AAPG HEDBERG CONFERENCE
"Late Paleozoic Tectonics and Hydrocarbon Systems of Western North America – The Greater Ancestral Rocky Mountains"
July 21-26, 2002, Vail, Colorado

A Basement Framework Hypotheses for the Tectonic Architecture and Geologic History of the Western Mid-Continent, USA

Marvin P. Carlson, Nebraska Geological Survey

Introduction

Historical Perspective: The southward growth of North America after formation of the Hudsonian continent at about 1.82 Ga (billion years ago) is generally characterized across the mid-continent as the Transcontinental Proterozoic province with possibly several subdivisions depending on the perspective of the individual author.

Contention: Available data on rock type and age allows the interpretation that several families of island arcs accreted to the Hudsonian continent during the 1.8 to 1.6 Ga interval. This southern expansion of North America emplaced a series of sutures and boundary zones that controlled later tectonic events.

Historical Perspective: In many publications about the western mid-continent, the Phanerozoic structural pattern is described as dominated by the Transcontinental Arch. This feature has been portrayed with a wide variety of locations, trends, and influence depending on the intent of the individual author. There are also a large number of transverse structures that have been rejuvenated repeatedly during the Phanerozoic that are seemingly unrelated to one another or to the accepted regional stress events.

Contention: There is no transcontinental structural feature extending northeast-southwest across the western mid-continent. Instead, there are a series of smaller northwest-southeast trending structures that have a history of reactivation and, when taken together and enhanced by the development of the Williston and Anadarko basins, appear as a backbone feature.

Historical Perspective: There is no published framework defining and interrelating the tectonic architecture, the depositional patterns and the unconformities all of which are critical to mineral and petroleum exploration in the western mid-continent.

Contention: A systematic development is suggested that effectively interrelates the geologic and tectonic history of the western mid-continent since its inception during the Precambrian.

Transcontinental Proterozoic Belt

The Precambrian of the western mid-continent was discussed by Van Schmus et al (1993) including the Transcontinental Proterozoic Belt. Portions of this belt have been described by many including Sims and Peterman (1986), Karlstrom and Humphries (1998) and Carlson (2001). There is general agreement that available data suggest that this portion of the North American Precambrian basement represents an accumulation of island arc material. Prior to 1.8 Ga, the Wyoming and Superior Archean provinces were separate cratons slowly growing by marginal accretion. A significant addition on the south of the Superior province was the Penokean terrane accreted at about 1.84 Ga. At about 1.82 Ga,

The Wyoming and Superior began a somewhat transverse collision culminating in the TransHudson orogeny. As a result of the collisional process, major wrench stress was created within both Archean provinces. The resulting intervening TransHudson province contains craton-arc and arc-arc sutures and a variety of age and rock types that represent both new orogenic material and a conglomeration of the earlier craton and arch basement.

Following the 1.82 Ga consolidation of the Hudsonian craton there was a continuing process of island arc accretion expanding North America southward (Figure 1). Several families of arcs participated in this growth period from 1.8 to 1.6 Ga. Accreting from the southwest were the consecutive series of terranes; the Mojave (Mv) at 1.75 Ga, the Yavapai (Yv) at 1.70 Ga, and the Mazatzal (Mz) at 1.65. Accreting from the south were the Dawes (Da) at 1.78 Ga, the Frontier (Ft) at 1.71 Ga, the Hitchcock (Hi) at 1.67, and the Kansas (Ks) at 1.61 Ga. Accreting from the southeast were successors to the Penokean terrane, the Southern Iowa (SI) at 1.76 Ga, the Northern Missouri (NM), and the Central Missouri terranes (CM). Each period of island arc accretion created a fundamental suture in the basement architecture of this portion of North America. These sutures persist as zones of weakness in the crystalline basement and are the trends of rejuvenation during periods of regional stress. Later Precambrian history, as well as that of Phanerozoic tectonics, delineates the location and trends of these fundamental sutures by both sedimentational and structural patterns.

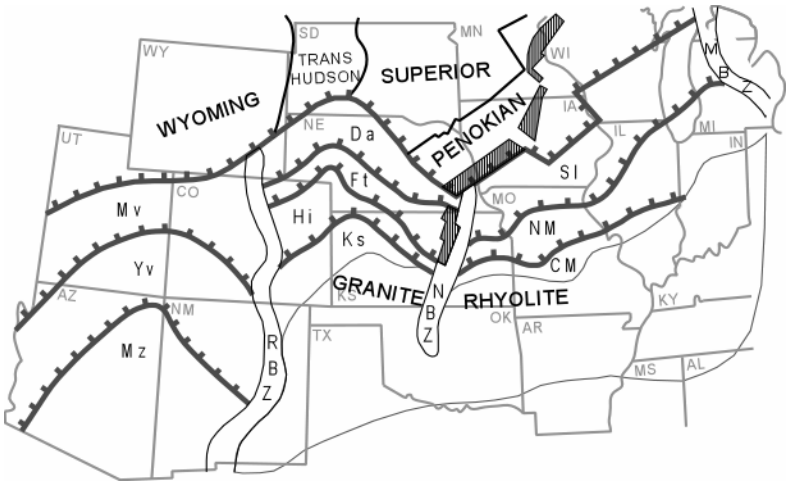

Figure 1

Two strong N-S structural trends appear anomalous across the mid-continent; the Rocky Mountains and the Nemaha Uplift. These trends have a similar history of repetitive rejuvenation during the late Precambrian and throughout the Phanerozoic. This N-S fabric is not apparent in the accretionary trends that emplaced the basement rocks of this area during the Precambrian. It is proposed that these two trends, the Rocky Mountains and the Nemaha Uplift, represent the boundary zones between the series of island arcs that accreted onto the Hudsonian continent during the period 1.8 to 1.6 Ga. The Rocky Mountains represent the general N-S boundary between the series of arcs accreting onto the southwest margin of North America and the series of northward accreting arcs across the Nebraska-Kansas area. The Nemaha Uplift reflects the boundary

between these central arcs and a series accreting from the southeast across Iowa and Missouri.

Phanerozoic Architecture of the Central United States

A major North American structural element, "the backbone of the continent", was included by Keith in his 1928 presidential address to the Geological Society of America. He illustrated a sinuous trend extending from central Canada into central Mexico, which he said "has persisted through all the ages back to the beginning of the Paleozoic". Eardley's interpretations (1951) suggested that the arch included numerous fragments, which he said constitute "a central northeast-southwest-trending transcontinental arch". In the literature, the concept of a transcontinental arch across North America is commonly depicted as having had tectonic and/or depositional influence throughout much of geologic history. However, the location, magnitude, and even the dominant trend of the feature through time are inconsistent among these studies; inconsistent beyond what would usually be considered appropriate for a major tectonic feature.

Carlson in 1999 created a series of maps that illustrated zero edges and major thickness patterns for segments of the geologic record. These compilations and several derivative maps (paleogeologic and suprageologic) demonstrate the recurrence of significant tectonic features at various intervals during the Phanerozoic. Upon closer examination of the details of local stratigraphy, this transcontinental trend is seen to consist of a variety of smaller features that acted independently and that had differing local significance for the stratigraphic record (Figure 2). These tectonic features are for the most part basement controlled and recur as positive areas on the system isopachous maps and on the derivative maps. These northwestward-trending highs, when taken in concert with the intervening lows or sags, create a sense of a broad northeastward-trending transcontinental platform. This apparent trend was further emphasized by the major basin development of the Williston to the north and the Anadarko to the south.

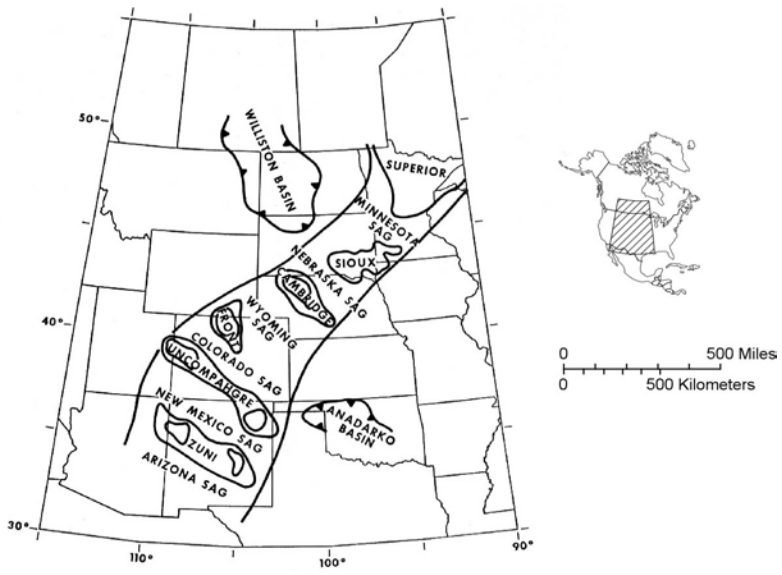

Figure 2

These segments of the transcontinental trend are a few of the many Phanerozoic structures that represent reactivation of the basement. The broad tectonic pattern now

present in the central United States consists of structures, generally NW-SE or NE-SE most of which reflect reactivation of the individual sutures that resulted from the progressive accumulation of accretionary arcs during the 1.8 to 1.6 Ga southward growth of the North American continent. Examples of the Phanerozoic features related to the Precambrian sutures are the Uncompaghre uplift, the Zuni uplift, the Chadron-Cambridge arch, the Central Kansas uplift and many more current structures. The repetitive rejuvenation of the Rockies boundary zone is evidenced by the trend of the Ancestral Rockies, the later Laramide orogeny, and the Rio Grande Rift. Rejuvenation of the Nemaha boundary zone is evidenced by the 1.1Ga placement of the Kansas segment of the Midcontinent Rift System and the series of Phanerozoic structures that together make up the Nemaha Uplift.

Conclusion

Progress has been made in relating the known Phanerozoic structures to the tectonic patterns created by the evolution of the underlying Precambrian basement in the central United States. The tectonic features created during the Phanerozoic have dominate trends of NE-SW, NW-SE, and N-S and reflect rejuvenation of the underlying sutures created by the accretionary arcs that formed the basement from 1.8 to 1.6 Ga. As a composite feature, the "Transcontinental arch" is a broad, discontinuous platform containing a series of transverse, persistent, basement-controlled structures. The individual highs served as local sediment sources and the lows (or sags) allowed marine transgressions. To effectively interpret the geologic history, the impact of local structural trends and local sediment sources should be carefully separated from the broad patterns expressed by this platform-like feature. Close attention must be given to the Precambrian accretionary terranes and their bounding sutures in order to understand the Phanerozoic history across the western mid-continent and better plan exploration strategies for natural resources.

References

Carlson, M.P., 1999, Transcontinental Arch – a pattern formed by rejuvenation of local features across central North America: Tectonophysics, v. 305, p. 225-233.

Carlson, M.P. 2001, Accretionary basement control on structure of central USA; Geological Society of America, Abstracts 2001 Annual Meeting, Boston MA

Eardley, A.J., 1951, Structural Geology of North America: Harper, New York, NY, 624 p.

Karlstrom, K.F. and E.D. Humphreys, 1998, Persistent influence of Proterozoic accretionary boundaries in the tectonic evolution of southwestern North America; Interaction of cratonic grain and mantle rock modification events: Rocky Mountain Geology, v. 33, p. 161-179.

Keith, A., 1928, Structural symmetry of North America: Geological Society of America Bulletin v.39, p. 321-386.

Sims, P.K., and Z.E. Peterman, 1986, Early Proterozoic Central Plains orogen; a major buried structure in the north-central United States: Geology, v.14, p. 488-491.

Van Schmus, W.R., et al., Transcontinental Proterozoic province, in Reed, J.C., et al., Precambrian: conterminous U.S.; Boulder, Colorado, Geological Society of America, Geology of North America, v. C-2, p. 270-281.