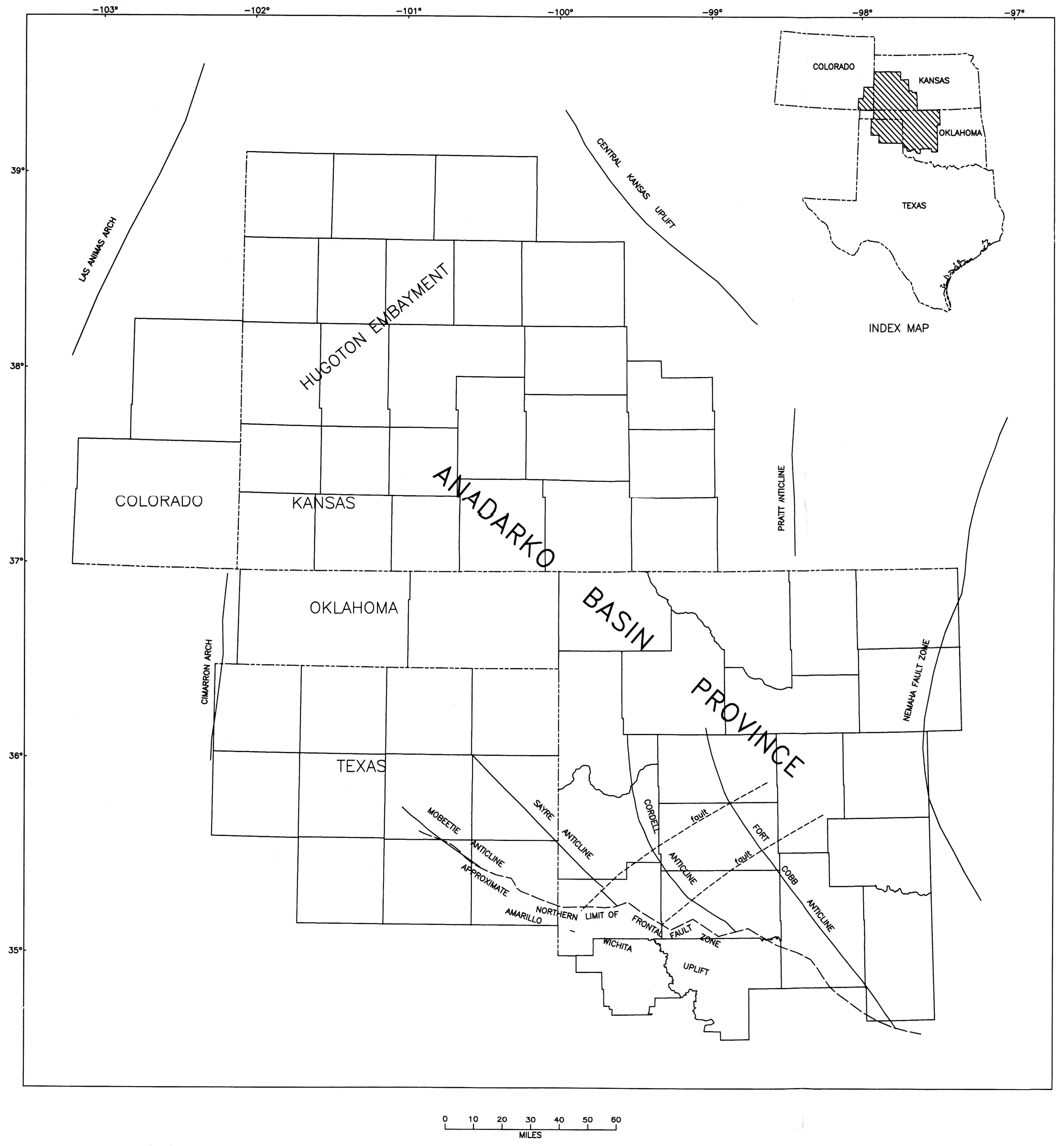
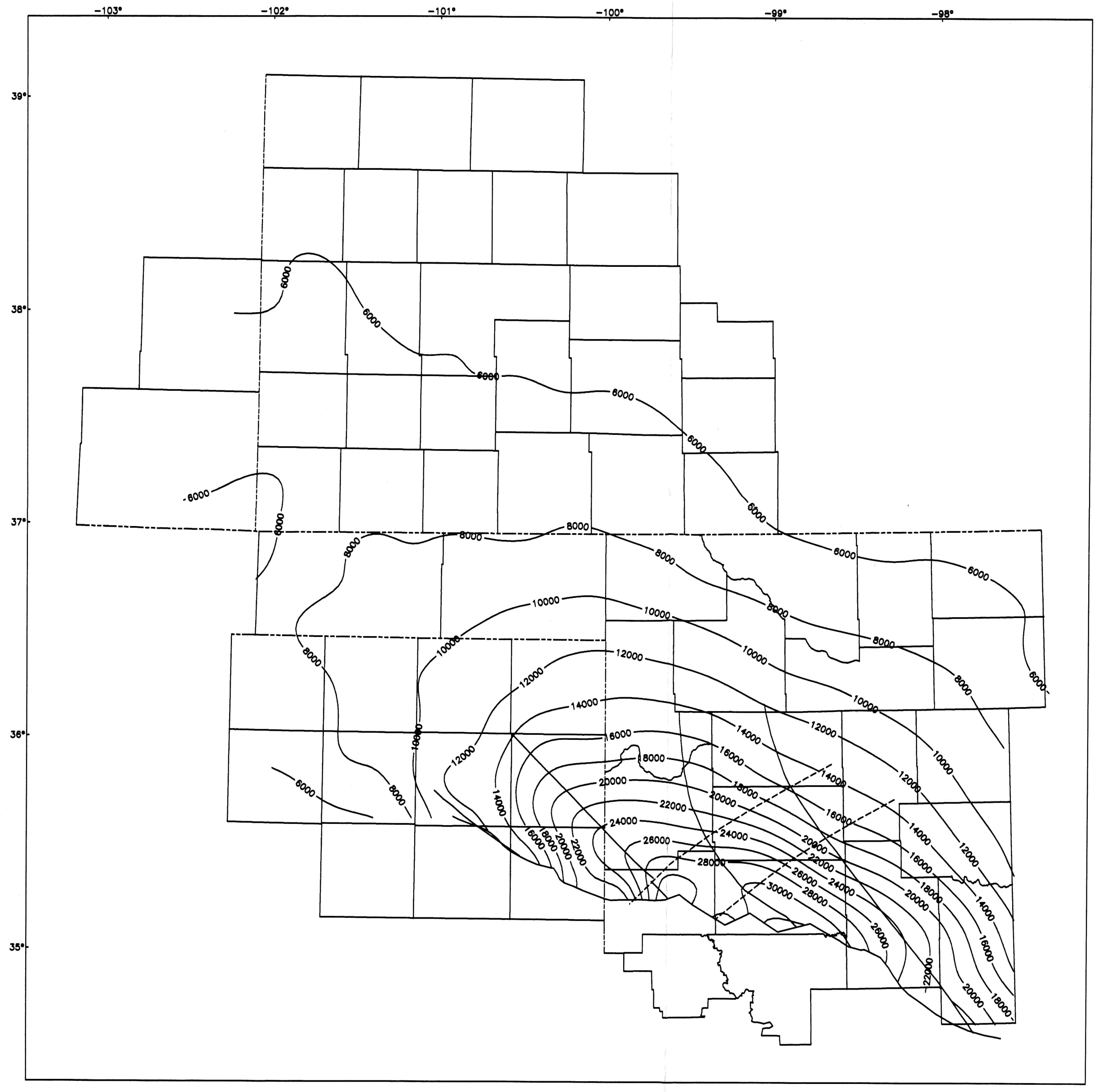
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

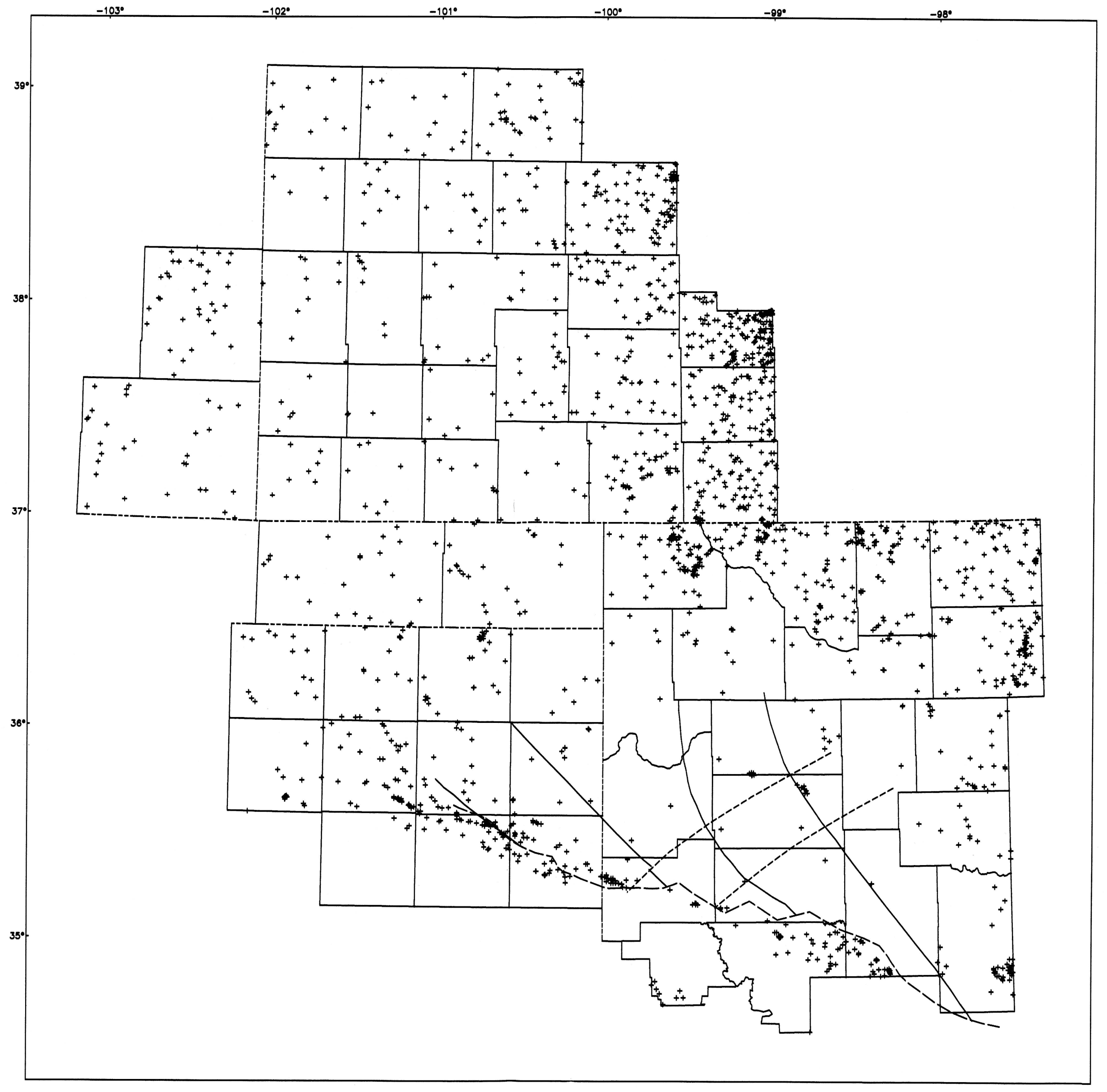
MISCELLANEOUS FIELD STUDIES
MAP MF-2313 (SHEET 1 OF 3)



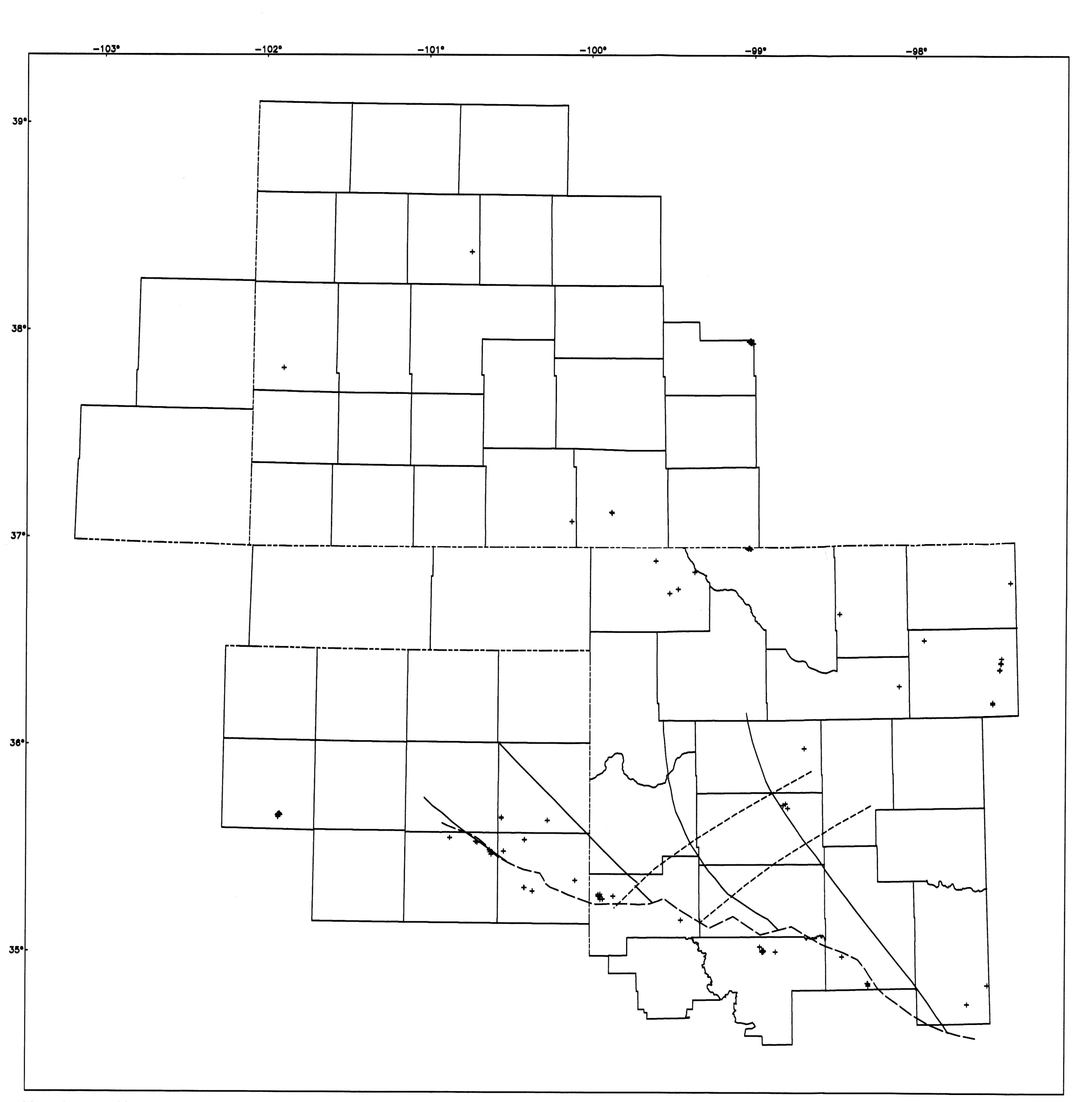
Map A. Anadarko basin province and selected basin-bounding structures (from Barrett, 1963). Major pre-Mississippian anticlines and faults in southern part of province are from Wroblewski (1967). The boundary between the deep basin and the Amarillo-Wichita uplift is represented by a line showing the approximate northern limit of the mountains-front fault zone. The scale bar is also applicable to maps B-F.



Map B. Depth to top of Arbuckle or Ellenburger Groups. Contour interval is 2,000 ft. Arbuckle and Ellenburger Group rocks exist within the fault zone but because of structural complexity, the contours have been omitted. See map A for explanation of other features on this map.

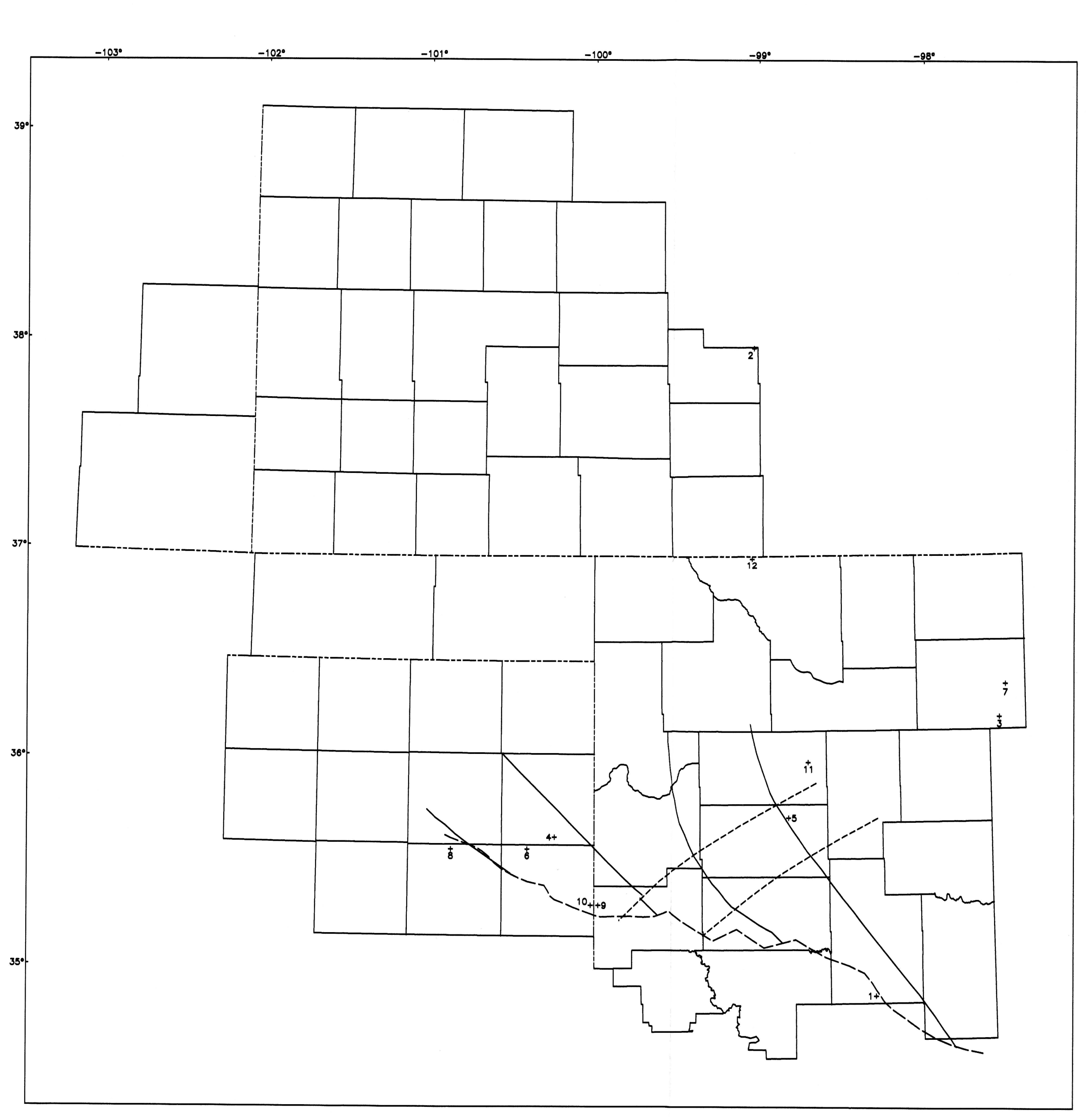


Map C. Locations of wells reporting Arbuckle or Ellenburger Group tops. See map A for explanation of other features on this map.

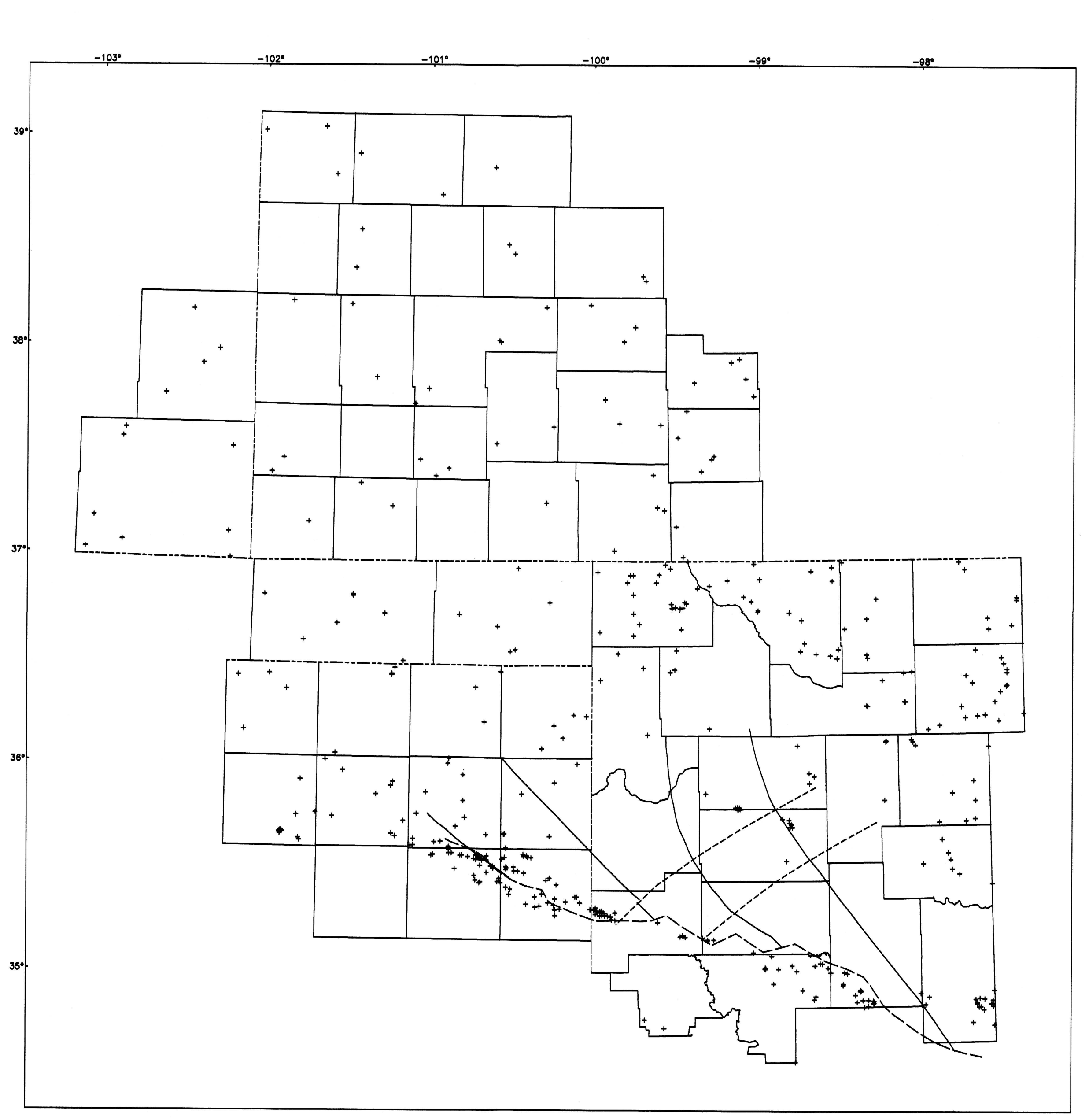


Manuscript approved for publication August 7, 1995

Map D. Locations of wells reporting Arbuckle or Ellenburger Group petroleum production. See map A for explanation of other features on this map.



Map E. Locations of fields that have major Arbuckle or Ellenburger Group petroleum production. Field locations are approximate centerpoints and do not reflect the areal extent of the accumulation. Field names and field-size codes (estimated ultimate recovery) associated with field numbers are shown in table 1. Explanation of field-size codes is shown in table 2. See map A for explanation of other features on this map.



Map F. Locations of wells that penetrate Arbuckle or Ellenburger Group tops by more than 250 ft. Exploration intensity within the Arbuckle or Ellenburger Groups declines rapidly after the first 250 ft of penetration (compare to map C). See map A for explanation of other features on this map.

INTRODUCTION

The Anadarko basin is a large, deep, two-stage Paleozoic basin (Feinstein, 1981) that is petroleum rich and generally well explored. The Anadarko basin province, a geographic area used here mostly for the convenience of mapping and data management, is defined by political boundaries that include the Anadarko basin proper. The boundaries of the province are identical to those used by the U.S. Geological Survey (USGS) in the 1995 National Assessment of United States Oil and Gas Resources. The data in this report, also identical to those used in the national assessment, are from several computerized data bases including Nehring Research Group (NRG) Associates Inc., Significant Oil and Gas Fields of the United States (1992); Petroleum Information (PI), Inc., Well History Control System (1991); and Petroleum Information (PI), Inc., Petro-Rom: Production data on CD–ROM (1993). Although generated mostly in response to the national assessment, the data presented here are grouped differently and are displayed and described in greater detail. In addition, the stratigraphic sequences discussed may not necessarily correlate with the "plays" of the 1995 national assessment. This report uses computer-generated maps to show drilling intensity, producing wells, major fields, and other geologic information relevent to petroleum exploration and production in the lower Paleozoic part of the Anadarko basin province as defined for the U.S. Geological Survey's 1995 national petroleum assessment. Hydrocarbon accumulations must meet a minimum standard of 1 million barrels of oil (MMBO) or 6 billion cubic feet of gas (BCFG) estimated ultimate recovery to be included in this report as a major field or reservoir. Mapped strata in this report include the Upper Cambrian to Lower Ordovician Arbuckle and Lower Ordovician Ellenburger Groups, the Middle Ordovician Simpson Group, and the Middle to Upper Ordovician Viola Group.

GEOLOGIC SETTING

The Anadarko basin province covers nearly the entire western part of Oklahoma, the southwestern part of Kansas, the northeastern part of the Texas Panhandle, and the southeastern corner of Colorado. The province, and thus the Anadarko basin proper, is bounded by major uplifts—the Amarillo-Wichita uplift to the south, the Cimarron and Las Animas arches to the west, the Central Kansas uplift to the north, the Pratt anticline to the northeast, and the Nemaha fault zone to the east (map A). The province, as defined here, covers about 50,000 mi^2.

The Anadarko basin contains sedimentary rock thicknesses in excess of 40,000 ft. Strata range in age from Cambrian to Permian with some Mesozoic and Cenozoic strata in the northwestern part. Mississippian and older rocks are predominately carbonates, whereas Pennsylvanian and younger rocks are mostly shale with some sandstone. Every Paleozoic system represented in the basin has produced some hydrocarbon. The province produces primarily gas. According to recent production data, more than 2.3 billion barrels of oil and more than 65.5 trillion cubic ft of gas have been produced from the province since the early 1900's.

The province has been drilled at least 200,000 times for an average of about 1 well for each 0.25 mi^2. This drilling density decreases significantly with depth. At the top of the Arbuckle, for example, drilling density is reduced to about 1 well for each 27 mi^2. Drilling density in the deep basin is even lower.

ARBUCKLE AND ELLENBURGER GROUPS

The Upper Cambrian to Lower Ordovician Arbuckle and the Lower Ordovician Ellenburger (in the Texas panhandle) Groups are present in the Anadarko basin (map A) in all but the most southern part—the Amarillo-Wichita uplift. These rocks consist of a sequence of shallow-water limestone and dolomite beds (Ham, 1969; Gatewood, 1978) that ranges in thickness from about 240 ft in the Hugoton embayment to possibly more than 10,000 ft in the deep southern part of the basin. A computer-generated map showing drilling depths to the top of the Arbuckle and Ellenburger Groups was created from Petroleum Information (PI) data (map B). Because of intense faulting and large variations in depths to the top of the Arbuckle or Ellenburger, drilling depths are not modeled south of the line showing the "approximate northern limit of the frontal fault zone" (map A), which separates the Amarillo-Wichita uplift from the deep Anadarko basin. Few well penetrations in Arbuckle or Ellenburger rocks exist in the deep (>15,000 ft) Anadarko basin (map C). Therefore, depths to the top of the Arbuckle or Ellenburger in the deep basin are estimated from reported depths to the tops and combined thicknesses of the Ordovician Simpson and Viola Groups, and the Upper Ordovician to Lower Devonian Hunton Group. These estimated depths were then combined with reported depths to help control the shape of the grid calculated by the modeling program. Map B is intended to show only a rough outline of the basin at the top of the Arbuckle or Ellenburger and an estimated depth to top.

Map C shows the locations of all wells in the PI Well History Control System (WHCS) file that penetrate the Arbuckle and Ellenburger Groups in the province; about 1,800 wells are shown on this map. The density of Arbuckle or Ellenburger penetrations is greatest near the Amarillo-Wichita uplift, the Nemaha fault zone, and the Central Kansas uplift. This increase in drilling intensity probably results from the relatively shallow depth and higher drilling-success ratio in this area relative to elsewhere in the basin. The Arbuckle has been drilled throughout the basin, although fewer wells are drilled with increasing distance from the surrounding uplifts. Although there are probably many wells that penetrate the Arbuckle and Ellenburger that are not shown on map C, the pattern of drilling intensity is believed to be representative of the present-day level of exploration.

Significant production from the Arbuckle is present in only a few fields within the province; however, oil and gas have been produced in large quantities from Arbuckle reservoirs outside the province on the Nemaha and Central Kansas uplifts, in south-central Oklahoma, and in the Permian Basin of west Texas. Map D shows the locations of the 106 wells found in the PI-WHCS data base that contain reported Arbuckle or Ellenburger production in the province. The pattern of producing wells is similar to the overall pattern of drilling intensity. The western and northern parts of the basin are nearly devoid of Arbuckle production and are lightly drilled.

Gatewood (1978) reports that the Arbuckle is productive from nearly 200 fields in Oklahoma, most of which are outside the Anadarko basin province. Petroleum Information well data show that in the Anadarko basin alone, the Arbuckle and (or) Ellenburger produce (or have produced) from only 39 named fields, and from 10 wells with no field name. Twelve major accumulations in Arbuckle or Ellenburger rocks are shown on map E; they are all concentrated near the uplifts that bound the basin, or along the major structural features of the deep basin.

Most large Arbuckle accumulations have been found in dolomite. Dolomitization of Arbuckle limestones may have resulted from a variety of mechanisms. Ham (1955) discussed dolomitization related to faulting. Burgess (1964) reported the occurrence of stratigraphic dolomite that he interpreted as an early diagenetic feature affecting what were originally lime mud deposits. In a recent study by Gao and others (1992), evidence was presented for both shallow and deep dolomitization of the Arbuckle. Read and Richmond (1993) describe four different types of dolomite in the Arbuckle "Brown zone" that formed at various times during the history of the rock. Timing of diagenetic porosity enhancement by deep burial dolomitization probably occurred after the Early Pennsylvanian (Gao and others, 1992). Unconformities at the top and within the Arbuckle predate petroleum that may have been generated and migrated from Simpson rocks.

Known major accumulations are found in combination traps near major structural features. We expect that most new discoveries will also be found in combination traps. Seals for accumulations in Arbuckle and Ellenburger reservoirs may result from low-porosity carbonate strata within the groups, younger low-porosity rocks overlying the groups, or possibly evaporites interbedded with the carbonates (Gatewood, 1978). Table 1 shows selected characteristics of the major Arbuckle and Ellenburger accumulations. These data come from the Nehring Research Group (NRG) data base (NRG Associates, Inc., 1992). Table 2 shows class size intervals that correspond to letter codes in table 1. Field size intervals, rather than specific numbers, are used here because the data (from Petroleum Information, Inc., 1993, and NRG Associates, Inc., 1992) are proprietary. Field sizes include cumulative production and estimates of recoverable reserves, and have been adjusted for growth using factors developed by Emil Attanasi and David Root of the U.S. Geological Survey (written commun., 1993) to yield an estimated ultimate recovery.

Organic-rich rocks directly above or within the Arbuckle are considered the most likely sources for undiscovered petroleum in the greater part of the Anadarko basin. In areas where the Arbuckle is directly overlain by potential source rocks, the importance of self-sourcing is not as great as it is in other areas. In an early report on the Arbuckle of the Wichita Mountains near Lawton, Oklahoma, Decker (1939) described the presence of "large amounts of dark shaley limestone...... and at two localities semi-liquid asphalt has seeped along the joint cracks of the rocks." Because of the possibility that Arbuckle rocks in the Wichita Mountains may be adjacent to a variety of potential source rocks (as a result of faulting), the presence of asphalt could indicate migration from younger source rocks, rather than from within the Arbuckle itself. Samples of the carbonaceous and asphaltic material were analyzed by destructive distillation and all yielded some gas and a little oil (Decker, 1939). Other published reports contain conflicting conclusions regarding the source potential of the Arbuckle (Trask and Patnode, 1942; Cardwell, 1977).

Petroleum geochemists generally agree that the onset of oil generation begins at a thermal maturity level equivalent to a vitrinite reflectance (Ro) of about 0.6% and that significant gas generation begins at about 1.3%. In the Anadarko basin, depths of about 6,000 ft more or less coincide with an Ro value of about 0.6%. Depths of about 13,000 ft coincide with an Ro value of about 1.3% (Schmoker, 1989). Simpson rocks, which directly overlie the Arbuckle, are within the oil window (0.6% to 1.3% Ro) in most of the Oklahoma and Texas parts of the province. Burruss and Hatch (1989) show that Simpson rocks are generally low in total organic carbon (TOC, ranging from 1 to 9%), and contain a mixture of types I and III organic matter. They state that the genetic potential of Simpson rocks is poor to moderate. Potential Simpson and Arbuckle source rocks probably reached the oil window about 320 million years ago (Schmoker, 1986).

Although the Arbuckle has been fairly well explored areally (there are no large parts of the province without Arbuckle penetrations), it is poorly explored in terms of the volume of rock present. The average drilling depth below the top of the Arbuckle is only 251 ft. Only 90 wells were found that reported drilling into these rocks more than 1,000 ft. Map F shows the locations of wells that have been drilled to more than 250 ft below the top of the Arbuckle or Ellenburger. The median penetration depth into the Arbuckle is only 118 ft. Of 106 wells (PI data) that reported Arbuckle or Ellenburger production, 51 produced from the upper 250 ft of these rocks. Some of the production that is reported to be from greater than 250 ft below the top of the formation, may actually be closer to the top. For example, in structurally complex, reverse-faulted areas where inclined formations are drilled vertically, drilling depths may not reflect formation thickness. At Yellowstone field, one example of Arbuckle production, the maximum producing thickness of the Arbuckle is about 152 ft (Fox, 1963); the location of that interval relative to the top of the Arbuckle is not known.

Because of the apparent correlation between reservoir quality and major structures, the less well explored parts of the province are also considered less prospective. The potential of the Arbuckle or Ellenburger for significant undiscovered petroleum accumulations is considered by the authors to be low. This judgement, however, carries a large measure of uncertainty. The source of this uncertainty results mostly from the fact that, volumetrically, the Arbuckle is not well explored. Recent work suggests that, although difficult to predict, stratigraphic traps could be numerous in the Arbuckle (Gao and others, 1992), and if the Arbuckle has within it an effective hydrocarbon source, the quantity of undiscovered petroleum could be large. One of the most serious negative factors related to the potential of the Arbuckle is the overall lack of production in areas where major structural features do not exist (that is, most of the province). This suggests that the Arbuckle has not been an effective source rock and that structural deformation is required to either improve reservoir quality or to provide migration pathways or traps sufficient for major accumulations. The future petroleum potential for Arbuckle and Ellenburger rocks in the Anadarko basin is not considered significant, primarily because of a general lack of data regarding source potential of these rocks. Positive evidence of a significant hydrocarbon source within the Arbuckle could greatly alter our current view.

Table 1. Selected data for oil accumulations greater than 1 million barrels and gas accumulations greater than 6 billion cubic feet in Arbuckle or Ellenburger Group reservoirs.

FIELD NAME	FIELD NUMBER	RESERVOIR LITHOLOGY	RESERVOIR DEPTH(ft)	MAJOR PRODUCT	ESTIMATED ULTIMATE RECOVERY CODE *
APACHE TOWNSITE	1	DOLOMITE	4264	GAS	a
BRADBRIDGE	2		4050	GAS	b
BROWN	3	DOLOMITE	6239	OIL	a
BUFFALO WALLOW	4	DOLOMITE	21116	GAS	a
CUSTER CITY, NORTH	5		15945	GAS	a
GAGEBY CREEK	6	DOLOMITE	16161	GAS	a
GARBER	7	LIMESTONE	4200	OIL	a
HOOVER, NORTHEAST	8	DOLOMITE	9030	GAS	a
MAYFIELD, WEST	9	DOLOMITE	16502	GAS	c
MILLS RANCH	10	DOLOMITE	22918	GAS	b
OAKWOOD, NORTH	11		12417	GAS	a
YELLOWSTONE	12	DOLOMITE	6000	GAS	a

* See Table 2 for key to letter codes

Table 2. Letter codes for estimated ultimate recoveries

MILLIONS OF BARRELS (OIL)	CODE	BILLIONS OF CUBIC FEET (GAS)	CODE
1 to 4	a	6 to 24	a
>4 to16	b	>24 to 96	b
>16 to 64	c	>96 to 384	c
>64 to 256	d	>384 to 1536	d
>256 to 1024	e	>1536 to 6144	e
>1024	f	>6144	f

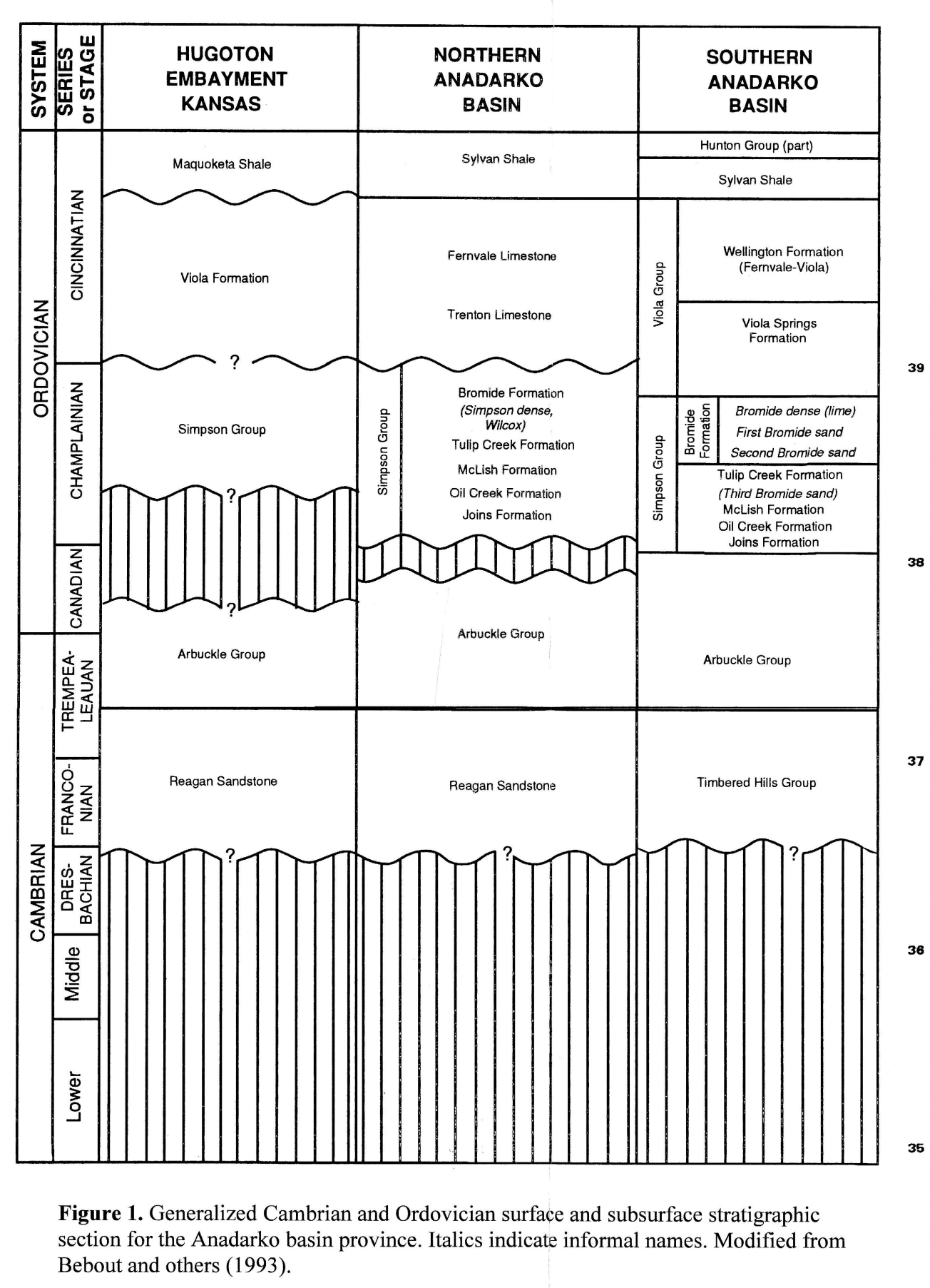


Figure 1. Generalized Cambrian and Ordovician surface and subsurface stratigraphic section for the Anadarko basin province. Italics indicate informal names. Modified from Bebout and others (1993).

SELECTED REFERENCES

Barrett, E., 1963, The geologic history of Oklahoma—an outline, *in* Cramer, R.D., and Wessman, H.G., eds., Oil and gas fields of Oklahoma, Reference Report: Oklahoma City Geological Society, v. 1, p. 1–32.

Bebout, D.G., White, W.A., Hentz, T.F., and Grasmick, M.K., eds., 1993, Atlas of Major Midcontinent Gas Reservoirs: Gas Research Institute, 85 p.

Borak, B., and Friedman, G.M., 1982, Simpson (Ordovician) sandstone and Hunton (Late Ordovician to Early Devonian) carbonate textures from deep parts of the Anadarko Basin: Oklahoma City Geological Society Shale Shaker, v. 32, no. 6, p. 1–8.

Brown, H.A., and Banta, A.D., 1993, Unusual occurrence of oil in the Viola limestone, Pratt anticline, Kansas, *in* Johnson, K.S., and Campbell, J.A., eds., Petroleum Reservoir Geology in the Southern Midcontinent, 1991 Symposium: Oklahoma Geological Survey Circular 95, p. 104–112.

Burgess, W.J., 1964, Stratigraphic dolomitization in Arbuckle rocks in Oklahoma, *in* McHugh, J.W., ed., Symposium on the Arbuckle: Tulsa Geological Society Digest, v. 32, p. 45–47.

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, *in* Johnson, K.S., ed., Anadarko Basin Symposium, 1988: Oklahoma Geological Survey Circular 90, p. 53–64.

———1992, Geochemistry of Pennsylvanian crude oils and source rocks in the greater Anadarko basin, Oklahoma, Texas, Kansas, Colorado, and Nebraska: An update [abs.], *in* Johnson, K.S., and Cardott, B.J., eds., Source Rocks in the Southern Midcontinent, 1990 Symposium: Oklahoma Geological Survey Circular 93, p. 197.

Cardwell, A.L., 1977, Petroleum source-rock potential of Arbuckle and Ellenburger Groups, southern mid-continent, United States: Quarterly of the Colorado School of Mines, v. 72, no. 3, 133 p.

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

Dapples, E.C., 1955, General lithofaces relationship of St. Peter Sandstone and Simpson Group: American Association of Petroleum Geologists Bulletin, v. 39, no. 4, p. 444–467.

Decker, C.E., 1939, Carbonaceous and asphaltic material in Lower Arbuckle limestones of Wichita Mountains, Oklahoma: American Association of Petroleum Geologists Bulletin, v. 23, no. 7, p. 1093–1094.

Feinstein, Shimon, 1981, Subsidence and thermal history of southern Oklahoma aulacogen—implications for petroleum exploration: American Association of Petroleum Geologists Bulletin, v. 65, no. 12, p. 2521–2533.

Fox, H.D., 1963, Yellowstone, *in* Cramer, R.D., Gatlin, L., and Weesman, H.G., eds., Oil and Gas Fields of Oklahoma, Reference Report: Oklahoma City Geological Society, p. 122–A–123–A.

Gao, Guoqiu, Land, L.S., and Folk, R.L., 1992, Meteoric modification of early dolomite and late dolomitization by basinal fluids, upper Arbuckle Group, Slick Hills, southwestern Oklahoma: American Association of Petroleum Geologists Bulletin, v. 76, no. 11, p. 1649–1664.

Gatewood, L.E., 1978, Arbuckle environments—some models and examples: Oklahoma City Geological Society Shale Shaker, v. 29, no. 2, p. 28–39.

Gautier, D.L., Dolton, G.L., Takahashi, K.I., and Varnes, K.L., eds., 1995, 1995 National Assessment of United States oil and gas resources—Results, methodology, and supporting data: U.S. Geological Survey Digital Data Series 30 [CD–ROM].

Ham, W.W., 1955, Field conference on geology of the Arbuckle Mountain region: Oklahoma Geological Survey Guide Book 3, 61 p.

Ham, W.E., 1969, Regional geology of the Arbuckle Mountain region: Oklahoma Geological Survey Guide Book 17, 52 p.

Johnson, K.S., 1991, Geologic overview and economic importance of Late Cambrian and Ordovician rocks in Oklahoma, *in* Johnson, K.S., ed., Late Cambrian-Ordovician Geology of the Southern Midcontinent, 1989 Symposium: Oklahoma Geological Survey Circular 92, p. 3–14.

Longman, M. W., and Palmer, S. E., 1987, Organic geochemistry of mid-continent Middle and Late Ordovician oils: American Association of Petroleum Geologists Bulletin, v. 71, no. 8, p. 938–950.

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

Nehring Research Group Associates, Inc., 1992, Significant oil and gas fields of the United States: Nehring Associates, Inc., P.O. Box 1655, Colorado Springs, CO 80901.

Read, D.L., and Richmond, G.L., 1993, Geology and reservoir characteristics of the Arbuckle Brown zone in the Cottonwood Creek field, Carter County, Oklahoma, *in* Johnson, K.S., and Campbell, J.A., eds., Petroleum-Reservoir Geology in the Southern Midcontinent, 1991 Symposium: Oklahoma Geological Survey Circular 95, p.113–125.

Petroleum Information, Inc., 1991, Well history control system: Petroleum Information Corporation, P.O. Box 2612, Denver, CO 80201.

———1993, Petro-Rom—Production data on CD-ROM: Petroleum Information Corporation, P.O. Box 2612, Denver, CO 80201.

Schmoker, J.W., 1986, Oil generation in the Anadarko basin, Oklahoma and Texas—modeling using Lopatin's method: Oklahoma Geological Survey Special Publication 86–3, 40 p.

———1989, Thermal maturity of the Anadarko basin, *in* Johnson, K.S., ed., Anadarko Basin Symposium, 1988: Oklahoma Geological Survey Circular 90, p. 25–31.

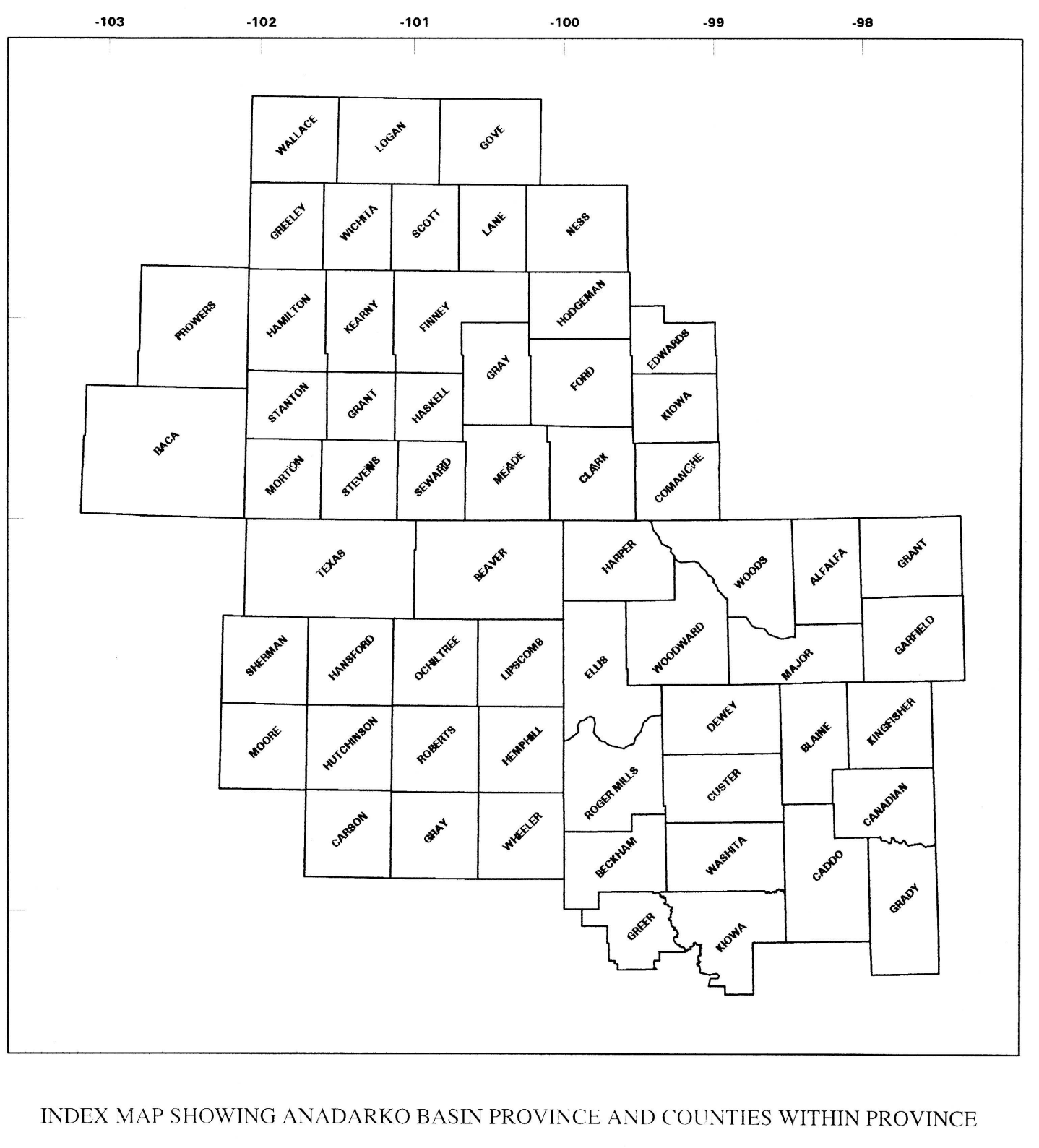
Schramm, M. W., 1964, Paleogeologic and quantitative lithofacies analysis Simpson Group, Oklahoma: American Association of Petroleum Geologists Bulletin, v. 48, no. 7, p.1164–1195.

Trask, P.D., and Patnode, H.W., 1942, Source beds of petroleum: Tulsa, Oklahoma, American Association of Petroleum Geologists, 566 p.

Waples, D.W., 1980, Time and temperature in petroleum formation—Application of Lopatin's method to petroleum exploration: American Association of Petroleum Geologists Bulletin, v. 64, no. 6, p. 916–926.

Wavrek, D.A., 1992, Characterization of oil types in the Ardmore and Marietta basins, southern Oklahoma Aulacogen, *in* Johnson, K.S., and Cardott, B.J., eds., Source rocks in the southern midcontinent, 1990: Oklahoma Geological Survey Circular 93, p. 185–195.

Wroblewski, E.F., 1967, Exploration problems in the "deep" Anadarko basin: Oklahoma City Geological Society Shale Shaker, v. 17, no. 7, p. 369–374.



INDEX MAP SHOWING ANADARKO BASIN PROVINCE AND COUNTIES WITHIN PROVINCE

ARBUCKLE AND ELLENBURGER GROUPS

MAPS SHOWING PETROLEUM EXPLORATION INTENSITY AND PRODUCTION IN MAJOR CAMBRIAN TO ORDOVICIAN RESERVOIR ROCKS IN THE ANADARKO BASIN

By

Mitch Henry and Tim Hester

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