are found near or at the contact between the granites and gabbros. These have interesting mineralogy, but make up a very small fraction of the SOA fill. Rhyolite dikes also occur but are not common, and late diabase plugs and dikes are widely scattered.

Gilbert and Denison (1993) proposed six steps in the evolution of the SOA (Figure 7).

1. Latest Proterozoic to early Cambrian (~550 Ma) rifting related to the opening of the proto-Atlantic ocean. "The limits of the rift are not clear." (Gilbert and Denison, p. 313). Gilbert favors just the Wichita, Mountain area, but Denison thinks it underlies the Andarko basin, too. Arbuckle Granites form a northern boundary, but the southern boundary is buried and they consider it "seismically defined…[by]…enigmatic layered rock" (p. 313). The N60°W tectonic trend is reflected as far away as Colorado.
2. Rifting caused the rise of basaltic magma from the mantle to the depth of ~15 km (~9 mi). Some of the magma ponded at shallower levels to form the Raggedy Mountain Gabbro Group. Mineralogy of the gabbros suggests shallow emplacement. There was tilting during the emplacement: the younger Roosevelt Gabbros are not parallel to the older Glen Mountain Layered Complex. The area was then uplifted and eroded to expose the shallow gabbros. The layered complex was tilted by as much as 15°. The surface was deeply weathered with a relief of several hundred feet over 100 million years.
3. Heat from the cooling basaltic body at 15 km (9 mi) melted roof rock of the Southern Granite Rhyolite Province to form a felsic melt that was first extruded as the Carlton Rhyolite Group across the surface of the gabbro in the Wichita Mountain area and over a thick basalt sequence just to the north. The Rhyolite spread over 39,000 km^2 (15,000mi^2) primarily as fissure eruptions centered just south of the Raggedy Mountain Gabbro Group. Present day rhyolite thickness may reach ~2,300 m (~7,500 ft). Simultaneously, granite was intruded beneath the rhyolite along the rhyolite-gabbro erosional surface as thin sills. The granitic magma was dry and used the same feeder system as the rhyolites.
4. The final igneous activity of the area was the emplacement of diabase dikes at the rift margin both inside and outside.
5. Paleozoic seas transgressed and deposited thick sediments. The first Cambrian sediments are dated at 520 Ma.

6. Two-stage uplift in the late Paleozoic exposed and eroded the igneous core, creating the present arrangement of basins and uplifts.

Discussion

A biblical earth history must reject the uniformitarian classification of basement rocks by their isotopic dates and purported uniformitarian plate tectonic affinity. How then are they to be classified? The most obvious method is to first determine their relationship to the Genesis Flood, if any, and if not, explain their features by the events of the creation week and subsequent antediluvian geologic processes (probably minor). It is worthwhile to remind ourselves that the creation events are by definition largely outside of the scope of scientific study. This is one reason why creationists must insist that natural history and natural science are two distinct enterprises.

Austin and Wise (1994) provide a series of criteria to determine the basal Flood boundary. They claimed that a combination of several of five discontinuities was diagnostic of the pre-Flood boundary. These included: (1) a mechanico-erosional discontinuity, (2) a time discordance, (3) a tectonic discontinuity, (4) a sedimentary discontinuity, and (5) a paleontological discontinuity. Over much of Oklahoma, the first and fourth are present, and within the SOA, the third is present, too. Although it is quite obvious, there are two characteristics of the Oklahoma basement that provide clues to the origin of its features: (1) the dramatic lithologic change from widespread igneous rocks (predominantly granite) to overlying Phanerozoic sediments and (2) the erosional contact between those two groups.

As obvious as these features are, uniformitarians generally downplay this transition because it points to a sharp discontinuity in geologic processes that does not conform to their approach to natural history. The break between igneous and metamorphic basement and overlying sediments has long been recognized as a global phenomenon, and even according to uniformitarian history, the existence of sedimentary rocks prior to this unconformity is restricted in spatial extent and lithologic diversity. The hiatus becomes ever clearer when one breaks away from the framework of the geologic column, evaluates the physical evidence, and sees many "Precambrian" sedimentary rocks having exactly the same character as "younger" rocks, which also rest on top of the eroded basement surface. For example, thick arkosic clastic sediments in basins adjacent to the Midcontinent Rift System can be interpreted as very early Flood deposits, since the marine inundation of the continents would not have happened immediately (Reed, 2000).

The eroded basement surface in northern Oklahoma is probably the pre-Flood/Flood boundary. It marks a significant erosional and lithologic discontinuity covered by widespread marine sedimentation. The depth of erosion into the igneous rock is unclear. There are some indications, but an answer requires assumptions that cannot be demonstrated. The Central Oklahoma Granite Group is differentiated from other units in northeastern Oklahoma by its mesozonal texture. If crystal size (epizonal vs. mesozonal) indicates the depth of crystallization, then that body may show a greater depth of erosion than the epizonal rocks. However, a simple correlation between crystal size and depth of erosion may not be warranted. Likewise, differential erosion is concluded based on the absence of rhyolite over the Spavinaw Arch, but this assumes that rhyolite was present over the arch initially.

The irregular topography of the basement surface (Figure 3) suggests one or more of several possibilities about the top basement hiatus: (1) erosion was not by sheet flow, (2) small-scale differential uplift occurred during erosion, or (3) differential erosion was caused by laterally varying rock properties. The lithologic similarity seen in core samples argues against the latter. Oard (2001) describes the transition from widespread sheet erosion to channelized erosion during the recessive stage of the Flood. Conversely, channelized erosion would be expected during the early days of the Flood on continental interiors, prior to inundation by the marine front of the Flood. The closest modern analogy would be flash flooding, only on a much larger scale.

Reed (2002a; 2002b) has documented the challenge to uniformitarianism offered by the presence of any large hiatus in the rock record. Although such gaps are explained away, uniformitarians do not appear to grasp that the lack of physical evidence (the rock record) decreases confidence in their interpretations. Though the absence of large portions of the rock record does not itself invalidate the uniformitarian position, it does point out the weakness of a positivist approach to natural history. The supposed time interval between the basement and the first Cambrian sediments of the Reagan Formation ranges up to almost 900,000,000 years (Denison, 1997; Gilbert, 2002). Please note that this interval is almost twice the extent of the Phanerozoic, which constitutes the overwhelming bulk of the rock record of North America. Philosophical uniformitarianism cannot survive large demonstrable irregularities in the historical record (Reed, 1998).

Uniformitarian difficulties with the time discontinuity between the basement and overlying sediments are exacerbated by the on-off-on-off problem of structural motion and deformation. Geologic literature is replete with references to "reactivation" of faults and tectonic features and Oklahoma is no exception. Although the concept of structural motion occurring preferentially along existing zones of weakness makes sense, crustal dynamics are not quite as simple. A zone of weakness is only a necessary cause of motion, not a sufficient cause, and the question is not so much why the motion reoccurs along a weak plane, but why the motion reoccurs at all. Plate tectonics purports to provide a continuous impetus throughout the crust, but plate tectonics also results in significant changes in the location and orientation of any given preexisting fault over time. In other words, a N-S oriented fault that moved at one time may be oriented E-W at some later time due to plate rotation. Do primary stress axes rotate in symphony with faults?

An advantage of the creationist perspective is its dismissal of the long intervening times of quiescence between motion on faults. Strain responses along a fault may be intermittent, even when the stress is constant. A "hesitation" along a fault combined with irregular, rapid sedimentation may allow for the appearance of fault reactivation, but only if the time of sedimentation is assumed to take millions of years. Likewise, creationists should begin to look at examples of inversion as a part of one complete episode, not a new tectonic movement initiated millions of years later. Southern Oklahoma provides an opportunity to evaluate both approaches. For example, the Meers Fault, located in the frontal fault zone (Figure 6) was active during Pennsylvanian and Permian time, but shows both Quaternary and recent movement. This raises the question, what makes more sense, recurrent small motion after a few thousand years or a few hundred million?

In addition to the timing of structuring, catastrophist views address its extent, too. If a global Flood occurred, one consequence would be megaregional to continental scale tectonism. As geological knowledge increases, it has become clear that large-scale structuring has occurred. Thomas and Baars (1995) proposed a structural connection between northwest trending structures in North America from Florida to Washington State: a trend they named the Paradox Transcontinental Fault Zone. They note nine distinct zones and three distinct periods during which deformation occurred: >1 Ga, at the Precambrian-Cambrian boundary, during the late Paleozoic, and in the early Mesozoic. A biblical model would predict active tectonism during the creation week, at the onset of the Flood, and later during tectonic readjustments following the Flood highstand. Additional tectonism would be expected following the Flood and throughout the ice age as the land masses adjusted to their new subaerial state. Periods of predicted elevated geologic energy were noted by Reed et al. (1996).

Uniformitarians provide a general sequence of events at the SOA that can be accommodated within a Flood model. Like other such features, the key difference is in the timing of the events. Both groups would agree that early tectonism led to the formation of the SOA and its igneous fill, followed by subsidence, as evidenced by thickening Paleozoic sedimentary units into southwestern Oklahoma. Later tectonic inversion led to the formation of the Anadarko Basin and the Wichita uplift, and the associated smaller basins and uplifts (Figure 1). What does the field evidence demonstrate regarding the timing of these events? The rock record suggests much less time than proposed by uniformitarians.

First, unlike modern examples and most ancient ones, the SOA does not show evidence of rift basin sedimentation. There are only two sedimentary bodies (both metamorphosed) associated with the SOA. The first is the Tillman Metasedimentary Group located at the southern end of the rift and the Meers Quartzite, located on top of mafic rocks and beneath late sheet granites. Most examples of rifting produce downwarping and the accumulation of large prisms of sediment. For example, the Lake Superior Basin contains almost 10 km (33,000 ft) of Proterozoic sediments associated with the MRS. But the SOA is different.

> The SOA does not seem to have accumulated a sedimentary record. This is a somewhat unusual rift zone where magmatism and tectonism were intimately interlinked as it seems to be nearly totally filled with igneous rocks. (Gilbert 2002 p. 33)

Why were there no sediments? Gilbert and McConnell (1991) suggest that there was initial crustal uplift with magmatism. But the absence of sediments also may indicate rapid magmatism. It is difficult to understand how crustal uplift would have prevented sedimentation. Local sedimentation would have contributed some fill over millions of years. After all, this was before the evolution of plants and normal weathering, erosion, and local transport would have been unimpeded by plants. All of the later sedimentary fill shows dramatic downwarping. Why would the rift have experienced uplift during the igneous fill phase and downwarp immediately after?

In addition to the absence of sediments, the SOA igneous fill indicates tectonism happening at the same time as the igneous activity. Attitude discordance exists between and among successively younger igneous units. If there was original horizontality of layering in igneous complexes, then the units were being tilted between flows. Finally, the local rugged relief on the top of the Carlton Rhyolite suggests rapid subsidence inside the SOA.

Reed (2000) interpreted the MRS as the extensional breakup of the northern midcontinent at the onset of the Genesis Flood. Is the SOA a southern example of a similar phenomenon in the southern midcontinent? Uniformitarians would be forced to disagree, since they place the two events over 600,000,000 years apart based on isotopic dating. But if the two are related, then the uniformitarian position becomes another argument for the inadequacy of isotopic dating. Although the plate tectonic bandwagon effect leads to most of the discussion of the SOA as one arm of a triple junction (Burke and Dewey, 1973), there are also difficulties with that interpretation.

The most striking difficulty is the lack of any similarity in composition or history between the Tobosa Basin, the SOA, and the Rome-Rough Creek-Mississippi Valley Graben. These were all supposedly connected at one time, and there should be some similarities; at least during the time that they were joined. As mentioned above, there is no evidence of rift valley sedimentation. There is no evidence of the numerous expected transform faults adjacent to the basins, nor is there any evidence of buried rift margin prism.

These problems led Viele and Thomas (1989) to propose a large transform fault across the Ouachita front of the southern United States. But their interpretation would predict a rifted margin prism in East Texas where none has been found. At least one researcher disagrees with the common tectonic interpretation of southern Oklahoma; McBee (1995, p. 46) stated, “It was probably not an aulacogen.” He preferred the term, “Oklahoma Megashear” because he believed that the basin formed as a result of a large-scale left-lateral shearing in the crust (up to 55 km or 34 mi), related to continent-scale deformation caused by plate tectonic collisions. However, most other workers note that there is very little evidence for strike slip motions of this magnitude.

Conclusions

As geologists committed to biblical natural history continue the arduous task of reinterpreting the rock record within their framework, it becomes clear that it is seldom the physical evidence that demands the uniformitarian interpretations. Rather, the assumptions of deep time and evolution provide an overpowering filter that arranges data to fit these presuppositions. The basement in Oklahoma can be resolved within a young earth Flood history, and two features in particular argue against the uniformitarian position. The first is the absence of significant amounts of sedimentary rocks prior to the Cambrian transgression and the second is related: the statewide erosional discontinuity between the igneous basement and overlying sediments. Both would be predicted by the tremendous erosional power of the Genesis Flood.

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