The Geology of the Kansas Basement: Part I

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Abstract

The identification of deficiencies and errors in the presuppositions and methods of uniformitarian natural history should be accompanied by an empirical reinterpretation of geological data within the Biblical Worldview. The wealth of geological and geophysical data demands a systematic replacement of the ruling paradigm by creationist explanations of the rock record. Such a reinterpretation is underway for the geology of Kansas, and the first step in that project addresses the basement. The erosional contact between the crystalline basement and overlying sediments can be interpreted as the erosional basal Flood boundary. The exception to this interpretation is found at the Midcontinent Rift System, a complex of basalt flows and adjoining sedimentary basins. This feature is interpreted as the tectonic basal Flood boundary, marking tectonic disruption associated with the Flood onset, with both basalt flows and sedimentation occurring between the onset of the Flood and its marine inundation of the region.

Introduction

Natural history is an important battleground between the worldviews of Christianity and naturalism. The latter has internal fatal defects (Reed, 2001), although its adherents continue to place great confidence in it as a bulwark against Christianity. Having dominated the arena since the time of Charles Lyell, the father of modern uniformitarian geology, it has a large corpus of literature, but since the framework and method are logically flawed, it follows that interpretation is, too. Christians have a coherent method for natural history, but few detailed models and a relatively modest corpus.

Conflict over natural history cannot be resolved at the empirical level, but can be by the demonstration of contradictions between presuppositions, conclusions, and methods within Naturalism. This level of analysis is becoming more prevalent with regard to evolution, but connections between Naturalism and uniformitarian natural history appear to escape many capable critics (e.g., Johnson, 1997; Pearcy and Thaxton, 1994; Behe, 1996; etc.).

Although a formal case against uniformitarian natural history can be argued successfully, those arguments do not resonate in our empirically oriented culture. Thus, the argument should be supplemented by a reinterpretation of natural history within the Biblical Worldview to attract the attention of our contemporaries and still the voices of skeptics. Interpretation must be constrained by the primacy of Scripture, a strong distinction between history and science, and the mixed question approach (Reed, 2001).

A major barrier to comprehensive reinterpretation is scale. On one end, global Flood models have been proposed, and on the other, specific locales interpreted. However welcome these efforts, it remains true that with few exceptions (e.g., Austin, 1994; Reed, 2000), most creationist efforts have not attempted the systematic displacement of uniformitarian interpretation point by point over a regional extent and/or the entire range of the geologic record.

The geology of North America is perhaps as well known as that of any other place on Earth, and the geologic profession in North America led the discipline in the twentieth century. A complete reinterpretation of North American geology within a biblical framework is a strategic goal that must be pursued by North American creationists; just as similar strategies are undertaken worldwide by our international colleagues (e.g., Lalomov, 2001; in press).

This paper addresses the midcontinent region of North America and the centrally located state of Kansas. Advantages include geographic centrality, an extensive historic database, and a relatively uncomplicated stratigraphic record. A goal of this and future efforts is to examine the regional geology from basement to surface and to reinterpret its geological features into a historical model constrained by the biblical record. A regional study of the Midcontinent Rift System (MRS) has been completed (Reed, 2000), and this paper will interrelate this feature in Kansas with the remainder of the predominantly crystalline basement.

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Methods and Data

Except for xenoliths found in kimberlite pipes in Riley

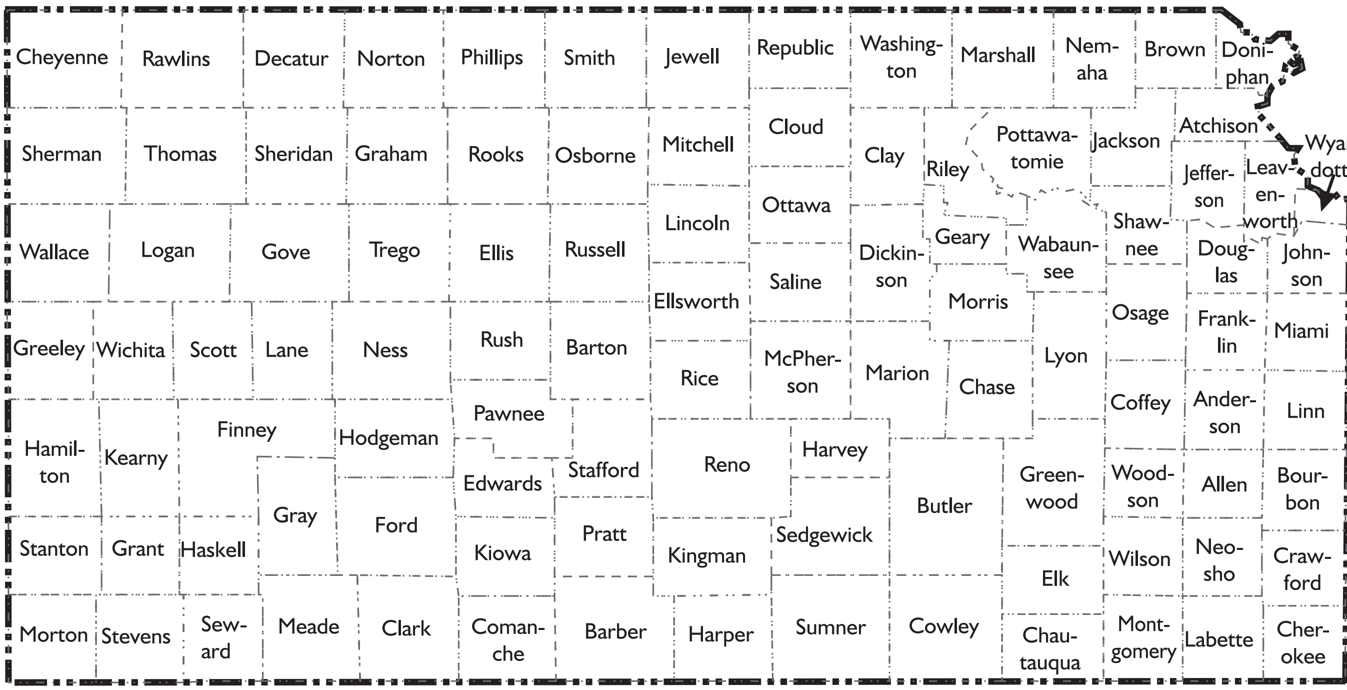

Figure 1. Kansas counties.

and Marshall Counties (Figure 1) and granite xenoliths occurring in peridotites in Woodson County, no basement rocks are exposed in Kansas (Brookins, 1970; Berendsen et al., 2000; Bickford et al., 1971). The oldest exposed strata are Mississippian [mention of the systems, etc. of the uniformitarian geologic column is presented for comparative reference only; the author rejects their absolute and sometimes, their relative dating efficacy], found in far southeastern Kansas (Ross, 1991). Thus, only subsurface methods are available to researchers to delineate basement features (Figure 2). These include geophysical (gravity, aeromagnetic, and seismic) surveys; and cores, cuttings, and logs from wells.

Regional studies of unexposed Precambrian basement have focused on geochemical (especially isotopic) data from cores to define specific domains of chemical and isotopic

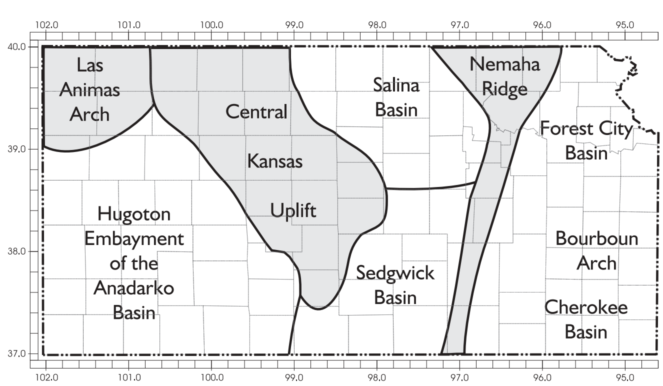

Figure 2. Basement features of Kansas after Zeller (1968).

similarity. However, geophysical data often do not recognize the boundaries derived from geochemical studies and vice versa (Van Schmus and Bickford, 2001). Geophysical data are more regularly distributed (especially statewide gravity and magnetic surveys), but provide only indirect measurement of selected basement properties; seismic velocity, acoustic impedance, density variations [base on gravity field variation], and magnetic polarization contrasts (Hinze and Braile, 1988). A good summary of data sources, their strengths and weaknesses, and their relevance to the midcontinent basement is found in Hinze (1996).

Gravity

The Kansas Geological Survey (KGS) collected gravity measurements between 1976 and 1992. Over 62,000 station measurements were recorded at one-mile intervals on an east-west axis, and between two and six mile intervals on a north-south axis. These stations were tied into a series of KGS base stations, which were in turn tied to Department of Defense stations and the International Gravity Standardization Net of 1971. Data were corrected for earth tide effects and instrument error, and the Bouguer anomaly at each station was calculated by adding the free air correction, and subtracting the reference field and Bouguer correction (Lam, 1986). A map was produced from the calculated Bouguer gravity anomaly (Xia, 1992; Xia et al., 1993) with a specified accuracy of 0.1 to 0.2 mgals, depending on the accuracy of the field location (X-

Y-Z) measurements for each station.

Interpretation of gravity data was enhanced by separation of local and regional gravity anomalies using trend surface analysis (Lam, 1986). Detection and interpretation of gravity anomaly trends were correlated to magnetic data. He used artificial illumination of the gravity map to reveal subtle trends and obtained an isostatic anomaly by subtracting the isostatic correction from the Bouguer anomaly.

Limitations of the gravity method restrict its application in geologic interpretation. Spacing of the measurements limits the detectable size of the body generating an anomaly. Anomalies can be generated by density variations in the crust, however density ranges of crustal materials overlap and can be further affected by porosity, temperature, water and gas saturation, and mineralogy. Anomalies depend on the size, shape, depth, and density contrast with surrounding crust. Large, shallow or smaller, deep bodies result in long wavelength spectra. Shallow, small bodies generate short wavelengths. The variety of solutions to the potential field problem require additional data be used to constrain gravity anomaly interpretations (Lam, 1986).

Magnetic Data

More than 72,000 line kilometers of high quality aeromagnetic data were acquired by the KGS in the late 1970's and early 1980's (Yarger, 1983). Measurements were tied to specific locations and the resulting map was transformed to the spectral domain, filtered to enhance interpretation, and then transferred back to the spatial domain. Details of filtering are provided in Table 1 of Yarger (1983). The root mean square error for the magnetic data was calculated at 3 nanoteslas (nT).

Xia (1992) and Xia et al. (1995) performed inversion of a combination of gravity and magnetic data to study the thickness and nature of the crust. Since both gravity and magnetic anomalies are partly caused by the shape of the basement topographic surface and its lithology, and since the topography can be modeled (Cole, 1976), the anomalies relative to lithology can be derived. Although density and magnetization are not unique to lithology, they can provide significant information about rock types. Using this information with well and seismic control, Xia (1992) and Xia et al. (1995; 1996) derived a basement lithology map based upon the inversion of the potential-field data.

Seismic Data

Although significant numbers of seismic lines exist in Kansas, most are proprietary to oil and gas companies, or are

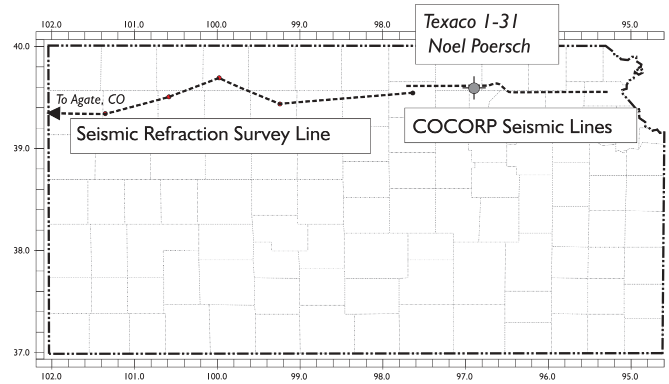

Figure 3. Location of Texaco #1 Noel Poersch well, COCORP seismic reflectionline, and Kansas Geological Survey seismic refraction line. After Berendsen et al. (1988) and Steeples and Miller (1989).

too expensive to acquire. Sophisticated manipulation of such data requires workstation capability. However, published reports of several seismic datasets are available in the general literature. Between 1979 and 1981, the Consortium for Continental Reflection Profiling (COCORP) acquired three lines totaling 317 km of reflection seismic data in northeastern Kansas, across the MRS, the Nemaha Tectonic Zone, and the Humboldt Fault (Figure 3). The lines were interpreted initially by Serpa et al. (1984), and were later reprocessed and reinterpreted by Woelk and Hinze (1991), and even later reinterpreted by Berendsen (1997).

A seismic refraction line (Figure 3) was acquired from Concordia, Kansas to Agate, Colorado (Steeples and Miller, 1989). Seismic refraction data are useful for determining gross crustal properties, such as thickness. These data showed an average crustal velocity of 6.1 km/sec and an average upper mantle phase velocity of 8.29 km/sec. Depth to the Mohorovicic Discontinuity (MOHO) was 36 km at Concordia, steepening to 46 km in Agate. The depth to Moho was modeled by gravity inversion by Xia and Spowl (1995) and derived similar results. They derived comparative depths of 35.2 km and 43.5 km, respectively.

Well Data

Oil and gas have historically been produced from numerous fields in Kansas (Jewett, 1954). Significant production is associated with the Hugoton embayment of the Anadarko Basin, the Forest City Basin, and fields associated with the Central Kansas Uplift and Nemaha Anticline structures. As of 1983, almost 3500 wells had been drilled to basement (Cole and Watney, 1985). Between 1984 and the present, roughly 1000 additional wells have

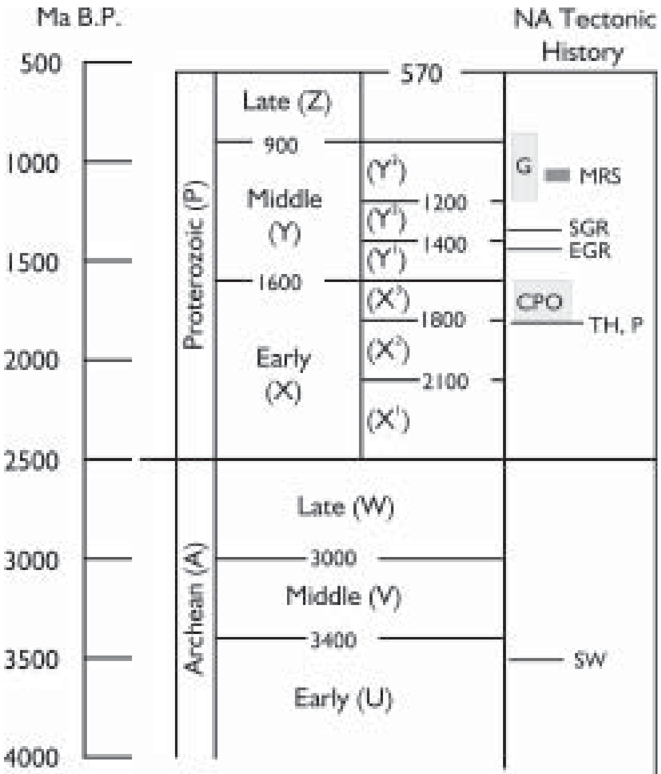

Figure 4. Precambrian time scale with elements of North America's uniformitarian tectonic history. SW is the Superior/Wyoming province, TH is the Trans-Hudson orogen, P is the Penokean orogen, CPO is the Central Plains Orogen, EGR is the Eastern Granite-Rhyolite province, SGR is the Southern Granite-Rhyolite province, G is the Grenville orogeny and MRS is the Midcontinent Rift System. The timescale is from Reed (1993).

been drilled to basement in Kansas (Watney, personal communication). Although the data from these wells varies (drill cuttings, cores, logs, etc), all of them are sufficient to give a depth to basement, and the gross lithology of the rocks encountered. Of those wells documented by Cole and Watney, only 253 penetrated 100 feet or more into the Precambrian basement. A more detailed description of pre-Paleozoic rocks was obtained from the drilling of the Texaco 1-31 Noel Poersch well in 1985 (Berendsen et al., 1988) to test oil and gas potential in MRS clastic sediments.

Geology of the Midcontinent Basement

Some knowledge of the surrounding regional Precambrian basement is required to place the features of the Kansas basement in context. Precambrian basement is exposed only over roughly 10% of the conterminous United States, of which only 25% has been mapped in detail (Reed, 1993). Interpretations of the basement are performed with reference to two fundamental assumptions: (1) the existence of joined crustal terranes of distinct origin and history, defined on the basis of radiometric ages (with consideration of lithology, geochemistry, rare-earth geochemistry, and structure), and (2) the application of the plate tectonics paradigm, despite sparse evidence relative to Phanerozoic examples. Therefore, emphasis is placed on grouping terranes by isotopic age and a presumed plate tectonics history. Timing of Precambrian events is considered less understood than Phanerozoic events tied to dates via fossils and stratigraphic position. A generally accepted time scale (Figure 4) was not derived until the early 1980's (North American Committee on Stratigraphic Nomenclature, 1983).

The midcontinent basement is a part of the North American craton. Sloss (1988) defined a craton as a stable continental interior, but noted that the transition from a geosynclinal approach to a plate tectonics approach rendered the definition of cratonic margins uncertain and time dependent. A marked feature of a craton is its stability for "…tens of millions of years of the solid surfaces of cratonic lithosphere within tens of meters (or at most, one or two hundred meters) of sea level…" (Sloss, 1988, p. 2). Cratonic stability is less emphasized within the paradigm of plate tectonics, and development of cratonic basins is tied to stresses transmitted from tectonic events (Leighton, 1996), although it is not suggested that dramatic vertical and lateral motions occur in continental interiors. Hinze and Braile (1988) defined the North American craton as that portion of the continent between the Appalachian-Ouachita orogenic belt and the Rocky Mountains, noting its relative stability for roughly one billion years. According to uniformitarian accounts, accumulation of a lasting, widespread sedimentary cover did not occur until the Phanerozoic, some 500,000,000 years later.

General physical features of the crust include crustal thickness, and mean compressional wave velocity for both the crust and upper mantle. Mean values for these features in the midcontinent region have been calculated as 42 km, 6.5 km/s and 8.1 km/sec, respectively (Hinze and Braile, 1988; Hinze, 1996). Hinze (1996) also notes that average heat flow for the northern midcontinent is approximately 1.4 HFU, average Bouguer anomaly is approximately –39.5 mGal, and average elevation is near 278 m.

Topographically, the regional basement surface in the midcontinent (Sims, 1990) dips to the south from surface exposures in Minnesota and Wisconsin (exposed basement extends north and east into the Canadian Shield) to deeply buried rocks in the south in the Anadarko-Arkoma-

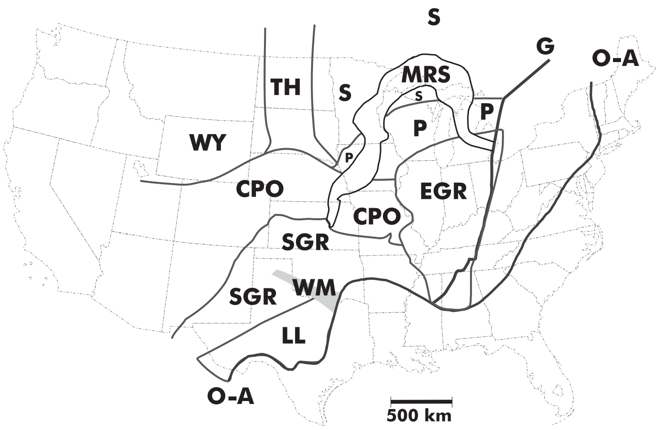

Figure 5. Basement provinces of the North American Midcontinent. S is the Superior province, W is the Wyoming province, TH is the Trans-Hudson orogen, CPO is the Central Plains Orogen, P is the Penokean orogen, EGR is the Eastern Granite-Rhyolite province, SGR is the Southern Granite-Rhyolite province, G is the Grenville front, MRS is the Midcontinent Rift System, LL is the Llano province, WM is the Witchita Magmatic province, and OA is the Ouachita-Appalachian front. Modified from Van Schmus et al. (1993) and Hinze (1996).

Ardmore basins at the Wichita Magmatic Province. Depths to crystalline rock in the Anadarko Basin ranges up to 12,192 m (40,000 ft) (Dutton et al., 1982; Johnson et al., 1989). This general south-dipping surface is interrupted by various cratonic basins, most of which are interpreted as having been formed during the Paleozoic (e.g., Williston, Illinois, Michigan, Salina-Forest City).

There are a number of Proterozoic cratonic fold and fault zones interpreted by Marshak and Paulsen (1996) and Marshak et al. (2000) as the result of late Proterozoic extension that fractured the craton of North America into tectonic blocks and later served as zones of weakness for Phanerozoic inversion, transpression, and transtensional faulting. These trends are predominantly oriented in two directions; north to northeast, and east to southeast. Structural influences on initial Phanerozoic sedimentation were predominantly extensional (Marshak and Paulsen, 1996), resulting from Proterozoic to Eocambrian rifting at numerous locales in the craton. Extension was supposedly caused by the late Proterozoic rifting.

Uniformitarian Precambrian history is presented as the gradual accretion of the continents during the Archean and Proterozoic by plate tectonic processes. Thus, the Midcontinent basement is divided into distinct provinces (Figure 5), grouped on the basis of isotopic dates (Van Schmus et al., 1993; 1996) and inferred plate tectonic history. These include:

Superior and Wyoming Provinces	Up to 3600 Ma
Central Plains Orogen	
North	1800–1700 Ma
South	1700–1600 Ma
Trans-Hudson Orogen	1880–1830 Ma
Penokean Orogen	1880–1830 Ma
Southern Granite Rhyolite Province	1370 Ma
Eastern Granite Rhyolite Province	1470 Ma
Llano Province	~1200 Ma
Grenville Province	1240–800 Ma

The core of the Precambrian North American craton is the Archean to early Proterozoic Superior Province (also called the Hudsonian craton). It extends south from Canada into the Dakotas where it is bounded by the north-south trending Trans-Hudson orogen (Figure 5). On the west side of this orogen, the Wyoming Province extends into northeastern Nevada. The Superior Province is truncated in the southeast by the Grenville province. South of the Superior Province, in Iowa, Wisconsin, Michigan, and Ontario, lies the 1.85 Ga Penokean orogen, a region of deformed and metamorphosed rock.

The Central Plains orogen (Sims, 1990; Sims and Peterman, 1986) is more than 1000 km long and 500 km wide, and is delineated based on basement drilling and geophysical data from several states. It is a broad curving belt of metamorphic and granitoid rocks that extends from Missouri into exposed sections of equivalent rocks in Colorado and Wyoming, but is currently undefined in the eastern midcontinent. It includes an older northern unit (1.8–1.7 Ga) and a younger southern unit (1.7–1.6 Ga). Lithotypes, including metaigneous and metasedimentary rocks, have been described in numerous wells drilled in Kansas, Missouri, and Nebraska, and are described in detail by Van Schmus et al. (1993). Overlying some of the metamorphic rocks of the Central Plains orogen is the Sioux Quartzite, believed to be coeval with the Baraboo Quartzite in Wisconsin.

Rocks in the southern Central Plains orogen are primarily granite, and are known from numerous wells in Kansas, and from less numerous wells in Missouri. Current interpretation (Van Schmus et al., 1993) of these data includes formation of a volcanic-plutonic suite between 1.66 and 1.67 Ga as a possible island arc, which was later intruded by younger (1.62 Ga) granite batholiths. Those portions known from drilling data in northern Kansas are considered to represent the core of the batholith, indicating severe erosion of this part of the crust.

Outboard of the Central Plains orogen lie the south-

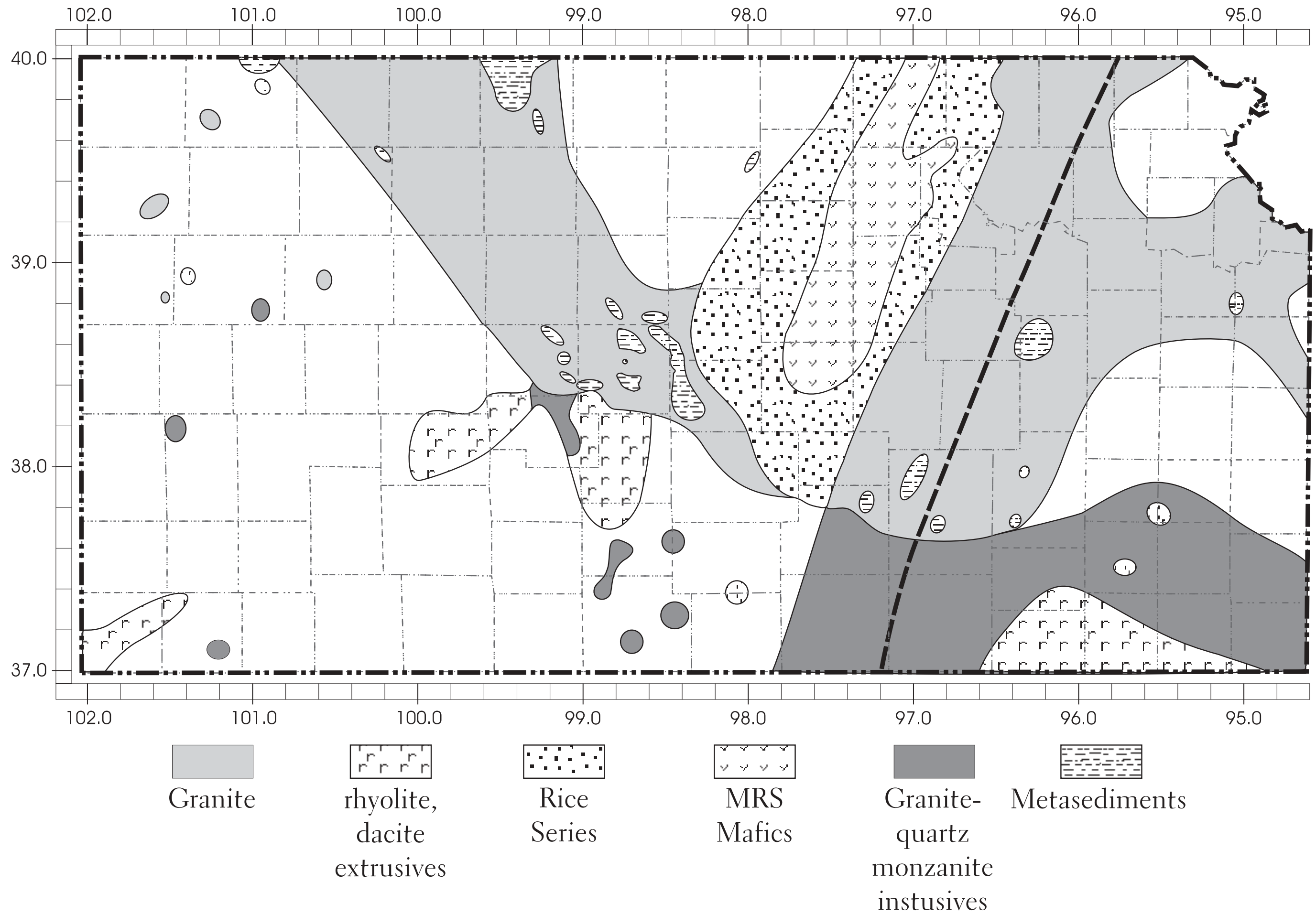

Figure 6. Precambrian subcrop (lithology) in Kansas. From Bickford et al. (1979).

ern and eastern granite-rhyolite provinces. Sm-Nd crustal age data (Van Schmus et al., 1996) lead researchers to believe that much of the granite-rhyolite provinces are veneers covering older crust of the Central Plains orogen. The Southern Granite-Rhyolite Province is 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, with gneissoid rocks in southern Oklahoma. These rocks are chemically and petrographically similar to the Eastern Granite-Rhyolite Province (Figure 5), but are isotopically dated as younger than those 1.47 Ga rocks.

Suites of younger granite plutons intrude rocks of the Central Plains orogen in many locations. There are two age distributions of these plutons that correspond to the Eastern and Southern Granite Rhyolite provinces; circa 1.47 Ga and 1.37 Ga. Some of these plutons can be identified by circular magnetic anomalies with no corresponding gravity anomaly (see Figure 11). Some of these plutons have been confirmed by drilling and range from less than 1 km to greater than 40 km across. The largest, the Red Willow batholith, is located in southwestern Nebraska and northwestern Kansas (Lidiak, 1972).

Morphology and Basement Features

Key features of the Kansas basement include two distinct lithologic/isotopic terranes and several structural/tectonic features. A map of the basement surface in Kansas (Figure 6) shows the Precambrian subcrop at the Cambrian unconformity (Bickford et al., 1979). Additional detail has been added since then at the MRS and Nemaha Tectonic Zone (Berendsen and Blair, 1996), but knowledge of the general morphology of the subcrop remains much as originally mapped by Bickford et al. (1979).

The surface of the Kansas basement ranges from slightly above sea level in the Nemaha Tectonic Zone to almost

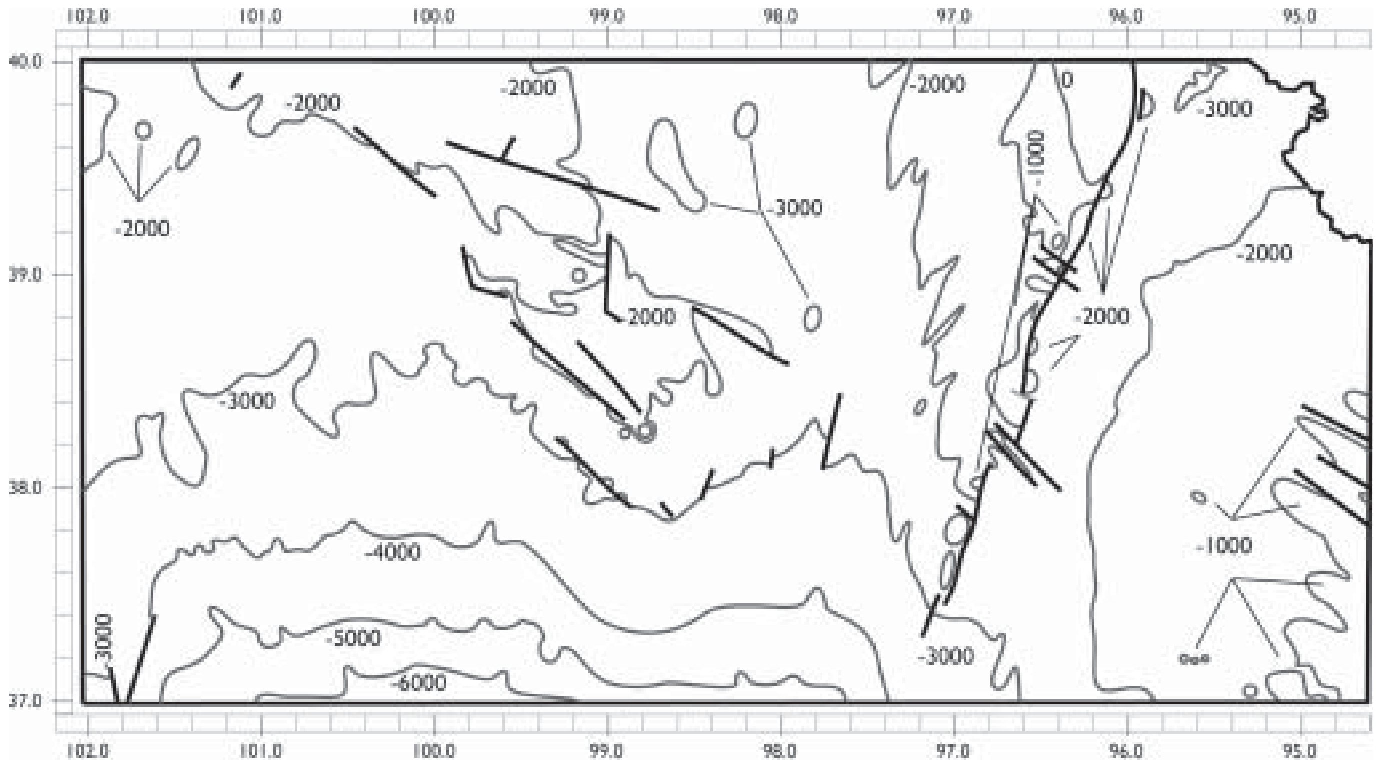

Figure 7. Precambrian subcrop structural surface elevations. After Cole (1976) and Bickford et al. (1979).

-2,134 m (-7,000 ft) subsea at the Oklahoma border (Figure 7). The physiographic surface in Kansas ranges from 207 m (680 ft) to 1,231 m (4,039 ft) above MSL. Xia et al. (1996) report that the structure map of Bickford et al. (1979) has proven generally accurate within the 100 ft. contour interval. In eastern Kansas, the basement dips gently west into the Nemaha Tectonic Zone and north-northeast into the Forest City Basin (Figure 8). This structural trend reflects dip off the roughly circular Ozark Uplift in neighboring southern Missouri, where basement rocks are exposed at the surface. In central and western Kansas, the basement dips to the south towards the Anadarko Basin in southern Oklahoma. The deeper basement in southwestern Kansas forms the Hugoton Embayment of the Anadarko Basin, noted for its extensive natural gas reserves.

The morphology of the basement highlights several other features (compare Figure 8 to Figure 2). The Nemaha Tectonic Zone (also called the Humboldt Fault Zone) runs roughly north-south through eastern Kansas from southeastern Nebraska to southern Oklahoma. Yarger (1983) determined that there was little to no strike-slip component to this fault based on magnetic data. However, the Nemaha Ridge has little gravity expression because the uplifted basement is juxtaposed against sediments of similar density. Steeples (1982) noted that the fault is still active at the present.

In north central Kansas, a basement high forms the Central Kansas Uplift, the southern extension of the Cambridge Arch in Nebraska; both are elements of the Transcontinental Arch. A +25 mgal gravity anomaly in Barton County and a +15 mgal anomaly in Norton County mark the ends of the Central Kansas Uplift (Figure 9). Between the Nemaha Tectonic Zone and the Central Kansas Uplift lies the Salina Basin, and to the east of the Nemaha Tectonic Zone lies the Forest City Basin. A +15 mgal anomaly in Republic, Smith, Jewell, and Mitchell counties (see Figure 1 for county locations) likely results from mafic rocks intruded at depth beneath the Salina Basin. Lam (1986) speculates that these mafics are related to the basin's origin.

Similarly, Yarger (1983) concluded that an arc of intrusives in the southern half of the Forest City Basin marks a zone of weakness that led to later Paleozoic basin deformation. They appear as roughly circular magnetic anomalies up to 14.5 km (9 miles) in diameter in northeastern Kansas. Several have been drilled and cored, confirming the presence of epizonal granite with up to two percent magnetite (Steeples and Bickford, 1981).

The Cherokee basin is found in southeastern Kansas, separated from the Forest City Basin by the Bourbon Arch (Figure 1). The Pratt Anticline separates the Hugoton

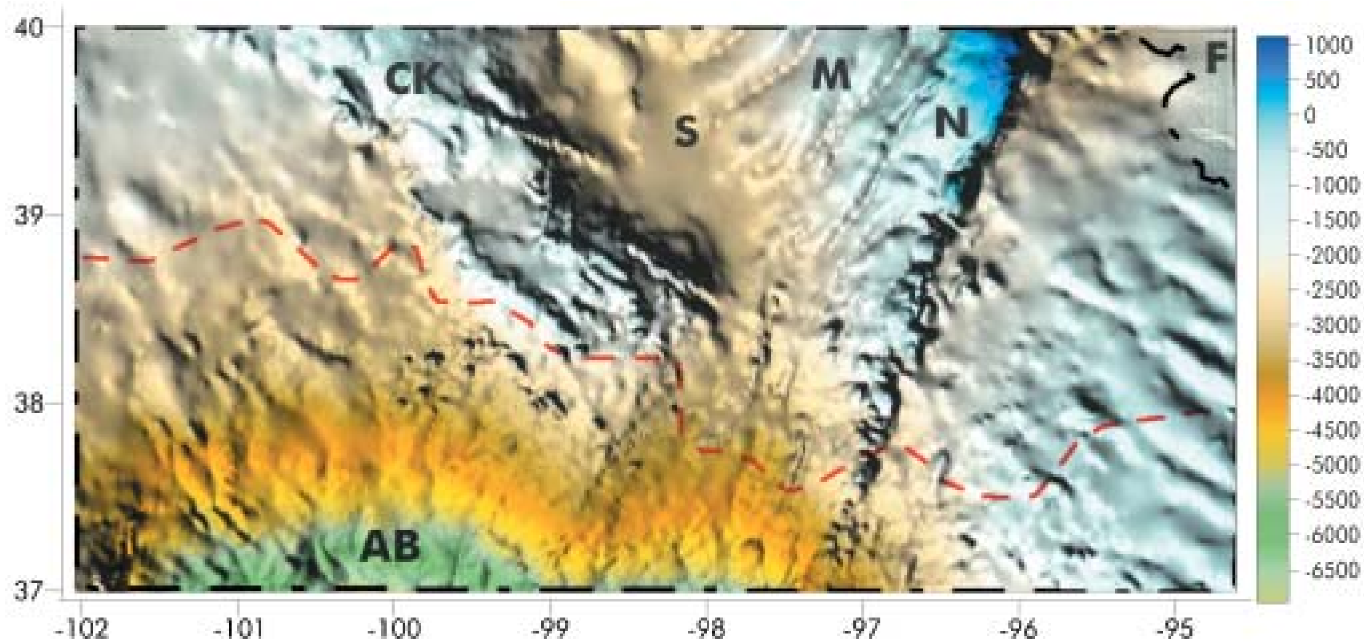

Figure 8. Precambrian basement surface showing 3-D elevation. AB = Anadarko Basin, CK = Central Kansas uplift, S = Salina Basin, M = Midcontinent Rift, N = Nemaha Uplift, F = Forest City Basin. Red dashed line shows boundary between northern and southern terranes according to Xia et al. (1995). Map axes are labeled in accordance with the unprojected latitude/longitude grid used. Based on Bickford et al. (1979).

Embayment and the Sedgewick Basin in south central Kans. (Newell et al., 1987). The Las Animas Arch is located in the northwest corner of the state, adjacent to the Central Kansas Uplift.

Thickness and Depth of the Phanerozoic Sedimentary Cover

The Kansas Geological Survey published cross sections of the Phanerozoic sedimentary cover in the state. These are shown in Figure 10, as east-west lines across the entire state, arrayed from north to south.

The below ground depth to Phanerozoic sediment ranges from 201 m (660 ft) in northeastern Kansas over the Nemaha Uplift (Xia, 1992) to 2,999 m (9,840 ft) in Meade County, southwest Kansas. According to uniformitarian geologists, the oldest dated outcropping sediments in Kansas are Mississippian in far southeastern Kansas (Ross, 1991). The cross sections show a general thickening of sediments to the south (Anadarko Basin) and west (Denver Basin). The general18 absence of pre-Mississippian strata atop the Central Kansas Uplift and the Nemaha Tectonic Zone is cited as evidence of erosion during late Mississippian to early Pennsylvanian time (Rascoe and Adler, 1983).

Line 2 of Figure 10 shows the crustal thickening of crystalline rocks across western Kansas, supported by the Bouguer gravity anomaly map (Figure 9) that reveals decreasing gravity readings across the same area. Gravity data (Lam, 1986) agrees with seismic refraction data, and support a westward increase in the depth of the base of the crust at the Mohorovicic Discontinuity from 38 km (23.6 miles) in north-central Kansas to 48 km (29.9 miles) in western Kansas.

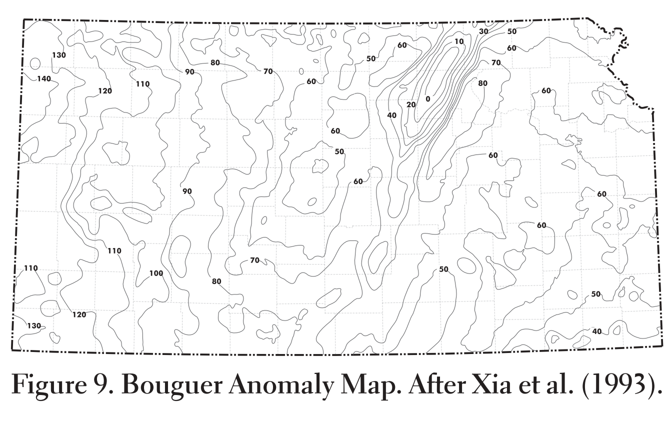

Figure 9. Bouguer Anomaly Map. After Xia et al. (1993).

Basement Terranes

The crystalline basement in Kansas has been divided into two distinct terranes—north and south (Figure 11) at a line running roughly across the southern third of the state (Bickford et al, 1981; Yarger, 1983; Sims, 1990; Van Schmus et al., 1993; Xia et al., 1995). The two terranes are distinguished lithologically, texturally, geophysically, and isotopically. The northern terrane is assigned to the southern Central Plains Orogen and the southern terrane is the northern part of the Southern Granite-Rhyolite Province that extends into Oklahoma and the Texas panhandle (Van Schmus et al., 1993). The northern terrane is composed primarily of mesozonal granite and metamorphic rocks; the southern terrane primarily of epizonal granite and rhyolite (Yarger, 1983; Lam, 1986). The southern terrane has an isotopically younger age, overlies thinner crust or lithosphere, has a higher geothermal gradient, and is more ductile (Bickford et al., 1981; Yarger, 1983; Lam, 1986).

Both terranes are composed primarily of granitic rocks; mafic and intermediate igneous rocks are uncommon outside of the MRS. Of the wells that penetrated the basement and were drilled prior to 1985 (Cole and Watney, 1985), 31% encountered granite and 39%, granite wash, often then penetrating underlying granite. Another 23% encountered metamorphic rock, predominantly quartzite, and 2% encountered arkosic sediments. Another 2% encountered rhyolite and 1% encountered basic igneous rocks.

The nature of the boundary between the two terranes is unknown. Earlier researchers (e.g., Anderson and Black, 1982) favored a rifting event, but Van Schmus et

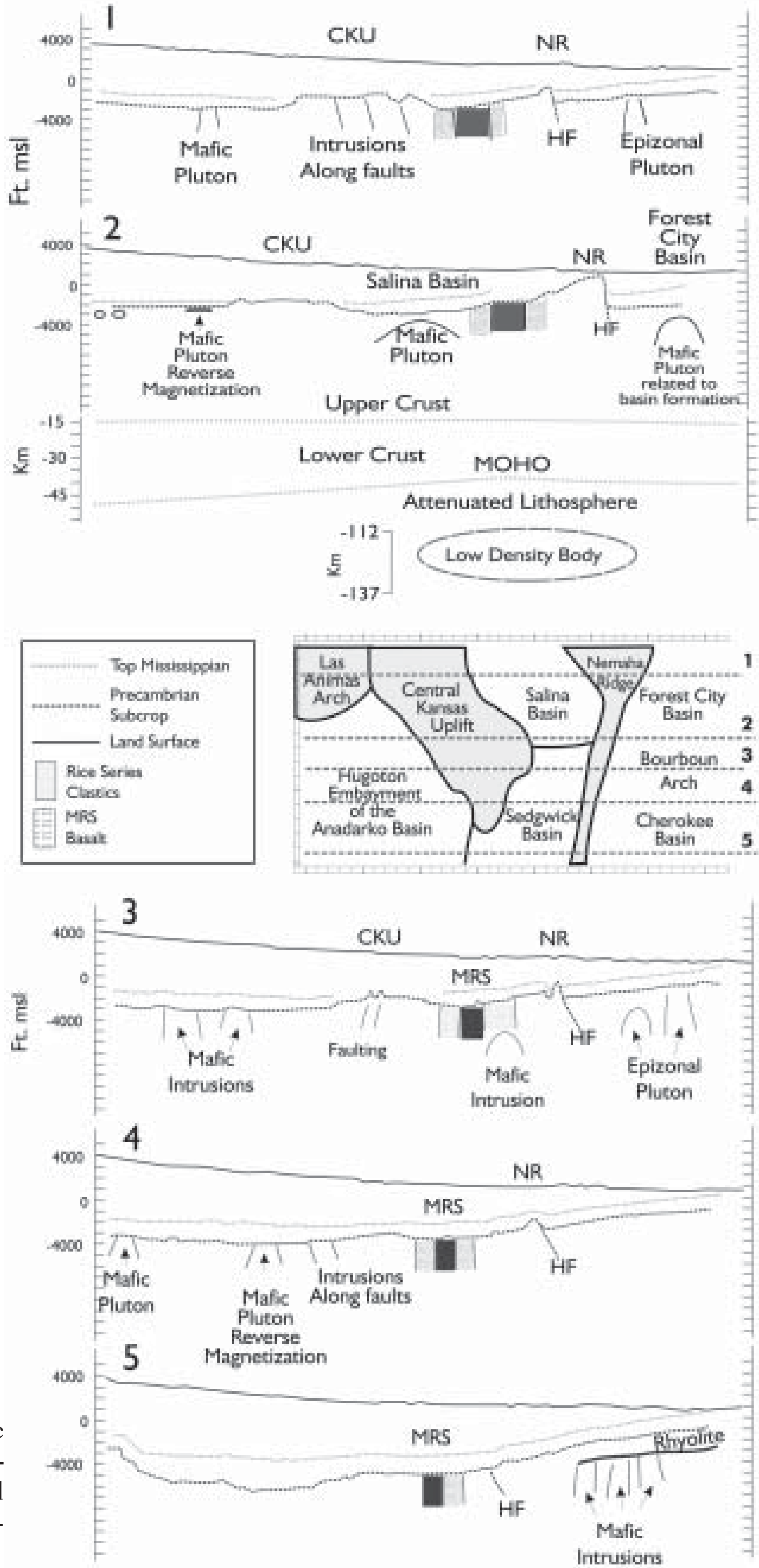

Figure 10. Cross sections of the Phanerozoic cover of Kansas. CKU is Central Kansas Uplift, MRS is Midcontinent Rift System, and NR is Nemaha Ridge. After unreferenced Kansas Geological Society publication.

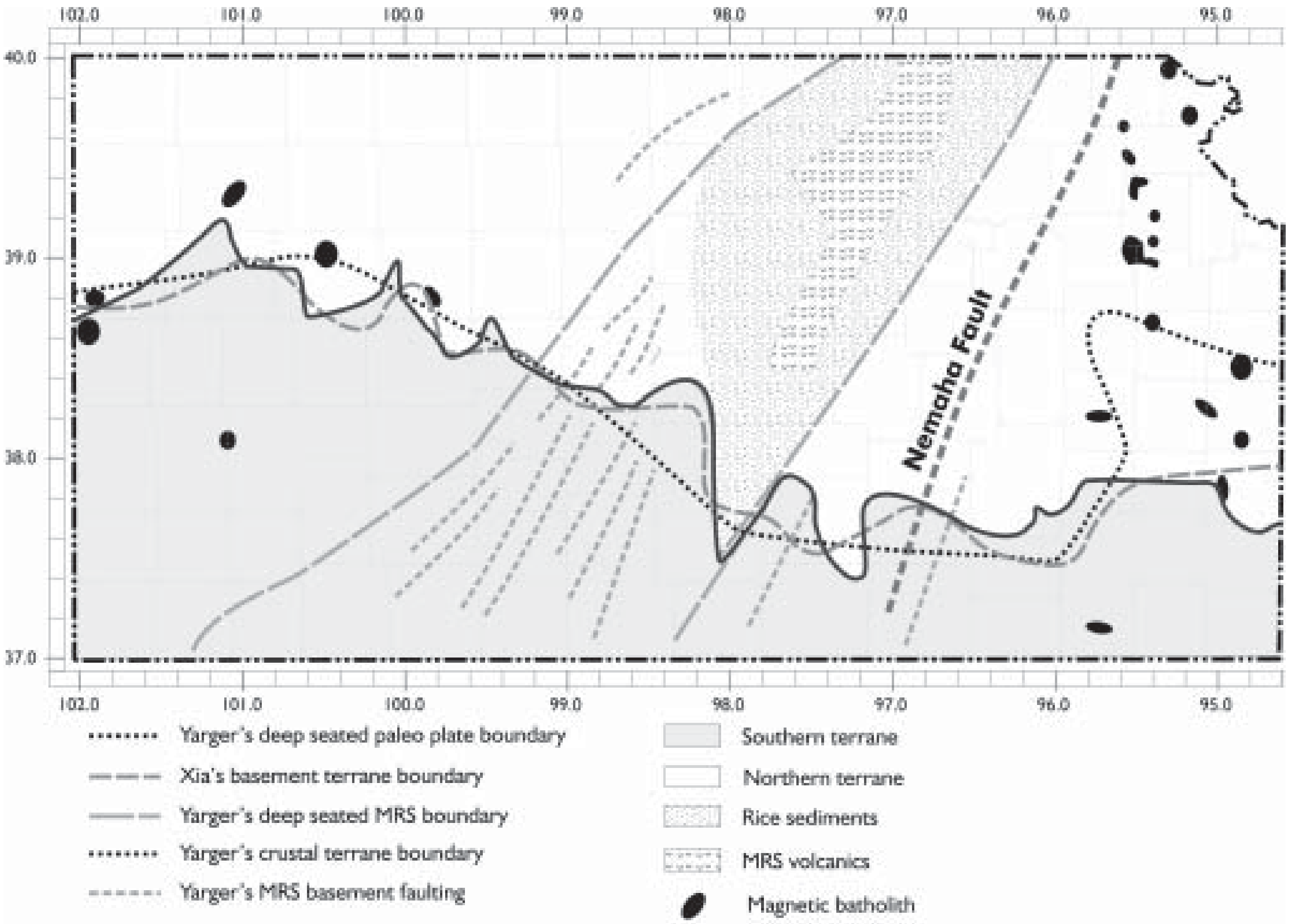

Figure 11. Basement terrane boundaries in Kansas. Modified from Yarger (1983) and Xia (1995).

al. (1986), Bickford et al. (1986), and Lam (1986) proposed an anorogenic intrusive event, possibly associated with a proposed 1.4 Ga subduction zone at the Llano front in Texas. Gravity data suggest that the differences between the two terranes are in the upper crust, and that the lower crust is similar in both.

Intruded into both terranes are epizonal plutons, visible as roughly circular magnetic anomalies. Several of these have been drilled and cored, confirming lithology and composition (Steeples and Bickford, 1981). Isotopic dates of these rocks are reported to be slightly younger than those of the southern terrane. Lam (1986) noted a +30 mgal gravity anomaly in Montgomery, Cherokee, and Labette counties with small positive closures. He interpreted the anomaly as rhyolite basement (less dense than granite) and concluded that the small closures were feeder pipes with more dense mafic rocks.

Northern Terrane

The northern terrane is defined by the presence of sheared igneous (primarily granitic) and metamorphic rocks (mostly metasedimentary). Granites are composed of zoned plagioclase, quartz, potassium feldspar, biotite, and accessory minerals such as zircon, sphene, apatite, and magnetite. The sheared texture is visible in fractures, shear zones, offset twin lamellae, brecciation, partially recrystallized cataclastic textures, polycrystalline quartz aggregates, and patches of myrmekite. They are age-dated at approximately 1630 Ma, some 100–200 Ma younger than equivalent exposed rocks in the front range of the Rocky Mountains (Van Schmus et al., 1993). Included in the sheared granites are bodies of younger granite (1.48–1.34 Ga [Bickford et al., 1981]) some of which are sheared and some of which are not.

Magnetic anomaly maps (Yarger, 1983) also reveal

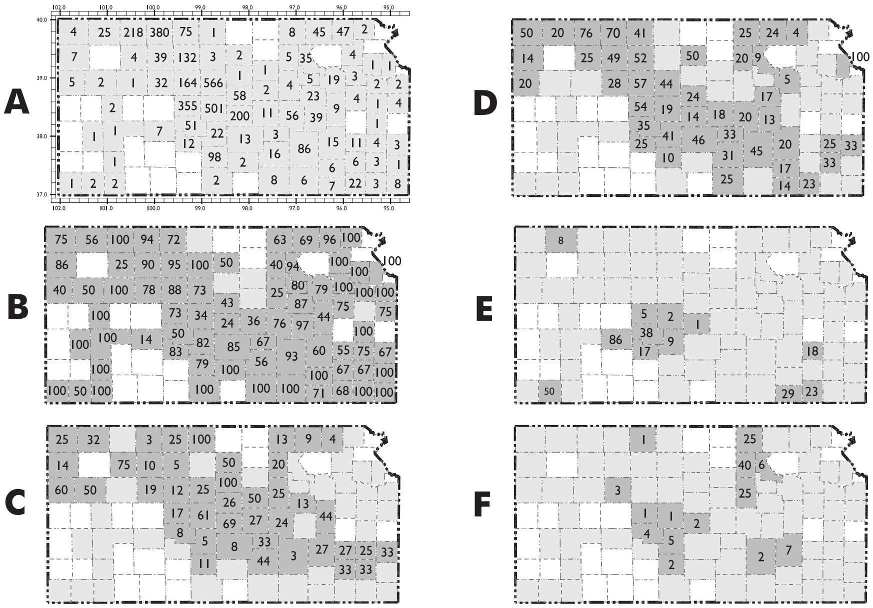

Figure 12. Basement lithology by county based on well penetrations. A = base map showing number of wells penetrating basement drilled in each county prior to 1985, B = percentage of wells encountering granite or granite wash, C = percentage of wells encountering metamorphic rocks, D = percentage of wells encountering granite wash, E = percentage of wells encountering rhyolite, F = percentage of wells encountering basic igneous rocks. Data from Cole and Watney (1985).

roughly circular bodies that contain higher than normal percentages of magnetite. Limited samples from these bodies have been dated at similar ages to southern terrane granites, but they lack granophyric intergrowths found in southern terrane granites.

Although many wells drilled in the northern terrane encounter granite and granite wash, a significant number of others penetrated metamorphics, mostly quartzites and schist (Figure 12). Quartzites are coarse-grained with anhedral quartz grains having sutured boundaries. Their texture suggests high-grade metamorphism, but a corresponding diagnostic high-grade metamorphic mineralogy is absent. The only sampled metamorphics with such mineralogy occur in Phillips and Norton counties near Nebraska. The metamorphic basement samples are interpreted to be the remnant of Precambrian weathering and erosion—only resistant quartzite remains.

Southern Terrane

The southern terrane samples are primarily unmetamorphosed rhyolitic and dacitic rocks, and granite of the same composition. The granite is epizonal, granophyric to micrographic, and medium grained (3–5 mm). The mineralogical composition (with rough percentages) is quartz (35%), perthite (40–45%), sodic plagioclase (15%), biotite (<5%), and accessory minerals of magnetite, sphene, apatite, and zircon. These rocks are age-dated at 1.48–1.34 Ga.

Approximately 90% of the volcanic rock samples are rhyolite with phenocrysts of plagioclase, perthite, and quartz (30–40%), and a groundmass of quartz and plagioclase. These rocks are interpreted as originating as ash-flow tuffs (Bickford et al., 1979), based on limited evidence. Two large fields near the southern junction of the Central Kansas Uplift and the MRS (Figure 6) show textural evidence of ash-flow tuffs. However, igneous rocks in the basement do not match modern examples of plate tectonic boundaries because they have no mafic or intermediate members or rift zones with bimodal suites and mafics.

The structural fabric of the southern terrane is divided into an eastern and western segments by the Nemaha Ridge fault zone, which juxtaposes mesozonal granite on the upthrown west side with epizonal granite on the downthrown east side (Bickford et al., 1979); now shown on Sims (1990) map). The southern Nemaha fault zone is similar, but it lacks the graphyric texture and has slight to moderate cataclastic texture. It is identified as mesozonal because of the texture, but a definitive identification is not available.

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Glossary

Arkose: A feldspar rich sandstone, commonly angular and poorly sorted, usually derived from granite or granitic rock.

Dacite: A fine-grained extrusive rock, the extrusive equivalent of andesite.

Epizonal: Referring to conditions of low metamorphic grade.

Gneissoid: Exhibiting the textural or foliated structure of a gneiss, yet not generated by metamorphic processes.

Granophyric: Referring to the texture of a porphyritic igneous rock in which the groundmass and phenocrysts penetrate each other as a result of simultaneous crystallization.

Graphyric: Referring to a granophyric texture in a rock in which the clasts are of microscopic size.

Mesozonal: Referring to a medium to high metamorphic grade.

Micrographic: Referring to the microscopic texture of an igneous rock in which the feldspar and quartz are intergrown.

Peridotite: A coarse-grained plutonic rock composed primarily of olivine with other mafic minerals.

Perthite: An alkali feldspar with visible intergrowths of potassium rich feldspar and sodium rich feldspar.

Rhyolite: A fine grained silicic volcanic rock; the extrusive equivalent of granite.

Xenolith: An inclusion in an igneous rock of different composition and texture.

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