To Accompany
KANSAS GEOLOGICAL SURVEY
Map M-9

Preliminary Geologic Map Of The Precambrian Basement Rocks Of Kansas

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PRELIMINARY GEOLOGIC MAP OF THE PRECAMBRIAN BASEMENT ROCKS OF KANSAS

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INTRODUCTION

There are no *in situ* exposures of Precambrian rocks in the State of Kansas. Exposures in states adjoining to the north, south, and east are limited to small areas in eastern and southeastern Oklahoma and southeastern Missouri. Therefore, indications of the nature of the basement rocks have been derived from study of cuttings and rare cores from deep drilling. Various workers have made mention of these rocks, but until Farquhar (1957) published a geologic map and a discussion of basement rock types there was no real effort to assemble the information available. Later Muehlberger and his co-workers at the University of Texas (Muehlberger and others, 1966; Goldich and others, 1966) published the results of an extensive study of the petrography, physical properties, and isotopic ages of the buried basement rocks of the Midcontinent region. Members of the Kansas Geological Survey cooperated in this study and, as a result, Scott (1966) published a paper describing the Rice Formation from the Precambrian of central Kansas.

Our interest in the buried basement rocks of Kansas and adjacent states was stimulated primarily by earlier, and then concurrent, work in the exposed Precambrian terrane of the St. Francois Mountains of southeastern Missouri. The rocks exposed there are exclusively silicic rhyolite, dacite, and minor volcanic rocks of intermediate composition that have been intruded by shallow plutons of similar composition. It seemed clear from the studies of Muehlberger and others (1966) and Lidiak and others (1966) that rocks of this composition extended across the continent from northern Ohio through the Midcontinent region to the Texas panhandle in a great arc-like feature. The formation of this extensive terrane about 1,400-1,500 m.y. ago (Bickford and Mose, 1975) was clearly a major addition to, or reworking of, the continental crust of North America (Bickford and Van Schmus, 1973). Whereas the detailed petrology, structure, and chronology of these rocks is best studied in the areas of exposure in Missouri and Oklahoma, the major problem of their role in the evolution of the continent requires that they be studied regionally. Thus we began to collect all of the basement rock material we could find for study.

As our work progressed it also became clear that although rocks in the basement of southern Kansas (and adjacent parts of Oklahoma) are strikingly like the rocks of the St. Francois Mountains, the buried terranes of northern Kansas (Goldich and others, 1966) are much more like the exposed Precambrian of the Front Range of Colorado. Moreover, parts of north-central Kansas are underlain by mafic igneous rocks that are a southerly extension of the Central North American Rift System (Ocola and Meyer, 1973). Without question, elucidation of the Precambrian evolution of the North American continent will depend upon our ability to determine the age and petrologic history of the buried basement of Kansas and the other plains states.

The map which is presented here is based entirely upon the identity of basement rocks in Kansas; these rocks were studied from thin sections prepared from cuttings and rare cores returned from deep drilling. More than 800 thin sections were studied, representing essentially all of the usable material from the more than 3,000 wells in Kansas that have penetrated the crystalline basement. In the initial phases of the work, which are discussed here, we have qualitatively described the lithology of the basement rocks studied and we have determined the ages of 59 samples by either Rb-Sr whole-rock or U-Pb (zircon) methods. Although the data are still sparse in many parts of the state, we made use of many more samples than any of the previous investigations. Moreover, our interpretations are strengthened by the results of our previous work in southeastern Missouri and by the knowledge of the Precambrian history of North America that has accumulated during the last 12 years.

In the future we will expand this study to include any new material that becomes available, particularly that from areas not now well represented. Additionally, we intend to study the composition of plagioclase feldspars and the trace element and Pb-isotopic composition of both plagioclase and alkalic feldspars in an attempt to delineate more clearly terranes of co-magmatic igneous rocks. The map should, therefore, be regarded as a preliminary study.

THE GEOLOGIC MAP

The geologic map presented here has been superimposed upon the basement topographic surface map of Cole (1976). All geologic contacts are shown as dashed lines because they are inferred from widely spaced sample points. However, dashed lines separating patterned areas from blank areas indicate the limits of adequate control. Control for the geologic map is indicated by dots which locate basement wells. We have interpreted the available data to produce the map, but it should be clear that the geologic relationships are generalized and that the degree of generalization increases as the number of control points decreases.

PRINCIPAL GEOLOGIC FEATURES OF KANSAS PRECAMBRIAN

Principal Rock Types:

"Older" Granitic and Metamorphic Rocks. Much of the northern part of Kansas is underlain by a terrane of igneous and metamorphic rocks. The metamorphic rocks are mostly quartzite and closely associated muscovitic schist, but amphibolite and other foliated rocks are also present. The metamorphic rocks occur as relatively small patches within larger areas underlain by granitic rocks and may be either remnants of an older terrane that are now inclusions in the igneous rocks, or erosional remnants of younger sedimentary rocks that were metamorphosed and then mostly stripped away.

The granitic rocks range in composition from granite to quartz monzonite and are commonly two-feldspar rocks with biotite, suggesting mesozonal emplacement. They are uniformly characterized by cataclastic textures, but extreme cataclasis is noted near faults which are known to occur in the overlying Phanerozoic section. In particular, cataclasis is noted along the Nemaha Ridge in eastern Kansas.

Rhyolitic to Dacitic Volcanic Rocks and Epizonal Granitic Plutons. The southern part of Kansas appears to be underlain by a terrane of silicic volcanic rocks and associated shallow plutons. This terrane is best recognized in southeastern Kansas where well control is greatest, but large volcanic fields have also been mapped in Stafford, Pawnee, and Hodgeman counties in west-central Kansas.

The volcanic rocks are typically rhyolitic to dacitic, and porphyritic. Phenocrysts include quartz, plagioclase, and alkali feldspar. Although many of these rocks are partially to extensively recrystallized, with granular matrix and sutured grain boundaries, others still preserve delicate volcanic textures such as trachytic orientation of microlites in flows, and eutaxitic textures in ash-flow tuffs.

The plutonic rocks are typically granophyric and uniformly contain strongly perthitic feldspars. In general, these rocks are low in ferromagnesian minerals; however, biotite and, in rare instances, hornblende, occur along with alkalic feldspars, plagioclase, and quartz. The petrographic evidence suggests crystallization in a shallow crustal environment under low water vapor-pressure conditions.

Neither the shallow plutons nor the volcanic rocks show the cataclasis which so characterizes the "Older" terrane of granitic and metamorphic rocks to the north. This observation and the minimal radiometric age data (to be discussed later) suggest that the volcanic-shallow plutonic terrane is younger than the rocks to the north.

Mafic Igneous Rocks and Associated Arkosic Sedimentary Rocks of the Central North American Rift System. North-central Kansas is underlain by a terrane of mafic igneous rocks that is marked by a major gravity and magnetic anomaly. The geophysical feature, the "Greenleaf Anomaly," or Midcontinent Geophysical Anomaly, is flanked on all sides by a basin filled with arkose and reddish siltstone. There seems little doubt that the rocks associated with the anomaly are of Keweenawan age (about 1.1 b.y. old) and are coextensive with the similar rocks that are exposed in the Lake Superior region. The gravity and magnetic anomaly can be traced almost continuously across Nebraska, Iowa, and southern Minnesota to the outcrop area. Mafic igneous rocks and arkosic sedimentary rocks are known from drill holes in those states as well as in Kansas. It has been proposed that this feature is an abortive rift (Chase and Gilmore, 1973).

The mafic rocks studied in Kansas are mostly olivine-bearing gabbroic rocks with strongly ophitic textures; no rocks studied are clearly surface basalt flows. The arkosic rocks and siltstone comprise the Rice Formation (Scott, 1966) and were evidently formed of immature sediment derived from the faulted edges of the rift basin and deposited within it.

Tectonic Features:

The Central North American Rift System. Little can be added to the above concerning this major tectonic feature of the Kansas basement. It is clearly a feature that can be traced into the Keweenawan Rift of the Lake Superior region, but it apparently terminates abruptly in south-central Kansas. The kimberlite intrusives of Riley County, Kansas (Brookins, 1970; Brookins and Meyer, 1974) apparently lie along the margin of the rift, but they are much younger features that are post-Permian in age. These intrusives are not shown on the basement-rock map.

The Nemaha Ridge. Certainly the most striking tectonic feature of the Kansas basement is the Nemaha Ridge, an element that may have been active since at least the early Paleozoic (Lee, 1943). The studies of Cole and of many others have shown that the Nemaha Ridge is bounded on the east by a major fault zone that clearly disrupts the crystalline basement rocks that are upthrown on the west side. Similar but smaller displacements have been observed in overlying Paleozoic rocks. Our studies of the basement rocks along and near the Nemaha Ridge also indicate that it is a major crustal fracture zone because cataclasis is widespread and often extreme.

Although we do not now understand the tectonic history of the Nemaha Ridge in the Precambrian, it may be significant that it almost parallels the rift feature of the Midcontinent Geophysical Anomaly. It is hoped that future studies of strongly recrystallized material along the Nemaha Ridge may yield the time of major movement; an age correlation with Keweenawan rifting may suggest a tectonic correlation as well.

Central Kansas Uplift. The Central Kansas Uplift is a broad region in which the basement rocks have been moved upward; it is also characterized by fault zones and cataclasis. Its northwesterly trend does not suggest a relationship to the Keweenawan rift feature, but this possibility cannot be completely ruled out on the basis of present knowledge.

Distribution of Rock Types:

The map suggests that the terrane of volcanic rocks and shallow plutons that underlies much of southern Kansas may have been emplaced upon and within an older terrane consisting of rocks now recognized mainly to the north. Apparently, this older terrane was exposed by pre-Late Cambrian erosion along both the Central Kansas Uplift and the Nemaha Ridge, suggesting that the older rocks lie beneath younger rocks of shallow crustal affinities to the south.

The rocks of the Central North American Rift System, and its associated arkosic sedimentary rocks, are clearly related to a younger tectonic event that has cut across the older rock terranes.

GEOCHRONOLOGICAL STUDIES

In addition to our petrographic studies, we have attempted to obtain radiometric age data for as many samples from the Kansas Precambrian as possible. The problem is a formidable one, indeed, as usually only small amounts of cuttings are available, and these are not always fresh.

Sixty Rb-Sr whole-rock age determinations were done, all on samples for which reasonable amounts (several grams) of rock chips were available (Harrower, 1976 and the present work). These have yielded ages ranging from about 1,200 m.y. to about 1,750 m.y. ($\lambda Rb^{87} = 1.42 \times 10^{-11}$ $yrs.^{-1}$). There is considerable uncertainty associated with "single-whole-rock" Rb-Sr ages, as the initial isotopic composition of the Sr cannot be determined and must be assumed. Moreover, numerous studies have shown that Rb-Sr ages are usually lower than U-Pb ages measured on zircons from the same rock; this effect is particularly pronounced for rocks with low Sr concentrations. Thus we must assume that the ages determined are probably minimum ages for most samples, although the effect of assuming the initial isotopic composition of Sr could in certain cases cause the calculated ages of some samples to appear greater than the actual age. It may be significant that the only rocks that have yielded ages greater than 1,500 m.y. are in the northern terrane or along the Nemaha Ridge.

Most workers agree that measurements of the U-Pb system in zircons usually yield more reliable ages. We have had only limited success in obtaining zircons for study from Kansas basement rocks because there are few core samples, and both these and the common cuttings are often too small to yield enough zircons for analysis. The table below summarizes zircon results and compares them with Rb-Sr whole-rock age measurements from the same rock sample.

TABLE 1.—Comparison of U-Pb Age Results from Zircons and Rb-Sr Whole-Rock Ages*

Locality	Rb-Sr Whole-Rock Age	U-Pb Age of Zircons	Comments
Greenwood County	1350	1380±33 m.y.	Zircons from clean cuttings; the well penetrated basement about 130 meters; rock is epizonal pluton.
Rose Dome, Woodson County	1100±100	1408±20 m.y.	Zircons rather discordant; samples from surface exposures of granite carried up as inclusions in Cretaceous ultramafic rock.
Stevens County	1345	1375±100 m.y.	Extremely discordant zircons from core of epizonal granite; only 15 mg zircon recovered.
Rush County	1460	1660±100 m.y.	Zircons from core; 13 mg recovered; zircons yielded extremely discordant results.
Russell County	1382	1500 m.y.	Zircons from cuttings; 45 mg recovered from well that penetrated basement about 27 meters.
Nemaha County	——	1636±20 m.y.	Zircons from cuttings; about 40 mg recovered from well that penetrated basement about 16 meters.

*Natural constants used are: λRb^{87} = 1.42 x 10^{-11}yrs.$^{-1}$; Sr^{87}/Sr^{88} (atomic ratio) = 0.1194; Sr^{84}/Sr^{88} (atomic ratio) = 0.0068; Rb^{85}/Rb^{87} = 2.5927; λU^{238} = 1.551 x 10^{-10}yrs.$^{-1}$; λU^{235} = 9.848 x 10^{-10}yrs.$^{-1}$.

Summary:

Our results indicate that the "Older" terrane in the north includes rocks which are as old as about 1,750 m.y., but there are also rocks present which are as young as about 1,450 m.y. This northern terrane is probably similar in age, as well as in petrographic character, to rocks exposed in much of the Front Range of the Rocky Mountains.

The silicic volcanic rocks and associated shallow plutons appear to be about 1,380 m.y. old. They are part of a great arcuate terrane of similar rocks that is known in the subsurface from northern Ohio at least to the Texas Panhandle. Published ages for these rocks range from 1,200 to 1,500 m.y. The major exposure of this belt occurs in the St. Francois Mountains of southeastern Missouri, where the rocks are mostly 1,480 m.y. old (Bickford and Mose, 1975).

As indicated earlier, the mafic igneous rocks of the southern extension of the Central North American Rift System are assumed to be of Keweenawan Age (about 1,100 m.y. old) because of their apparent correlation with exposed rocks that have been dated in the Lake Superior region.

A BRIEF GLOSSARY OF PETROGRAPHIC TERMS USED IN THIS PAPER

Alkali feldspars: Feldspars in the $NaAlSi_3O_8$-$KAlSi_3O_8$ solid solution series. These feldspars form solid solutions only under conditions of low water vapor-pressure and are typical of volcanic rocks and shallow intrusives.

Cataclastic: A textural term referring to rocks that have been mechanically disturbed. Granulation, shearing, and some recrystallization are common features.

Epizone: A term referring to the depth of emplacement of igneous intrusive rocks. *Epizonal* intrusives are emplaced in the shallow crust at depths of 6.5 kilometers or less.

Eutaxitic texture: A term referring to the flattened and streaked-out texture which is common in compacted ash-flow tuff deposits. Elements of the texture commonly include flattened glass shards and pumice fragments.

Granophyric texture: A term applied to the intimate intergrowth of quartz and alkalic feldspar that is common in granitic rocks that have crystallized in the shallow crustal environment under conditions of low water vapor-pressure. A synonym is *micrographic,* and such rocks are commonly called *micrograntites* or *granophyres.*

Kimberlite: An ultramafic rock that has commonly been emplaced explosively in pipe or dike-like masses. Kimberlites commonly are composed of rounded olivine phenocrysts, clinopyroxenes, garnets, and micas such as phlogopite; they often contain inclusions of ultramafic rocks from the mantle (various peridotites). Kimberlites are usually altered to serpentine group minerals and may contain carbonate minerals formed either primarily or as alteration products. No diamonds have been found in Kansas kimberlites.

Mesozone: A term similar to epizone, but referring to emplacement at intermediate depths between 6.5 and 13 kilometers.

Ophitic texture: A term describing the intergrowth of an earlier euhedral or subhedral mineral with a later anhedral mineral which partially surrounds it. This texture is very common in gabbros and diabases in which anhedral clinopyroxene partially encloses earlier euhedral or subhedral plagioclase.

Perthite: An intergrowth of a Na-rich (albitic) feldspar with a K-rich feldspar. Perthites form by the unmixing in the solid state of original alkalic feldspars and thus they are indicative of crystallization under low water vapor-pressure conditions. Perthite is very common in Precambrian rocks that were originally formed by crystallization in the shallow crust or as surface volcanics.

Trachytic texture: A texture of volcanic rocks formed by the alignment of phenocrysts and microlites (small crystals in the matrix) during flow of the lava.

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