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Geologic Structure of the Grand Canyon Supergroup

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INTRODUCTION

This chapter summarizes the geologic structure and tectonic history of the Grand Canyon Supergroup. This sequence of tilted Precambrian strata is approximately 4 km thick and is sandwiched between the overlying, subhorizontal Cambrian Tapeats Sandstone [500 Ma (million years ago)] and the underlying, highly contorted Granite Gorge Metamorphic Suite (1700 Ma) (Chapter 2, this volume; Ilg et al. 1996; Hawkins et al. 1996). The Grand Canyon Supergroup is unmetamorphosed, and its near pristine preservation provides a remarkable record of the formation of intracratonic extensional basins in the Late Precambrian.

John Wesley Powell first observed these tilted rocks in 1869 on his historic journey down the Colorado River and recognized that they record an important chapter in the tectonic history of the region. He concluded that the beds were folded, uplifted, and deeply eroded before the overlying Paleozoic rocks were "spread over their upturned edges" (Powell 1876). Charles Walcott outlined the geologic structure and stratigraphy of the sequence in a series of reports (e.g., Walcott 1883, 1890, 1894). Walcott recognized that the Grand Canyon Supergroup is Precambrian in age and suggested a correlation with other sequences in North America.

Since Walcott's pioneering geologic work, geologists have refined the stratigraphy and continue to debate how the Grand Canyon Supergroup correlates with other Precambrian strata of North America and other continents (see Chapters 3 and 4, this volume). Stratigraphic studies show there are major uncomformities within the Grand Canyon Supergroup that divide it into several sequences. From the base to the top, the major uncomformity-bounded sequences are as follows: (1) the Unkar Group and associated 1.1-Ga (billion years old) basaltic magmatism, (2) Nankoweap Formation, (3) Chuar Group, and (4) Sixtymile Formation. The groups are subdivided further into formations and, in most cases, members. Chapters 3 and 4 of this volume discuss the stratigraphy and depositional history of the Grand Canyon Supergroup.

Radiometric dating suggests that (a) the Unkar Group was deposited sometime between about 1.3 Ga and 1.1 Ga, in the Mesoproterozoic era, which lasted from 1600 to 1000 Ma, and (b) the Chuar Group was deposited sometime between about 1100 and 800 Ma, mostly in the Neoproterozoic Era, which lasted from 1000 to 540 Ma (Elston and McKee 1982; Bowring et al. 1996).

The Late Precambrian is an important yet still poorly understood period in the history of western North America, as well as globally. Recently, several researchers have proposed that during this time North America and other continental masses were assembled into a supercontinent called Rodinia. Following assembly at 1.0 Ga, Rodinia began to break apart in one or more episodes of rifting that took place between 750 to 550 Ma. The Grand Canyon Supergroup records part of this long history, and it is a key locality for unraveling the timing and processes of intracratonic rifting, the evolution in the character of global seawater, and the rapid diversification of life on earth leading to the Cambrian 'explosion' (Dalziel 1997).

Figure 5.1 shows the distribution of Mesoproterozoic sedimentary rock exposures in the eastern Grand Canyon. The Unkar Group occurs in isolated wedge-shaped remnants (grabens and half grabens) in areas along the river, between mile 65 and 137 (shown in Fig. 5.2). The Chuar Group is exposed in the Chuar Valley, a region west of the Colorado River and just west of the East Kaibab monocline. This monocline is a great step-like fold on the eastern edge of the Kaibab Plateau that formed in Laramide time by the reactivation of a Precambrian fault (see below). Farther west, Paleoproterozoic rocks of the Granite Gorge Metamorphic Suite (GGMS) emerge again near Granite Park (mile 207) and in the Lower Granite Gorge, but there are no more exposures of the Grand Canyon Supergroup beyond Deer Creek.

Early workers recognized that the Grand Canyon Supergroup is only preserved in fault-bounded, downdropped blocks, which protected it from pre-Tapeats erosion. We can piece these fragments together to decipher some aspects of the Meso and Neoproterozoic tectonic history of the Grand Canyon

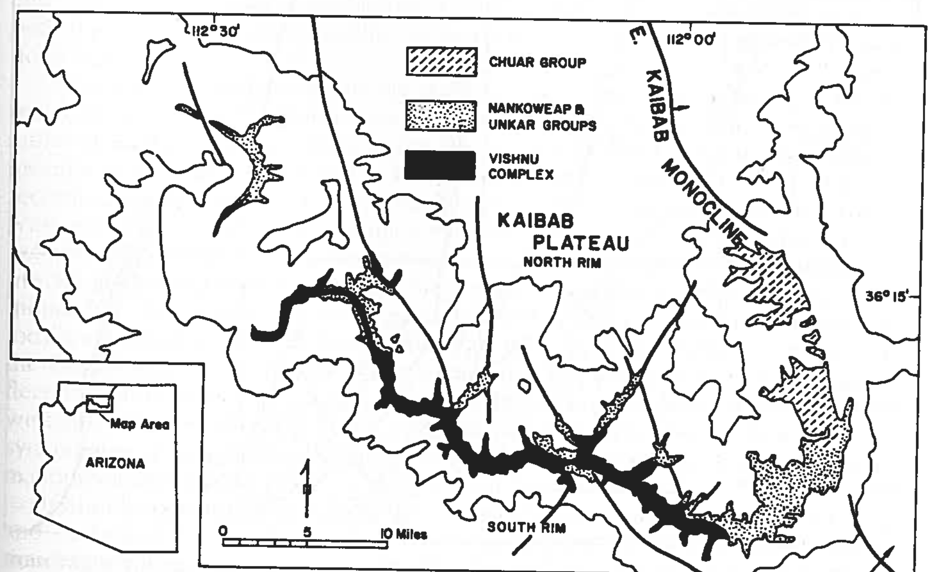

Figure 5.1. Precambrian rocks in eastern Grand Canyon. Major structures with Precambrian ancestry are also shown.

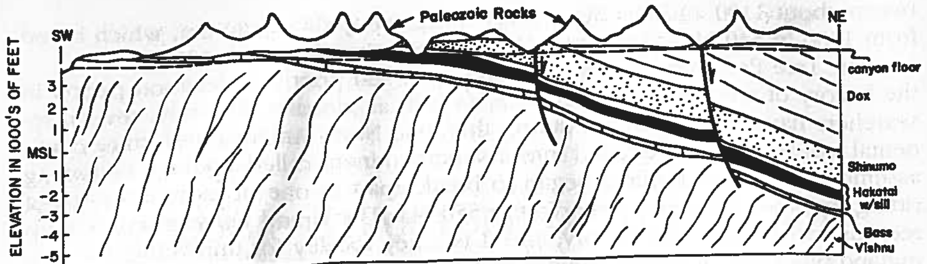

FIGURE 5.2. Cross section along the course of Bright Angel Creek, illustrating the wedge-like character of remnants of the Grand Canyon Supergroup.

region, but the original extent and distribution of the sediments and the shape of the basins remain unknown. Figure 5.3 provides a hypothetical view of the geology of the Grand Canyon region as it might have looked at the close of Proterozoic time, before Paleozoic sediments buried the region. The Proterozoic sedimentary rocks occupy a few large fault blocks bounded by north to northwest-trending, southwest-dipping normal faults with west-side-down sense of movement. Within the fault blocks, Proterozoic strata generally dip gently to the northeast, toward the southwest-dipping normal faults. Due to this regional tilt, basement metamorphic rocks emerge on the southwestern edges of the fault blocks and strata become younger toward the north. The youngest of the Proterozoic sedimentary rocks are found adjacent to the Butte fault, the eastern edge of a large asymmetric graben.

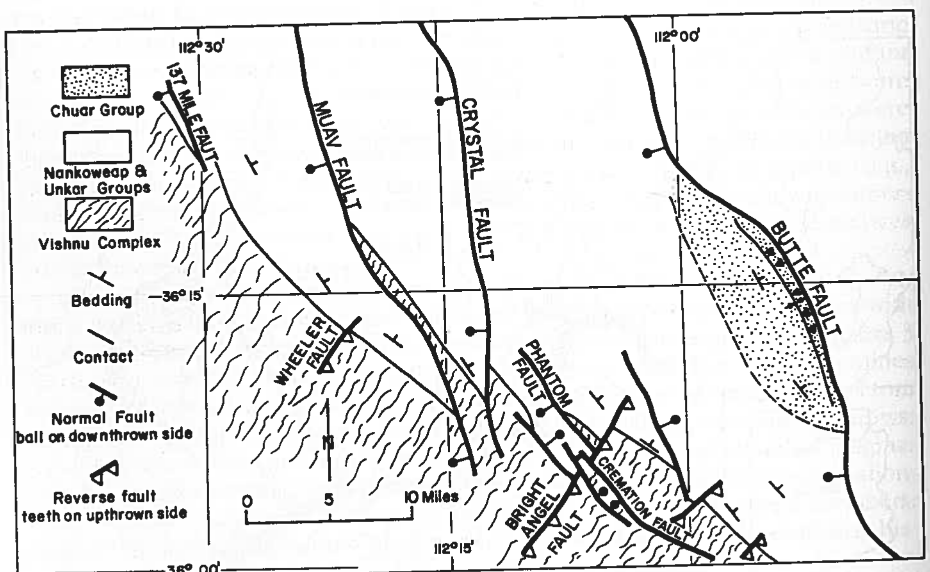

FIGURE 5.3. Schematic map of Precambrian structures and Supergroup rocks as it might have looked at the end of the Precambrian, prior to Paleozoic burial. This figure shows the same area as Fig. 5.1.

POST-1400-MA UPLIFT: EXHUMATION OF THE MIDDLE CRUST IN THE SOUTHWEST

The tale of the Grand Canyon Supergroup begins where the story of the Granite Gorge Metamorphic Suite (GGMS) ends. The GGMS experienced a complex interaction of deformation, metamorphism, and magmatism at 10- to 20-km depths between 1700 and 1680 Ma (Chapter 2, this volume; Hawkins et al. 1996). One wonders how and when the >10-km-thick section of crust was eroded prior to the Grand Canyon Supergroup deposition.

The Great Uncomformity developed by erosion of about 10 km of crust to expose middle crustal metamorphic and igneous rocks at sea level as a broad low-relief surface. This erosion took place mainly after the emplacement of voluminous granites at ca. 1.4 Ga (Anderson 1982; Nyman et al. 1994) like the Quartermaster pluton in the Lower Granite Gorge, and before the deposition of the Bass Limestone. The Bass Limestone was deposited between 1.3 Ga, a cooling age on micas in schists below the uncomformity (Bowring et al. 1996), and 1.1 Ga, the age of mafic intrusions into the limestone.

STRUCTURAL GEOLOGY OF THE UNKAR GROUP

The Unkar Group is a 2-km-thick section with carbonate at its base overlain by thick marine to fluvial siliciclastic rocks. The section is cross-cut by sills and dikes of diabase (ca. 1.1 Ga) and covered by the uppermost formation of the Unkar Group, the ca. 1.07-Ga Cardenas Lavas (Elston and McKee 1982). The Unkar Group contains both contractional and extensional faults, as discussed below, and apparently record a period of basin formation that overlapped in time with the early stages of Grenville collisions to the south (see regional implications below).

Contractional faults horizontally shorten (and vertically thicken) a section of rocks. A number of northeast trending, steeply southeast dipping contractional faults of Mesoproterozoic age cut the lower parts of the Grand Canyon Supergroup and the underlying Granite Gorge Metamorphic Suite. These brittle faults record southeast-side-up sense of movement (reverse sense), suggesting northwest–southeast-directed shortening. Faults die out up-section into step-like, monoclinal folds in Unkar strata, where slip was taken up along bedding planes. Figure 5.4 illustrates the evidence for Unkar-age slip on the Bright Angel fault and monocline. The monocline is very tight in the lower beds, which are vertical and locally overturned adjacent to the fault, but the fold opens steadily upwards in the Unkar section. Within the Dox Formation, the fold is a broad, subtle deflection. A thickness change of 60 m within the Shinumo Formation on the northwest side of the Bright Angel fault suggests that faulting and sedimentation were synchronous. Total displacement across the fault in Proterozoic time is about 240 m, southeast-side-up.

Other Proterozoic reverse faults and monoclines are exposed in Bass, Vishnu, and Red Canyons. Contractional faults tend to parallel the regional northeast trending metamorphic fabric (grain) of the Granite Gorge Metamorphic Suite. Apparently the faults follow older planes of weaknesses in the earth's crust. Proterozoic contractional structures are known only in the Unkar Group and older

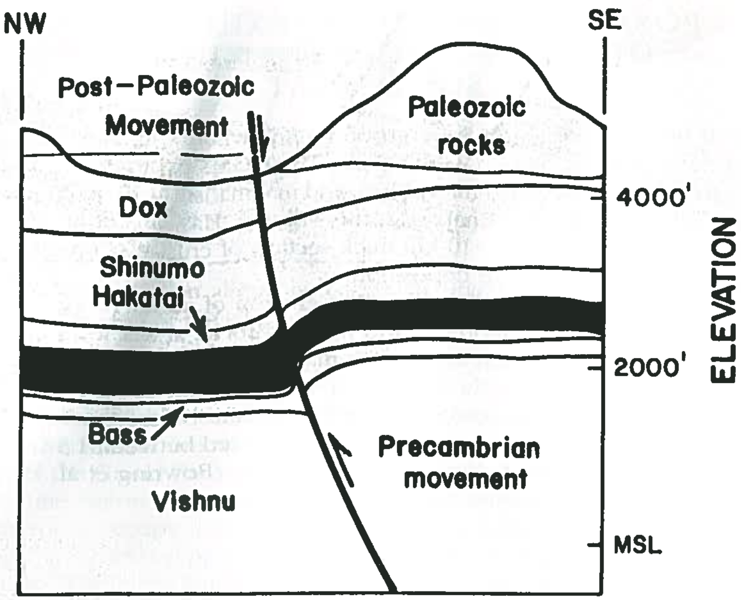

FIGURE 5.4. Cross section of the Bright Angel structure, northeastern Bright Angel Creek. Note that the Shinumo Quartzite is 60 m thicker on the northwest side of the fault, suggesting that faulting and sedimentation were synchronous.

rocks, suggesting that contractional brittle deformation is restricted to Unkar age. The timing of contractional faulting is important when we try to place the Unkar Group in a regional tectonic history (see regional implications below).

Extensional, or "normal" faults form during horizontal stretching of the earth's crust. Figure 5.5 shows five major extensional faults forming an array about 50 km wide from east to west in the depths of the Grand Canyon. Individual faults trend toward the north-northwest along curving traces, and they generally dip about 60° toward the west–southwest with west-side-down sense

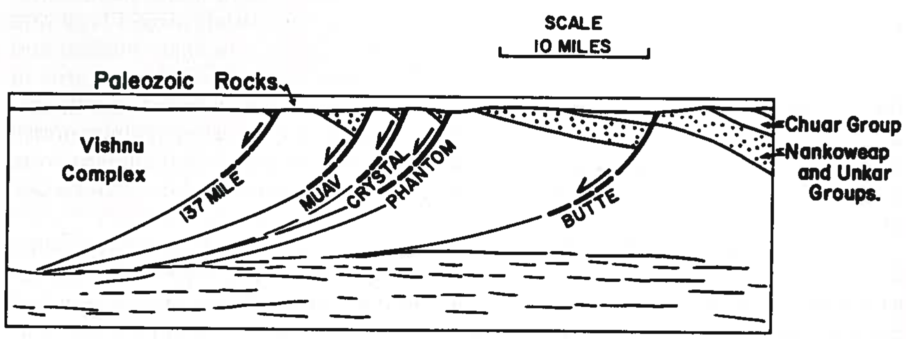

FIGURE 5.5. Schematic cross section showing major extensional faults of the Grand Canyon Supergroup. Rotation of the beds suggests that the faults flatten with depth.

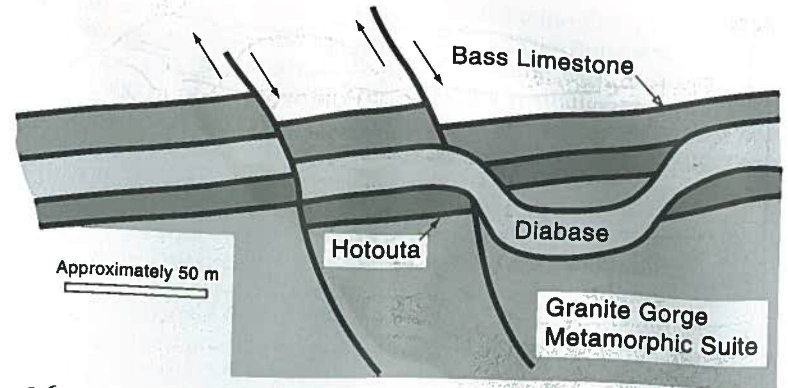

FIGURE 5.6. Fault relationship illustrating pre- and postdated 1.1-Ga faulting in the Unkar Group.

of movement. This geometry of tilted domino-style blocks is common in areas of crustal extension. Tilting of beds toward faults can also form if the faults, which are steep where exposed, curve and flatten with increasing depth. This listric geometry (Fig. 5.5) is also a pattern commonly documented in extensional terrains (Basin and Range province, Rio Grande rift, East African rift, and many others).

Documenting the timing of movement of extensional faults found within the Unkar Group is difficult. These faults are often truncated by the Cambrian Tapeats Sandstone and hence are Precambrian in age, but we have no way to test if those faults were truncated by younger Chuar sediments (indicating pre-Chuar age faulting). To further complicate timing interpretations, there is increasing evidence that extensional faults were active throughout deposition of the Grand Canyon Supergroup, suggesting that many of the faults had multiple movement histories. Figure 5.6 illustrates a fault relationship that indicates extensional faulting for both pre- and postdated 1100-Ma sill intrusions. There is also evidence for soft sediment deformation in the Dox Formation along the Butte fault, and the extensive convoluted bedding in the Shinumo Quartzite may suggest seismicity during Unkar deposition. Thus, available evidence suggests that Mesoproterozoic NW-trending extensional faults formed coevally with NE-trending contractional faulting and folding during Unkar deposition.

Nankoweap Formation

The Nankoweap Formation is a thin (100 m) section of red sandstones that is bounded above a below by uncomformities. Some workers have proposed that it represents a continuation of Unkar-like red bed sedimentation after the Cardenas Lavas, and noted a low angle angular uncomformity within the formation (Elston et al. 1993). Both the angular uncomformity and observed synsedimentary fault relationships suggest that extensional deformation was active during Nankoweap time. For example, in the Tanner graben we see a fault relationship that shows clear offset of the lower member of the Nankoweap Formation (Fig. 5.7). These offsets are filled and covered by the upper member of the Nankoweap Formation, clearly implying that faulting occurred during early Nankoweap time.

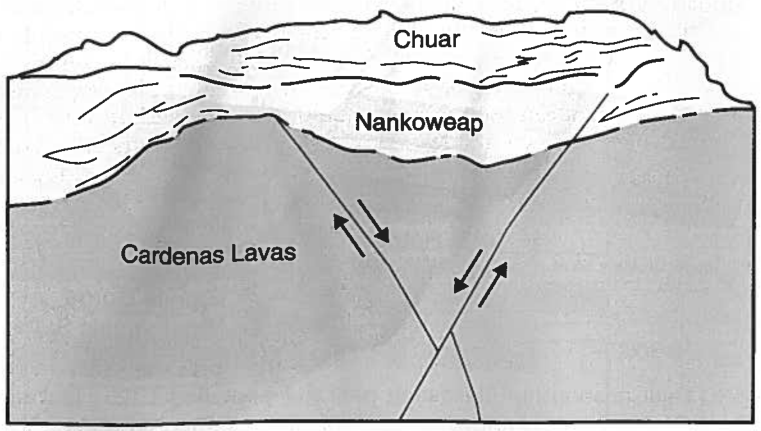

FIGURE 5.7. Graben in the Cardenas Lavas and lower Nankoweap Formation covered by upper Nankoweap and Chuar Group rocks.

STRUCTURAL GEOLOGY OF THE CHUAR GROUP AND SIXTYMILE FORMATION

Perhaps the preeminent structure in the Grand Canyon is the Butte fault system of the eastern Grand Canyon (Walcott 1890; Figs. 5.1 and 5.5). This structure was reactivated and now forms the main fault of the Laramide-age East Kaibab monocline, but its Precambrian movement history was longer and involved larger displacements. The Butte fault system is the easternmost structure of the array of exposed Precambrian normal faults (Fig. 5.5); it has the largest displacement and records a longer history of movement, warranting a separate discussion. Previous studies indicate the Butte fault may have been a basin-bounding normal fault, active during the deposition of the uppermost Chuar Group and Sixtymile Formation (Elston 1979; Ford and Breed 1973b; Cook 1991). Our new work has updated previous studies and suggests that most of the Chuar Group (Carbon Canyon, Duppa, Carbon Butte, Awatubi, Walcott Members) and Sixtymile Formation show thickness variations consistent with synchronous deposition, fault movement, and synclinal development throughout much of Chuar time.

The Chuar Group is a 2-km-thick section of shale and interbedded thin dolomite and sandstone that is spectacularly exposed in the eastern Grand Canyon. This section records relatively quiet water deposition, and the relatively abundant stromatolites and microfossils suggest an important increase in the diversity of organisms in the late Precambrian. The uppermost section also contains hydrocarbon-rich shales that are of interest as an oil source-rock. The sequence is not well-dated, but is post-1.1 Ga; uppermost units may be about 800 Ma, based on (a) reset K–Ar (potassium–argon) age determinations in the Cardenas Lavas (Elston and McKee, 1982) and (b) fossils present in the section (Andrew Knoll, personal communication, 1997).

BUTTE FAULT, CHUAR SYNCLINE, AND SUBORDINATE FAULT SYSTEM

The present Chuar Group exposures are bound on the east by the Butte fault, which is exposed for a length of 18 km before it is covered by Cambrian strata.

The continuation of the Butte fault, as expressed by the East Kaibab monocline, extends far to the north across the Utah border. The Butte fault trends to the north–northwest and dips moderately (60–70°) to the west. It presently has approximately 2900 m of Proterozoic west-side-down stratigraphic separation, but when Laramide reactivation (300 m west-side-up) is removed, it must have had on the order of 3200 m of west-side-down stratigraphic separation at the end of the Proterozoic (Elston and Mckee 1982; Elston 1989b). This magnitude of offset can only be seen in a traverse from the Colorado River to the Chuar Group outcrops along Carbon Creek. Movement was predominately dip-slip, as shown by slickensides oriented parallel to the dip of the fault.

Subordinate normal faults within the Chuar Group are parallel, and from the sedimentary record (see below) it apparently moved at the same time as the Butte fault. These faults include (a) other west-dipping faults that are parallel to the Butte fault and (b) a few east-dipping faults that form the sides of symmetrical grabens (as opposed to half grabens) such as the Basalt Canyon fault. Displacements on these faults are on the scale of meters to tens of meters and thus do not change the overall asymmetry of the Butte system.

The Chuar syncline is a broad, open, trough-shaped fold just west of and parallel to the north–south trace of the Butte fault (see Fig. 4.1, Chapter 4). The fold is asymmetrical with steeper dips on the east limb, adjacent to the Butte fault. The axial plane of the syncline dips 60–70° east, an orientation that is conjugate to the 60°-west-dipping Butte fault (Fig. 5.8). Parallelism of the synclinal axial plane and the Butte fault, its asymmetrical geometry, and tightening of the syncline at depth combine with intraformational faults and sedimentary evidence to show that the syncline is a growth structure that developed during progressive deepening of the basin on the downthrown side of the fault. The synclinal fold axis porpoises along the trace of the fault, suggesting differential extensional displacement along the fault during Chuar time. None of the synclinal features can be observed in the Paleozoic cover, indicating that the syncline is Proterozoic in age and unrelated to the reactivation (reverse sense) of the Butte fault in Laramide time.

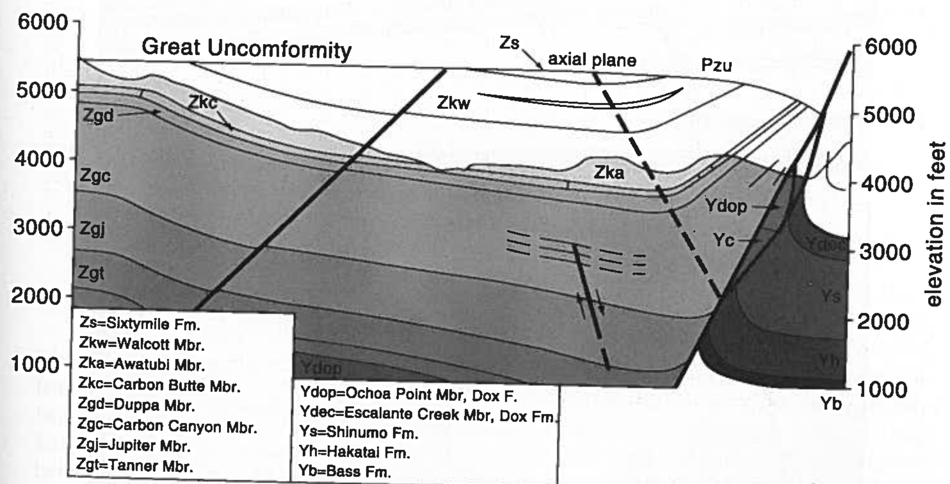

FIGURE 5.8. Schematic E–W cross section near Nankoweap Butte. Synclinal axial plane and Butte fault plane are parallel in strike (north) and are conjugate pairs (~50° angle between planes). Note thickness variation of upper members across syncline, along with intraformational fault in the Carbon Canyon Member.

SEDIMENTARY RECORD FOR PROLONGED INTERACTION OF SEDIMENTATION AND TECTONISM

Previous studies have proposed that there is evidence for synchronous deposition and fault movement in the uppermost Chuar Group and the Sixtymile Formation. For example, carbonate layers of the upper Walcott Member near the top of the Chuar Group pinch out toward the Butte fault, suggesting that deposition and synclinal development were synchronous (Fig. 5.8) (Elston 1979; Cook 1991). More dramatically, convolute bedding, bedding parallel slip surfaces, and intraformational breccias collectively indicate that synclinal development continued during deposition of the Sixtymile Formation. For more detail, see Chapter 4.

Our recent work shows that fault movement can be documented by sedimentation patterns and sedimentary structures within the Chuar Group. For example, measured sections between the basal sandstone of the Carbon Butte Member and the stromatolite at the base of the Awatubi Member are thicker in the synclinal axis and thinner on the east limb proximal to the fault. This is true for many different facies such that facies alone do not account for the thickness variation, and instead we suggest that the syncline was deepening and acting as a depocenter. Furthermore, the tightening of the syncline at depth requires there to be more sediment in the axis than on the east limb (Fig. 5.8). Abrupt thickness changes across subordinate faults can be observed in the Carbon Canyon Member (Fig. 5.9), and Carbon Butte Member. These structures tell us that the Butte fault system was responding to regional extensional stresses during sedimentation and synclinal growth. Wave-ripple crests in the sandstones of the Carbon Butte Member trend parallel to the syncline and Butte fault, suggesting that shorelines were parallel to structural trends. Widespread water-escape structures found in sandstone beds of the Carbon Butte Member may reflect recurrent seismic activity during deposition.

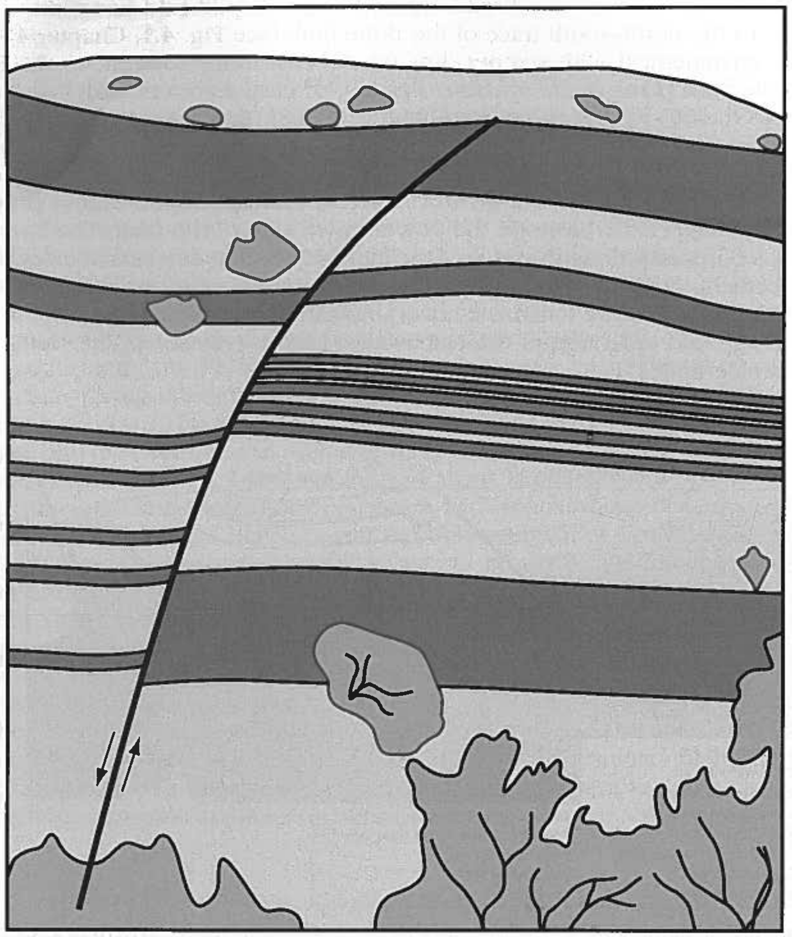

FIGURE 5.9. Sketch of an intraformational fault in the Carbon Canyon Member of the Galeros Formation, indicating that sedimentation and faulting were synchronous. View is to the southeast.

As detailed work continues in the Chuar Group, the model for Chuar basin evolution will become more refined. Combined with previous work in the Walcott Member of the Chuar Group and Sixtymile Formation, our new work suggests that basin deepening and synfaulting sedimentation took place during recurrent extensional slip on a regional scale fault system throughout Chuar Group deposition. The Sixtymile Formation marks a culmination of this syntectonic deposition, and possibly a change in the nature of deposition and tectonism at ca. 800 Ma.

Sixtymile Formation

The Sixtymile Formation marks a dramatic change in the style of deposition in the Chuar Group, from quiet-water marine shale to coarse sedimentary breccia and red sandstone indicating both higher energy deposition and probable tectonism on the Butte fault (Elston 1979). The Sixtymile Formation is exposed only in four outcrops in the hinge of the Chuar syncline. The lowermost member of the Sixtymile Formation is characterized by large (10-m scale) dismembered blocks surrounded by shale and olistostrome beds (slumped or gravity slide deposits) that record seismicity and fault movement during Sixtymile deposition. Several higher chert horizons and interbedded interclastic breccia in shale and tuffaceous shale mark continued episodic emergence and tectonism. The upper breccia on Nankoweap Butte fills 3-m-deep incised paleocanyons cut in shale that trend parallel to the Butte fault, suggesting continued influence of the Butte fault on sedimentary patterns.

POST-SIXTYMILE EROSION AND PHANEROZOIC REACTIVATION

There is no record preserved between the Sixtymile Formation and the uncomformity at the base of the Cambrian. Neoproterozoic faulting and tilting probably continued after Sixtymile deposition to bring the Cardenas Lavas and Dox Sandstone in the foot wall adjacent to upper Chuar Group shale. By Middle Cambrian time, erosion had again reduced the Grand Canyon Supergroup and underlying metamorphic rocks to a nearly smooth, flat plain. Ridges of Shinumo Sandstone rise up to 600 feet (180 m) above the generally level plain along the trends of the tilted blocks. The sea advanced over this plain from west to east and drowned the islands of Shinumo Sandstone in sand and mud of the Cambrian sea, about 510 million years ago.

After Paleozoic and Mesozoic strata buried the Grand Canyon region, many of the Precambrian Faults reactivated again and generated faults and folds in the younger beds. Nearly all of the major structures cutting Paleozoic rocks in the Grand Canyon region have a Proterozoic ancestry. The Butte fault was reactivated in a west-side-up sense and caused folding of the Paleozoic cover into a great east-facing monocline (Fig. 5.8). This monocline can be traced far to the north across the Utah border, and south to coincide with the Proterozoic Cherry Creek and Canyon Creek faults in the Apache Group of central Arizona. For more details on post-Paleozoic tectonism and reactivation of Proterozoic faults see Chapter 14.

REGIONAL IMPLICATIONS AND CONTINUED PROBLEMS FOR SUPERGROUP TECTONISM

This section highlights continued problems and uncertainties in understanding the long history recorded by the Grand Canyon Supergroup. Meso and Neoproterozoic sedimentary rocks of the Grand Canyon Supergroup, important uncomformities within this section, and the bounding uncomformities collectively record about 700 million years of earth history, a period longer than the entire Phanerozoic. We will never know what happened during this interval as well as we know the Phanerozoic because of incomplete outcrop and sparse fossil record, but ongoing studies are yielding new insights and questions about this important time in earth history.

The record as we now understand it involves a complex history of interaction between intracratonic basin formation (by faulting) and deposition to fill the basins. Was this a long progressive history or several discrete episodes? While it is possible that rifting took place more or less continuously from 1.3 Ga to 550 Ma, we favor the idea that rifting took place in two main pulses, recorded by sediments of the Unkar and Chuar Groups. The Unkar Group appears to contain evidence for synsedimentary NW contraction, NE extension, and mafic magmatism, and is possibly the result of far field stress associated with the Grenville collision in Texas (Fig. 5.10). Following a hiatus of unknown duration (Nankoweap uncomformities), the rocks of the Chuar Group and Sixtymile Formation record reactivation of preexisting faults that seem to be responding to regional E–W-directed extensional stresses around 800 Ma.

Much of North America was affected by the 1.3- to 1.1-Ga Grenville orogeny. This was a collisional suture between North America and another unknown continent, similar to the ongoing collision between Asia and India. The mountain belt with associated magmatic activity and metamorphism was concentrated in a belt that extended from Texas to New York. While this area was experiencing intense NW-directed contraction, large regions of the continental interior were trying to rift apart, extending in a NE–SW direction (Fig. 5.10). For example, the 1109- to 1086-Ma Midcontinent Rift System represents a large failed rift (Van Schumus and others 1992). Another 1100-Ma structure is the Central Basin Platform of northern Texas and southeastern New Mexico (Adams and Keller 1996). In Arizona, sedimentary rocks of the Apache Group and the Unkar Group were deposited between 1.4 Ga and 1.1 Ga and were intruded by 1.1-Ga diabase sills.

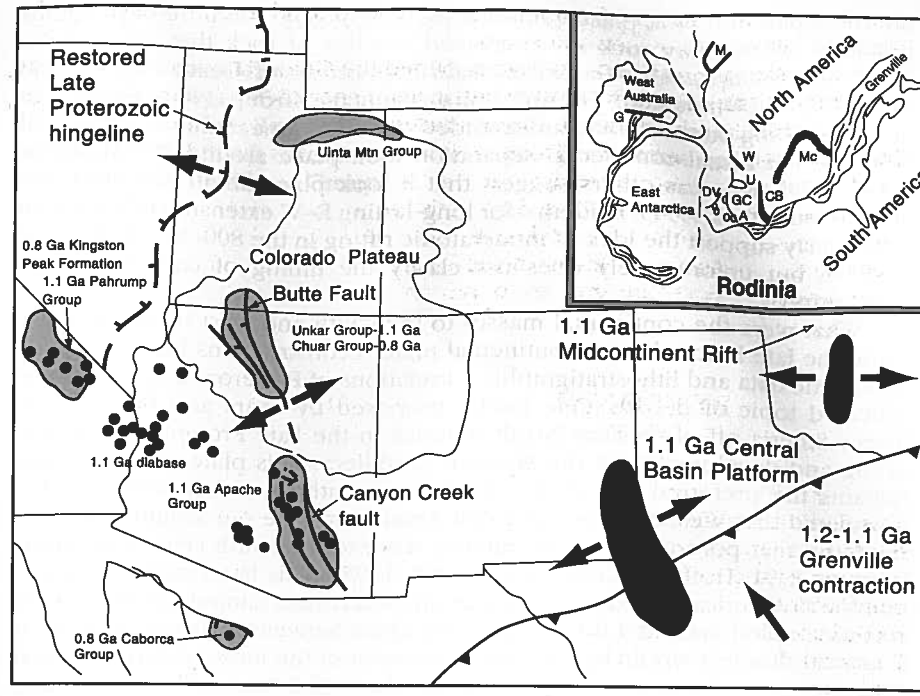

FIGURE 5.10. Mafic igneous rocks (black), sedimentary basins (stippled), and extensional structures of the Southwest from 1.1 to 0.8 Ga. Inset shows part of the Rodinian reconstruction after Borg and DePaulo (1994). (After Moores 1991.)

Both the Apache and Unkar sediments and their associated mafic sills may record the NW contraction and the NE extension caused by the Grenville orogeny. Although the shape of the basins are unknown (we do not know if the Unkar and Apache Groups were contiguous), we speculate that the development and filling of these basins may record the far-field effects of a continental scale collision.

There are several hints that the Chuar Group may record a second, separate, intracratonic rifting event at about 800 Ma. These rocks were deposited in a deepening fault-controlled basin or set of basins, with the N–S Butte fault as an important synsedimentary fault. Both fossils and preliminary paleomagnetic data suggest that the Chuar Group is less than 1 billion years old, and if the proposed 800-Ma age for the Sixtymile Formation is correct (Elston and McKee 1982), our new data suggests that this age is the culmination of Chuar rifting rather than the initiation of rifting as suggested by Elston.

There is also a record of Late Proterozoic extension in other ancient sedimentary basins of the western margin of North America (Fig. 5.10). In a zone from Death Valley to Northern Canada there is a major westward-thickening prism of sediment, the Cordilleran miogeocline, that marks the development of an Atlantic-style rift margin in Western North America in the Late Proterozoic. The immense length of this margin suggests that a major continental mass rifted away, but we do not know what continent it was, nor when the rift separation took place (Burchfiel et al. 1992). At the base of this thick prism of sedimentary rock are preserved patches of rock that are 1.45 Ga (Belt Supergroup), >1.1 Ga (lower Pahrump Group of Death Valley), and 800–700 Ma (Windemere Group, Uinta Mountain Group), suggesting that episodic rifting occurred over an extended period of time. Some workers suggest that the actual continental separation took place around 700 Ma (Ross et al. 1989), whereas others suggest that it took place about 550 Ma (Levy and Christie-Blick 1991). Evidence for long-lasting E–W extension in the Chuar Group may support the idea of intracratonic rifting in the 800- to 700-Ma time interval, but unfortunately does not clarify the timing of continental dismemberment.

What were the continental masses to the south and west of North America in the late Precambrian? Continental plate reconstructions based on paleomagnetic data and lithostratigraphic correlations of Proterozoic rocks remain a heated topic of debate. One model proposed by Sears and Price (1978) places Siberia off of western North America in the Late Proterozoic prior to rifting and development of the Western Cordillera. This plate reconstruction remains the preferred model of one of the coauthors. Other workers have postulated that West Australia and East Antarctica were our neighbors to the west and that portions of South America were to the south (Fig. 5.10, inset) (Moores 1991; Hoffman 1991; Dalziel 1991, 1997). This latter model suggests that North America was part of a supercontinental mass, named Rodinia, which was assembled around 1.0 Ga and broke apart between 750 and 550 Ma. If it existed, Rodinia would be the distant ancestor of the more widely accepted supercontinent Pangea, which assembled about 300 Ma and is still drifting apart today.

Ongoing work in the Grand Canyon Supergroup will continue to improve regional and global correlations as well as absolute ages for sedimentation and tectonism. Often, the subtle record preserved in sedimentary basins in continental interiors can provide clues to the nature of events at distant plate margins. It remains to be seen if the Grand Canyon Supergroup is recording the far-field effects of (a) 1100-Ma collision and coeval failed rifting (supercontinent assembly) and (b) ~800-Ma incipient rifting of a supercontinent.

SUMMARY

The Grand Canyon Supergroup offers a unique record that fills part of the gap in Powell's "Great Uncomformity," a time period we are just beginning to unravel. Emerging models point toward a prolonged history of tectonism in western North America that is cryptically recorded by an interaction of sedimentation and faulting in the Grand Canyon Supergroup. The Unkar Group and associated mafic magmatism appears to record an intracratonic basin that formed in response to NW contraction related to the Grenville collisions to the south (1.2–1.1 Ga). This was followed by a hiatus of unknown duration marked by uncomformities bounding the Nankoweap Formation. The Chuar Group records renewed intracratonic rifting, probably related to the early stages of supercontinent breakup. This rifting apparently failed in the Grand Canyon region, but eventually led to successful rifting and formation of the Cordilleran miogeocline between North America and the ancestral Pacific Ocean by 550 Ma (Link et al. 1993).

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