CAMBRIDGE ARCH/CENTRAL KANSAS UPLIFT PROVINCE (053)

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INTRODUCTION

The Cambridge Arch/Central Kansas Uplift Province is located in west-central Kansas and in western Nebraska; the area covers about 37,000 sq mi. The province is named after two northwest-trending uplifts which approximately bisect the province and are its most prominent tectonic features. The Cambridge Arch in Nebraska is bounded on the southeast and northwest, respectively, by the Central Kansas Uplift, and by the Chadron Arch of the Denver Basin Province (039). The Central Kansas Uplift is located in the Kansas portion of the province.

Oil and gas exploration and the largest, most productive oil and gas fields are concentrated along these anticlinal structures. The location and size of reservoirs are influenced by the creation of structural traps through uplift, erosional truncation of producing formations, and deposition of overlying low-permeability seal units, all tectonically related. Erosion during Late Mississippian-Early Pennsylvanian time created numerous topographic features and stratigraphic conditions favorable for trapping oil and gas (Merriam, 1963). Geologic history of the province includes periods of uplift and erosion during Paleozoic and Mesozoic time and repeated marine transgressions and regressions that resulted in the cyclic deposition of Pennsylvanian sandstone and carbonate sediments.

The six conventional petroleum plays assessed for this province were divided primarily by age of producing sediments. They are Permian Play (5303), Mississippian and Devonian Play (5304), Pennsylvanian Cyclical Carbonates and Sandstones Play (5305), Ordovician Play (5308), and Early Ordovician/Cambrian Arbuckle Play (5309). Several plays within and bordering this province are described and assessed in the Denver Basin Province (039); they are Niobrara Chalk–Shallow Biogenic Gas Play (3903), Dakota Group (Combined J and D Sandstones) Play (3905), and Permian Pennsylvanian Play (3908).

Two plays are the source of most oil and gas production in the province. The first, Pennsylvanian Cyclical Carbonates and Sandstones Play (5305), produces mainly from carbonates with lesser production from sandstone and conglomerate. The second principal play is Early Ordovician/Cambrian Arbuckle Play (5309), producing from dolomite of the Arbuckle Formation and the Reagan Sandstone. The lesser production and potential realized from the other plays are largely due to erosion over tectonic structures and associated less favorable reservoir traps and seals. Exploration and development are active in the province and smaller fields are still being discovered, although most of the larger fields were found by the 1950's (Newell and others, 1987).

The first hole drilled in the province (1915) was dry and this suggests the well was productive. The earliest field discovery, in 1923, was the Fairport oil field which has produced 56.072 MMBO from Pennsylvanian-age Lansing-Kansas City Group carbonate rock (Walters, 1991). The three largest fields in the province are located along the axis of the Central Kansas Uplift; these are Bemis-Shutts (1928), Chase-Silica (1931), and Trapp (1936). Cumulative production (through 1990) in order for the three fields are (1) 242 MMBO, (2) 268 MMBO and 7.6 BCFG, and (3) 228 MMBO and 0.248 BCFG.

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CONVENTIONAL PLAYS

5303. PERMIAN PLAY

Gas and minor amounts of oil are produced in the province from carbonate rocks and sandstones of the Chase, Council Grove, and Admire Groups, and small amounts of gas from the Sumner Group (Newell and others, 1987). Although the play area covers the province, the scattered Permian gas fields are located in the southern Central Kansas Uplift and the Pratt Anticline. Production is concentrated on crests of structures; fields are small and at shallow depths. Depth range for this play is estimated at 2,000-3,000 ft with a median depth of 2,600 ft.

Reservoirs: Reservoir-quality intervals of these cyclical carbonate rocks and sandstones are primarily uppermost, dolomitized regressive carbonates of each repetitive sequence. Reservoir heterogeneity and low permeability result mainly from stacking of thin carbonate rock-sandstone-shale beds and variable distribution of secondary porosity; this porosity is commonly skeletal molds, vugs, and intercrystalline porosity between dolomite crystals (Newell and others, 1987). Dolomitization of limestones also results in strata showing porosity enhancement; such strata may be concentrated on structural highs (Newell and others, 1987).

Source rocks: Permian, Pennsylvanian, and other potential source rocks in the province are thermally immature for oil and gas generation. Combined with other geologic information, this indicates that the gas was emplaced by migration and differential entrapment; the gas probably migrated from the Anadarko Basin to the south.

Traps: Major trap types are both structural and a combination of structure and updip porosity pinch-out into low-permeability strata.

Exploration status: The first Permian discovery was completed in 1947. Only one field in the province has reserves above the limit of 6 BCFG. The Brant field, discovered in 1977, is located proximal to the Pratt Anticline, in the southernmost county of the province. The Indian Cave sandstone of the Admire Group is the reservoir. Production through 1990 was 11.334 BCFG, with known and ultimate reserves of 14.4 and 36.4 BCFG. Producing depth is about 2,600 ft, average perforated thickness is 30 ft, and average porosity is 25 percent.

Resource potential: Potential for additional large fields is limited by extensive drilling across the province and the high exploration density required for 6 BCFG equivalent fields. Permian gas reservoirs are commonly underpressured. This can result in bypassing potentially productive wells. Small scattered gas reservoirs will probably continue to be developed, especially as offshoots of deeper field discoveries.

5304. MISSISSIPPIAN AND DEVONIAN PLAY

Producing formations in this play include the Mississippian limestone and chert (or "chat"), and the Misener (Kinderhookian) Sandstone. The Mississippian and Devonian play underlies approximately 8,000 sq mi of the province. These formations were eroded from most of the Central Kansas Uplift during Late Mississippian-Early Pennsylvanian tectonism and form a fringe along the southern margins of the province; therefore, the play is limited to these areas. Thickness of units is also largely dependent on this structural movement; these rocks thin over anticlines and uplifts (Newell and others, 1987).

Reservoirs and traps: Oil and gas are trapped by structure and a combination of structure and updip pinch-out of porous and permeable carbonate reservoirs. Most Mississippian production is located near or at the top of the section and just below the sub-Pennsylvanian unconformity (Adler, 1971); solution of limestones below this contact results in a residual cherty, porous weathered zone (Newell and others, 1987). Mainly oil is produced from the Upper Devonian and Lower Mississippian Misener (Kinderhookian) sandstone. Thickness decreases from a few feet near the Central Kansas Uplift to a thin edge in other areas of the province; localization of this unit is probably controlled by the ancestral uplift (Newell and others, 1987).

Depths to the Mississippian range from about 3,000 to 5,400 ft with a median depth of about 4,000 ft. Net pay ranges in thickness from 6 to 59 ft with a median of 6 ft for this play.

Source rocks: Pennsylvanian black shales and other potential source rocks are thermally immature for oil and gas generation in the province; oil and gas probably migrated into the Mississippian reservoirs from the south, possibly during Pennsylvanian and Permian time.

Exploration status: The first producing well was completed in 1938. The first MMBOE field discovery was Garfield in 1947; cumulative production from Mississippian limestones was 9.881 MMBO and 5.384 BCFG through 1990. Known oil and gas reserves are 10.080 MMBO and 5.550 BCFG; ultimate reserves are 15.246 MMBO and 8.394 BCFG. Nine fields in the province list cumulative production totaling 1 MMBOE or greater, from 6 Mississippian and 3 Mississippian–Pennsylvanian reservoirs. These fields, in order of discovery dates, are Garfield (1947), Carpenter (1953), Seevers Northwest (1954), Carver-Robbins (1955), Moody (1956), Lyons West (1963), Fitzpatrick (1964), Schadel Northeast (1966), and Schadel South (1967).

Resource potential: Potential for discovery of additional MMBOE fields is low due to small areal extent and moderate drilling over most of the play. Newell and others (1987) believe subtle stratigraphic traps in Mississippian rocks will continue to be exploration targets in densely drilled areas of Kansas, and that small discoveries will be the norm except in deeper, sparsely drilled regions south and west of the province.

5305. PENNSYLVANIAN CYCLICAL CARBONATES AND SANDSTONES PLAY

Pennsylvanian-age cyclic limestone-dolomite-shale-sandstone beds underlie almost the entire province, excluding Cherry County in northwestern Nebraska. Producing units include the Wabaunsee, Shawnee, Douglas, Lansing, Kansas City, Marmaton, Cherokee, and the informally named Pennsylvanian conglomerate and basal Pennsylvanian sandstone. These formations are evaluated together due to similar reservoir, trapping, and production characteristics, and because production is commonly commingled. Approximately 93 percent of the production from this play is oil, with 4 percent gas and the remainder oil and gas. The largest fields are located along and next to the Central Kansas Uplift and the southern Cambridge Arch.

Reservoirs and traps: Thin-bedded, cyclical, carbonate rock-shale-sandstone beds commonly produce from multiple pay zones. Trapping mechanisms are structural and combination structure and stratigraphy. Oil is structurally trapped on anticlines. Production is also dependent upon development of secondary porosity, and fracturing can greatly increase connectivity of porous zones. Subaerial exposure during regressive cycles resulted in fresh-water diagenesis of limestones and associated porosity enhancement (Watney, 1980).

There are 212 reservoirs in the province with reserves greater or equal to 1 MMBOE that produce from the Pennsylvanian. Most of these reservoirs are in fields that also produce from the Early Ordovician–Cambrian Arbuckle Play (5309). Drill depths to the top of the Pennsylvanian play range from about 2,000 to 5,400 ft in the province, with a median depth of about 3,500 ft. Net pay thickness averages about 15 ft and is as thick as 250 ft. Solution gas is the primary drive mechanism for many Pennsylvanian carbonate reservoirs in the province, including the Gorham field; this results in high initial production followed by a rapid decline (Walters, 1991). Due partly to the pressure decrease, waterflooding adds considerably to production, and Lansing-Kansas City zones are commonly acidized (Walters, 1991).

Source rocks: Pennsylvanian black shales and other potential hydrocarbon source rocks in the province are thermally immature for oil generation and migration (J.R. Hatch, U.S. Geological Survey, oral commun., 1992, 1993). Oil is believed to have been generated in the Anadarko Basin and to have migrated into the province. Migration of oil into Pennsylvanian reservoirs probably occurred during Pennsylvanian to Permian time, based on differential trapping of oil and gas and time of creation of reservoir seals (Walters, 1958).

Exploration status: Production is primarily from Lansing-Kansas City cyclical carbonates and Arbuckle dolomites. Largest fields are Gorham (1926), Bemis-Shutts (1928), Chase-Silica (1931), Hall-Gurney (1931), Geneseo-Edwards (1934), Trapp (1936), and Kraft-Prusa (1937). All of these fields were discovered early in the history of exploration, and all have produced in excess of 84 MMBO (Geneseo-Edwards) to as much as 268 MMBO (Chase-Silica). The largest fields reporting only Pennsylvanian production are

Fairport and Sleepy Hollow. Fairport, located in central Kansas, was the earliest field discovery (1923) in the province and has produced over 56 MMBO from Pennsylvanian Oswald limestones; ultimate reserves are estimated at 61 MMBO. The Sleepy Hollow field, discovered in 1960, is located in southwestern Nebraska. This field has produced over 50 MMBO from porous and permeable intervals of Lansing-Kansas City limestones and the basal Pennsylvanian sandstone (Carlson, 1989). Minor amounts of gas (0.339 BCF) have also been produced. Known ultimate oil recoverable for Sleepy Hollow is 53.0 MMBO. Depths of production and net pay thickness in this field average 3,172 ft and 36 ft for the Lansing-Kansas City, and 3,418 ft and 6 ft for the basal Pennsylvanian sandstone.

Resource potential: The Pennsylvanian has moderate potential for new MMBOE field discoveries. The primary limiting factor is extensive exploration in the most favorable areas, proximal to the Central Kansas Uplift. Predominance of stripper production is offset by the costs of these relatively shallow wells. There is also potential for new discoveries in southwestern Nebraska. Potential is limited in the northern third of the province because the Pennsylvanian section thins to less than 300 ft in central Nebraska and exhibits fewer effective hydrocarbon trapping mechanisms.

5308. ORDOVICIAN PLAY

Primarily oil is produced from limestones and dolomites of the Viola Group and sandstones and limestones of the Simpson Group. The Viola Group consists primarily of fine- to coarse-grained limestones and dolomites with variable amounts of chert (Bornemann and others, 1982). Simpson sandstones are glauconitic, quartz-rich, and cemented by carbonate or quartz (Cole, 1975). Trap types are mainly structural-stratigraphic and stratigraphic. Fields are located along the Pratt Anticline and southern fringes of the Central Kansas Uplift. The play area is less than 7,000 sq mi.

Reservoirs: The Simpson Group is as thick as 100 ft, near the southern tip of the province; the Viola Group thickness is less than 250 ft (Cole, 1975). Median net pay is 10 ft and net pay is as thick as 20 ft for 18 fields in the province. Median depths of Ordovician oil and gas reservoirs are about 3,800 ft and 4,100 ft, respectively. The Viola Group ranges in depth from 3,000 ft to as much as 5,300 ft near the southwestern corner of the province.

Source rocks: The stratigraphic section of this province is believed to be thermally immature for oil generation; oil and gas probably migrated into reservoirs of this play from the Anadarko Basin to the south. Time of oil generation and migration was probably Pennsylvanian and Permian (Walters, 1958).

Traps: The Simpson and Viola strata were stripped from most of the province, including the Central Kansas Uplift, by Late Mississippian-Early Pennsylvanian tectonic movement (Newell and others, 1987). Trap types are mainly structural-stratigraphic and stratigraphic. Structural-stratigraphic traps result primarily from (1) updip Simpson and Viola pinchout against the sub-Pennsylvanian unconformity, and (2) truncation of Simpson and Viola units by the overlying pre-Chattanooga unconformity (Newell and others, 1987).

Exploration status: The earliest field discovery for this play is Gates (1933) which produces oil and some gas from Pennsylvanian carbonate rocks and Arbuckle Group dolomites. Combined production for this field is 21.4 MMBO and 0.9 BCFG. Eighteen fields in the province with reserves equal to or greater than 1 MMBOE produce from this play. The primary producing intervals in 9 of these fields are Viola, Simpson, and/or Champlainian units; average known recoverable for the 9 fields that list production from only this play is 1.96 MMBO (Bayer, Crissman, Frederick, Jem, Lieb, Mackville, McCandless, Sawyer, and Stafford fields). The largest field is Stafford, discovered in 1940; cumulative production from Viola limestones is 3.8 MMBO with known reserves of 3.8 MMBO.

Resource potential: Potential for additional MMBOE discoveries is considered low due to (1) fairly extensive exploration in most of the play area, (2) the Simpson and Viola have been removed by erosion over most of the province, and (3) the low rate of MMBOE field discoveries (the last was Lieb, in 1967). Scattered small fields will continue to be discovered along the southern margins of the province, both

through exploration for underlying Arbuckle and Reagan fields and in possible stratigraphic traps near structures.

5309. EARLY ORDOVICIAN/CAMBRIAN ARBUCKLE

Mainly oil is produced from Early Ordovician and Cambrian Arbuckle Group dolomites and the Cambrian Reagan (Lamotte) Sandstone. The largest reservoirs are concentrated next to axes of the Central Kansas Uplift and its southward extension, the Pratt Anticline. The Arbuckle Group has the greatest production of any play in the province; more than 1.4 BBO were produced from 1929 to 1968 (Adler, 1971). This play contains 158 reservoirs with production of 1 MMBOE and greater. Most MMBOE fields were discovered before 1968; one MMBOE field has been completed since; the Riffe field in 1978.

Reservoirs and traps: Most traps are structural and combination structure and stratigraphy. Uplift and erosion during late Mississippian to early Pennsylvanian time resulted in enhanced porosity development of Arbuckle and Reagan strata, and in creation of stratigraphic traps as these units pinched out against overlying Pennsylvanian cyclical carbonate rocks. Arbuckle dolomites may also produce from small structures isolated by discrete fault blocks. Reservoir locations and quality are influenced by both paleotopography and paleo-weathering. That is, development of secondary porosity is associated not only with dolomitization, but also with the formation of Arbuckle karst plains that are in unconformable contact with overlying Pennsylvanian rocks. Reservoir seals are mainly overlying Pennsylvanian limestones and shales.

Depth of production for this play ranges from about 3,200 to 4,600 ft (Watney and Paul, 1983) and averages about 3,600 ft. Producing intervals of the Arbuckle Group are dolomite, sandy dolomite, cherty dolomite, minor cherty oolitic dolomite, and white dolomite (Walters, 1991). The Arbuckle Group is as much as 900 ft thick next to the southern border of the province; reservoir average thickness is 15 ft. The Reagan Sandstone is composed of clean quartz sandstones which coarsen downward into basal gravels. Reagan Sandstone thickness ranges from a thin edge to as much as 90 ft (Walters, 1991), and averages 40 ft (Goebel, 1968). Average net pay of the play is 30 ft (Parham, 1993a).

Source rocks: The probable source of Arbuckle oil in the province is long-distance migration of hydrocarbons from the Anadarko Basin; this is based partly on Walters (1958) study of differential entrapment of oil and gas in central Kansas reservoirs. Potential hydrocarbon source rocks in the province are thermally immature for oil generation (J.R. Hatch, U.S. Geological Survey, oral commun., 1992, 1993). Burruss and Hatch (1987, 1989) analyzed oils in the Anadarko Basin and central Kansas. They determined that the geochemistry of Arbuckle oils was very similar for the two regions and hypothesed that Arbuckle oil migrated into the province from Oklahoma. The time of oil migration into

the reservoirs was probably Pennsylvanian to mid-Permian (Walters, 1991). Average API gravity of oils from this play is 33°. Most pre-Mississippian gas fields contain elevated helium; He values range from 2.66 percent in the Benson field to 4.25 percent in the Bradbridge field (Moore and Sigler, 1985, Parham, 1993b).

Exploration status: The first Arbuckle well was completed in 1919. Giant oil fields were discovered early in the history of exploration. The first major oil reservoir, Gorham field, was discovered in 1926; about 93 MMBO has been produced with known and ultimate recovery of 96.0 and 116.9 MMBO. Sixty-six percent of the oil has been produced from Arbuckle dolomites and the Reagan Sandstone, 25 percent was from the Pennsylvanian Lansing-Kansas City carbonate rocks, and the remainder is primarily from the Pennsylvanian Topeka and Tarkio limestones. A small percentage of oil is from fractured Precambrian-age granite and quartzite. Precambrian production in the province is concentrated on summits of buried Precambrian hills (Walters, 1991). The Chase-Silica and Trapp fields were drilled in 1929; cumulative recoveries from Arbuckle dolomites and Pennsylvanian carbonate rocks are 268.5 MMBO and 7.6 BCFG, and 228.4 MMBO and 0.2 BCFG, respectively.

Resource potential: Despite the mature exploration status of this play, there is fair to moderate potential for additional MMBOE reservoirs. While uplifts have been extensively drilled, paleotopographic highs are locations for possible new reservoirs. Probable new discoveries include areas where the Arbuckle is in unconformable contact with overlying Pennsylvanian structural traps, and Arbuckle and Reagan stratigraphic pinch-outs along margins of structures. Arbuckle well penetrations and pay zones are commonly near the top of the unit. However, future Arbuckle and Reagan discoveries may also result from deeper investigations.

UNCONVENTIONAL PLAYS

There are no unconventional plays described in this province report. However, unconventional plays listed in the surrounding provinces may include parts of this province. Individual unconventional plays are usually discussed under the province in which the play is principally located.

REFERENCES

Adler, F.J., 1971, Future petroleum provinces of the Midcontinent, region 7, *in* Cram, I.H., ed., Future petroleum provinces of the United States--their geology and potential: American Association of Petroleum Geologists, Memoir 15, p. 985-1,120.

Beene, D.L., 1989, Oil and gas fields in Kansas, listing by name, location, and cumulative production through January 1, 1988: Kansas Geological Survey Open-file Report 89-01, p. 16.

Bornemann, E., Doveton, J. H., and St. Clair, P., 1982, Lithofacies analysis of the Viola Limestone in south-central Kansas: Kansas Geological Survey, Petrophysical Series 3, 44 p.

Burruss, R.C., and Hatch, J.R., 1987, Regional variations in crude oil geochemistry, Anadarko basin, Oklahoma, Texas, and Kansas-evidence for multiple sources, mixing, and migration distances: American Association of Petroleum Geologists, v. 71, p. 535.

Burruss, R.C., and Hatch, J.R., 1989, Geochemistry of oils and hydrocarbon source rocks, greater Anadarko basin-evidence for multiple sources of oils and long-distance oil migration: Anadarko Basin Symposium, Oklahoma Geological Survey, Circular 90, p. 53-64.

Carlson, M., 1989, Oil in Nebraska: Nebraska Geological Survey, Resource Report 11, 86 p.

Cole, V.B., 1975, Subsurface Ordovician-Cambrian rocks in Kansas: Kansas Geological Survey, Subsurface Geology Series 2, 18 p., 4 pl.

Goebel, E.D., 1968, Cambrian System, *in* Zeller, D.E., ed., The stratigraphic succession in Kansas: Kansas Geological Survey Bulletin 189, p. 11-14.

Merriam, D.F., 1963, The geologic history of Kansas: Kansas Geological Survey Bulletin 162, 317 p.

Moore B.J., and Sigler S., 1985, Analyses of natural gases, 1917-1985: U.S. Bureau of Mines Information Circular, Kansas Section, 239 p.

Newell, K.D., Watney, W.L., Cheng, S.W.L., Brownrigg, R.L., 1987, Stratigragraphic and spatial distribution of oil and gas production in Kansas: Kansas Geological Survey, Subsurface Geology Series 9, 86 p.

Parham, K.D., 1993a, Upper Cambrian Stratigraphic traps--Central Kansas Uplift: *in* Bebout, D.G., White, W.A., Hentz, T.F., and Grasmick, M.K., eds., Atlas of major Midcontinent gas reservoirs: Gas Research Institute, et al., p. 80.

Parham, K.D., 1993b, Ordovician structural traps--Central Kansas Uplift, *in* Bebout, D.G., White, W.A., Hentzm T.F., and Grasmick, M.K., eds., Atlas of major Midcontinent gas reservoirs: Gas Research Institute, and others, p. 81-82.

Rice, D.D., 1983, Chalks, *in* Rice, D.D. and Gautier, D.L., eds., Patterns of sedimentation, diagenesis, and hydrocarbon accumulation in Cretaceous rocks of the Rocky Mountains: Society of Economic Paleontologists and Mineralogists Short Course 11, p. 9-1 through 9-19.

Scholle, P.A., 1977, Chalk diagenesis and its relation to petroleum exploration--oil from chalks, a modern miracle?: American Association of Petroleum Geologists Bulletin, v. 61, p. 982-1009.

Walters, R.F., 1958, Differential entrapment of oil and gas in the Arbuckle dolomite of central Kansas: American Association of Petroleum Geologists Bulletin, v. 42, p. 2,133-2,173.

Walters, R.F., 1991, Gorham Oil field, Russell County, Kansas; Kansas Geological Survey Bulletin 228, 112 p.

Watney, W.L., 1980, Cyclical sedimentation of the Lansing–Kansas City groups in northwestern Kansas and southwestern Nebraska: Kansas Geological Survey Bulletin 220, 70 p.

Watney, W.L., and Paul, S.E., 1983, Oil exploration and production in Kansas-present activity and future potential: Oil and Gas Journal, v. 81, p. 193-198.

ERA	PERIOD	SERIES	STAGE	MAJOR PETROLEUM-PRODUCING ROCK GROUP
CEN.	Quaternary			
	Tertiary			
MESOZOIC	Cretaceous	Upper		Niobrara Formation
		Lower		
	Jurassic			
	Triassic			
PALEOZOIC	Permian		Custerian	Sumner Group Chase Group Council Grove Group Admire Group
			Cimarronian	
			Gearyan	
	Pennsylvanian	Upper	Virgilian	Wabaunsee Group Shawnee Group Douglas Group
			Missourian	Lansing Group Kansas City Group Pleasanton Group
		Middle	Desmoinesian	Marmaton Group Cherokee Group
			Atokan	"Atokan rocks"
		Lower	Morrowan	"Morrowan rocks" — Basal Penn. cgl. (age is variable)
	Mississippian	Upper	Chesterian	"Chesterian rocks"
			Meramecian	"Chat," Miss. limestones
		Lower	Osagian	
			Kinderhookian	Misener, "Kinderhookian" sandstone
	Devonian	Upper		"Hunton" limestone
		Middle		
		Lower		
	Silurian	Upper		"Hunton" limestone
		Lower		
	Ordovician	Upper		Maquoketa Formation
		Middle		Viola Formation Simpson Group
		Lower		Arbuckle Group
	Cambrian	Upper		Reagan, Lamotte Sandstone
		Middle		
		Lower		
PRECAMBRIAN				Fractured basement rocks