AY Osp: MIDDLE ORDOVICIAN ST. PETER SANDSTONE

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he Middle Ordovician St. Peter Sandstone gas play includes several small consisting of structural traps (Figures Osp-1, Osp-2) that are associated the Kentucky River and Irvine-Paint Creek fault zones in eastern Kentucky re Osp-3). The prospective area for the play extends from eastern Kentucky outhwestern West Virginia and possibly southern Ohio, generally following ortheast-trending Rome trough.

oduction History

The first significant St. Peter Sandstone gas reserves were discovered in in the Furnace field (renamed Irvine-Furnace Consolidated) in Estill ty, Kentucky. The discovery well, the South Central Petroleum Company 1 J.M. Garrett, Carter coordinate location 21-P-68, Estill County, Kentucky, completed in the St. Peter Sandstone at a depth of 2,538 to 2,586 feet and a final open flow of 8,500 Mcfg/d. The field was developed rapidly, with 14 s completed by 1949. Only two additional development wells have been pleted since 1949: one in 1953 and one in 1986. Gas analyses (McGuire and vell, 1963) indicate high concentrations of carbon dioxide (25.5 to 41.0 cent), nitrogen (1.4 to 2.3 percent), and hydrogen sulfide (0.0 to 0.56 percent). e presence of these gases results in Btu values ranging from 646 to 765. cause of the low Btu values, gas produced from the St. Peter Sandstone in the ine-Furnace Consolidated field was used for pressure maintenance at Big king oil field (McGuire and Howell, 1963). Cumulative production for the riod from 1947 to 1960 was reported to be 1.8 bcfg (Price, 1981).

The second major gas field in the St. Peter Sandstone was the Trapp field in ark County, Kentucky, discovered in 1962. The discovery well was the Smith o. 1 Vernon Chambers, Carter coordinate location 15-Q-66, Clark County, ntucky. This well was completed from the St. Peter Sandstone at a depth of 606 to 1,660 feet and had a final open flow of 2,500 Mcfg/d. Fourteen wells were mpleted between 1962 and 1986. Cumulative production for the Trapp field was ported to be 0.4 bcfg for the period from 1962 to 1974 (Price, 1981).

In addition to the two major fields, four small fields consisting of one or two ells each have been discovered in Kentucky, the most recent in 1984. It is ubtful that any of these fields have ever produced significant quantities of gas. he Stephens field in Elliott County, Kentucky, however, has one reported St. eter Sandstone gas well, the Monitor Petroleum No. 1 Cecil Ison, drilled in July 970, which flowed 5.3 MMcfg/d after stimulation (Price, 1981) from the St. Peter andstone, at depths of 4,634 to 4,646 feet and 4,712 to 4,734 feet. The Btu value f the gas was reported to be 1,017 (Price, 1981). The well was never connected o a pipeline (J.D. Silberman, written commun., 1994). Another significant well that has never commercially produced is the Signal No. 1 Elkhorn Coal Corporation in Johnson County, Kentucky. This well was abandoned as a dry hole in 1973 and was reported to have an open flow of 3 to 5 MMcfg/d (1,027 Btu) from the St. Peter Sandstone at a depth of 5,914 to 5,935 feet (Price, 1981; Sutton, 1981). The presence of gas with a high Btu value in both of these wells compared to the low Btu values in the Irvine-Furnace Consolidated and Trapp fields suggests a trend of increasing Btu values from west to east. An awareness of this apparent trend may be beneficial to the explorationist when doing economic evaluations of prospective gas areas in the St. Peter Sandstone. Gas shows have been reported from the St. Peter Sandstone in at least two wells drilled in Wayne and Cabell counties, West Virginia, but no gas fields have resulted (Cardwell, 1977). Currently, Ohio has no gas production from the St. Peter Sandstone. The total cumulative production from 1947 to 1974 for the St. Peter Sandstone gas play is at least 2.2 bcfg. The amount of gas produced from the St. Peter Sandstone play since 1974 is unknown, due to lack of reliable production data.

Stratigraphy

The St. Peter Sandstone of eastern Kentucky and western West Virginia is a dolomite-cemented quartzarenite, which unconformably overlies the Lower Ordovician Beekmantown Dolomite of the Knox Group (Figures Osp-4, Osp-5). In Kentucky, the St. Peter Sandstone grades vertically and laterally into the Middle Ordovician Wells Creek Dolomite. In West Virginia, the "Wells Creek Formation" unconformably overlies the St. Peter Sandstone. In southern Ohio, the Wells Creek Formation occupies the stratigraphic position of the St. Peter Sandstone, due to a lateral facies change. However, a maximum of 50 feet of sandstone, which has been called St. Peter Sandstone, occurs in southern Ohio and northern Kentucky, near the axis of the Cincinnati arch (Carpenter, 1965). Also, scattered pods of sandstone have been encountered in Fayette and Madison counties, Kentucky (Jillson, 1965). These isolated sandstone bodies are interpreted to be within the Beekmantown Dolomite and are not stratigraphically correlative with the St. Peter Sandstone of eastern Kentucky (Patton and Dawson, 1969).

Depositional environments of the St. Peter Sandstone include a variety of well-sorted strandline deposits such as beach sands, eolian dunes, and nearshore sand bars (Price, 1981). Deposition appears to have been influenced by growth faulting along the Kentucky River and Irvine-Paint Creek fault zones in the Rome trough (Woodward, 1961; McGuire and Howell, 1963; Silberman, 1972; Price, 1981; Cable and Beardsley, 1984). A stratigraphic cross section (Figure Osp-6) oriented from north to south across the Kentucky River and Irvine-Paint Creek fault zones illustrates substantial thickening of the Cambrian formations and moderate thickening of the Lower and Middle Ordovician formations. The regional distribution of the St. Peter Sandstone is shown by an isopach map (Figure Osp-7), which indicates several depocenters on the downthrown side of the Kentucky River and Irvine-Paint Creek fault zones. The thickest depocenter (more than 200 feet thick) follows the Kentucky River fault zone in a northeasterly direction across Elliott, Lawrence, and Boyd counties, Kentucky, into Wayne, Cabell, and Mason counties, West Virginia. The Monitor Petroleum

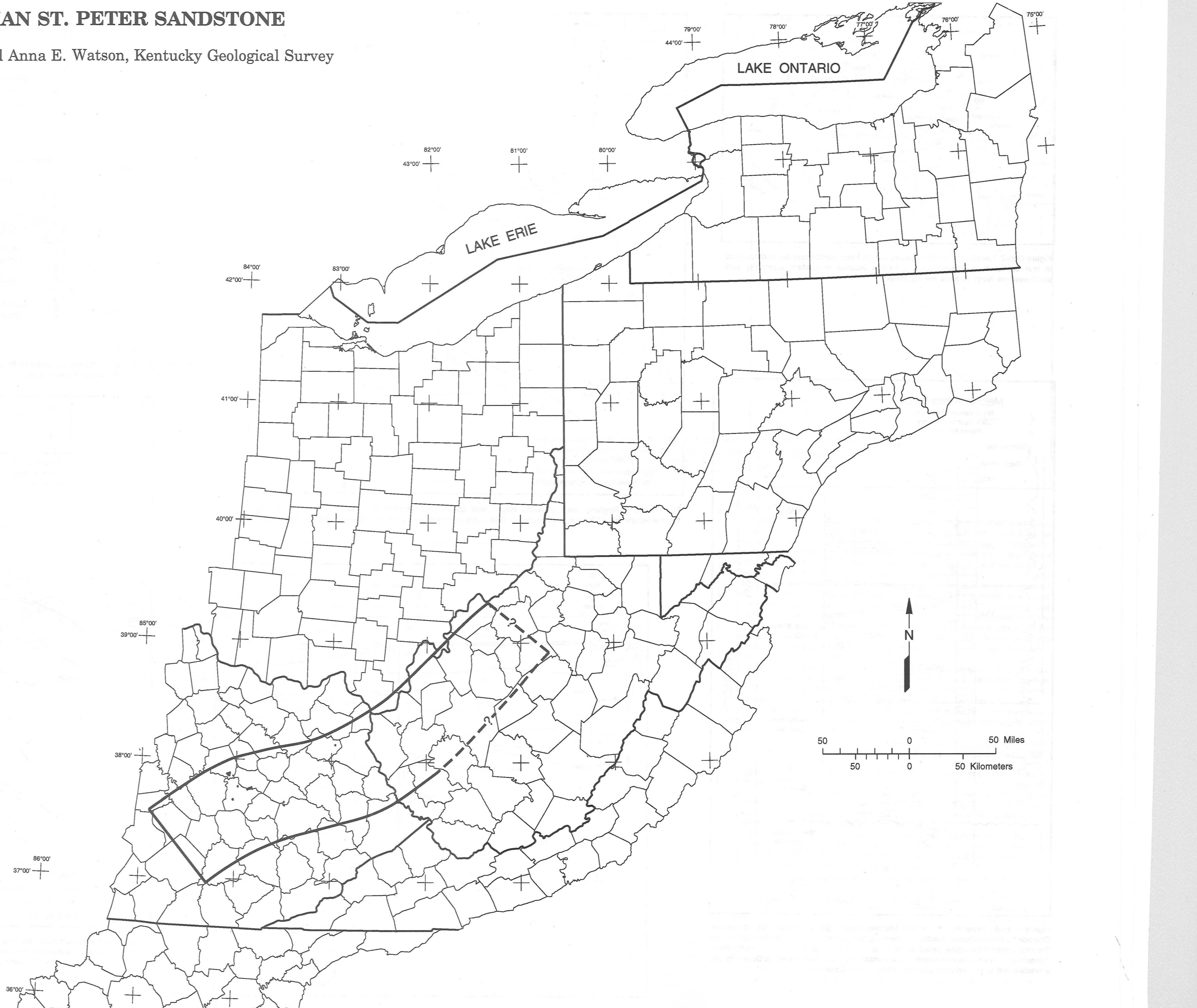


Figure Osp-1. Outline of the Middle Ordovician St. Peter Sandstone play within the Appalachian basin. Dots represent individual gas wells; areas where dots have merged represent fields. Dashed line indicates approximate play boundary; where queried, play boundary is conjectural.

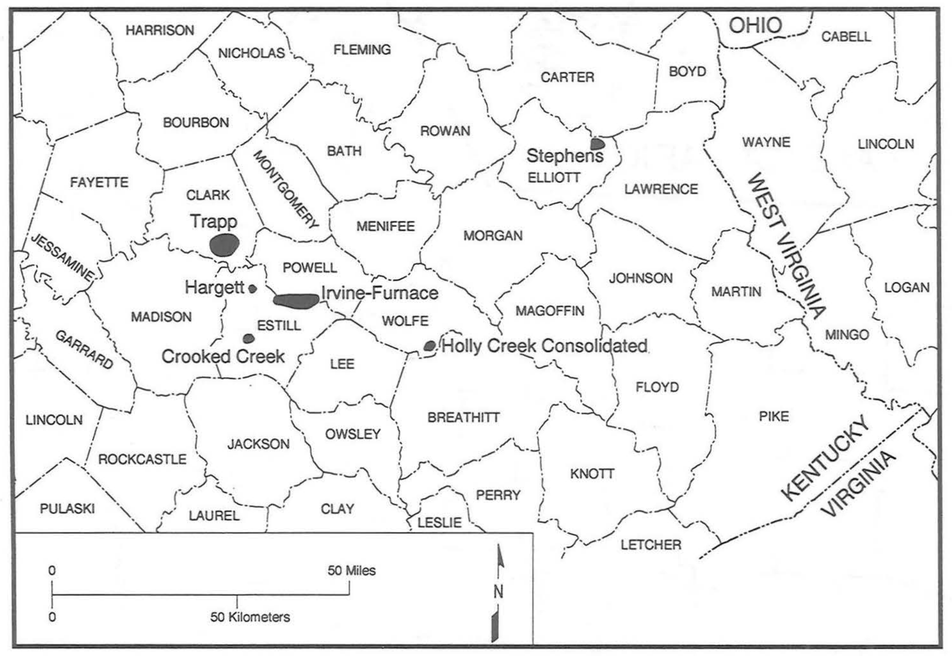


Figure Osp-2. Location of Middle Ordovician St. Peter Sandstone fields discussed in text or listed in Table Osp-1. Counties located in eastern Kentucky and southwestern West Virginia are identified.

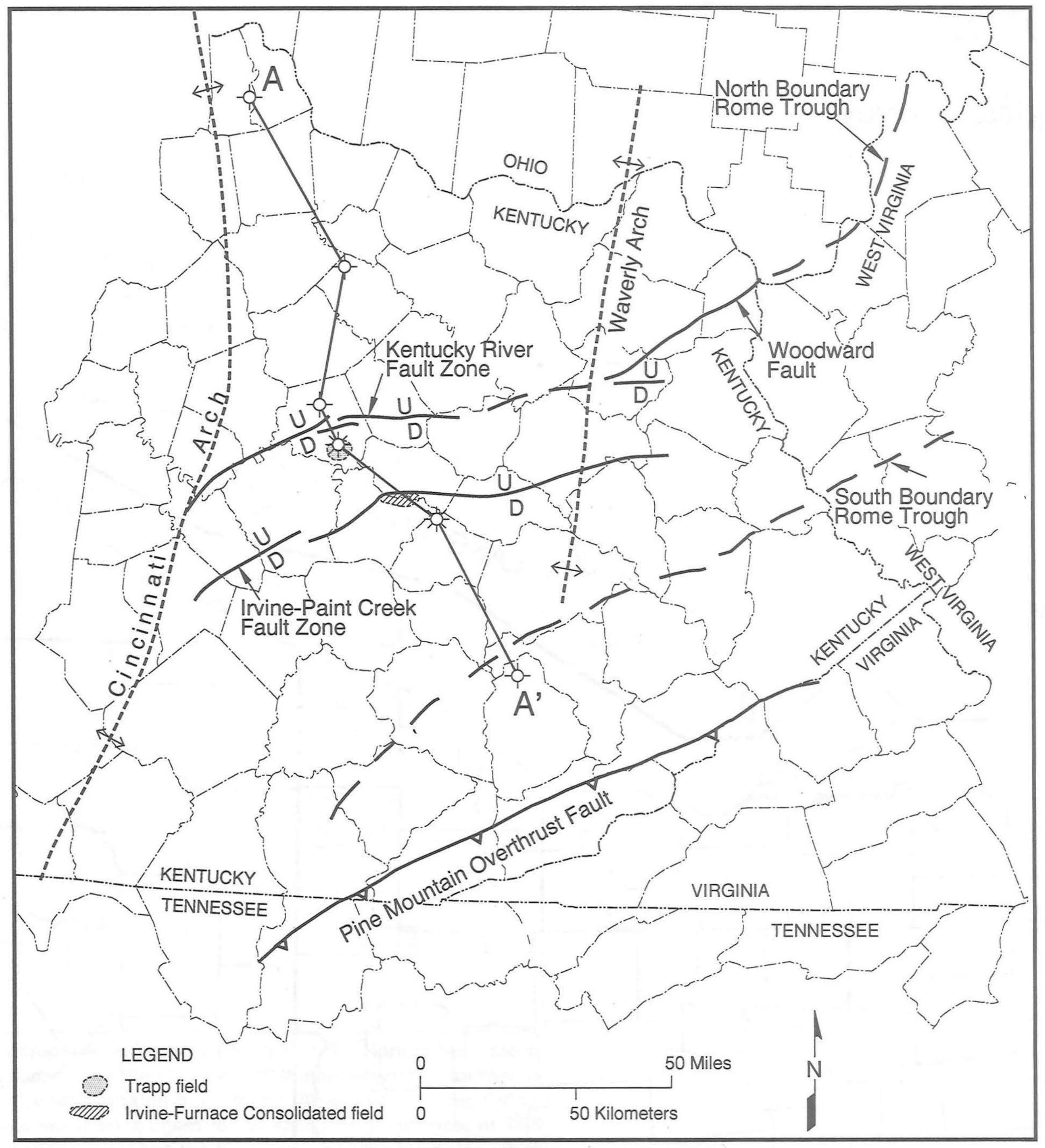


Figure Osp-3. Regional map showing major fault zones and tectonic features in eastern Kentucky, southwestern West Virginia, and southern Ohio. Line of cross section A-A' (Figure Osp-6) is also shown.

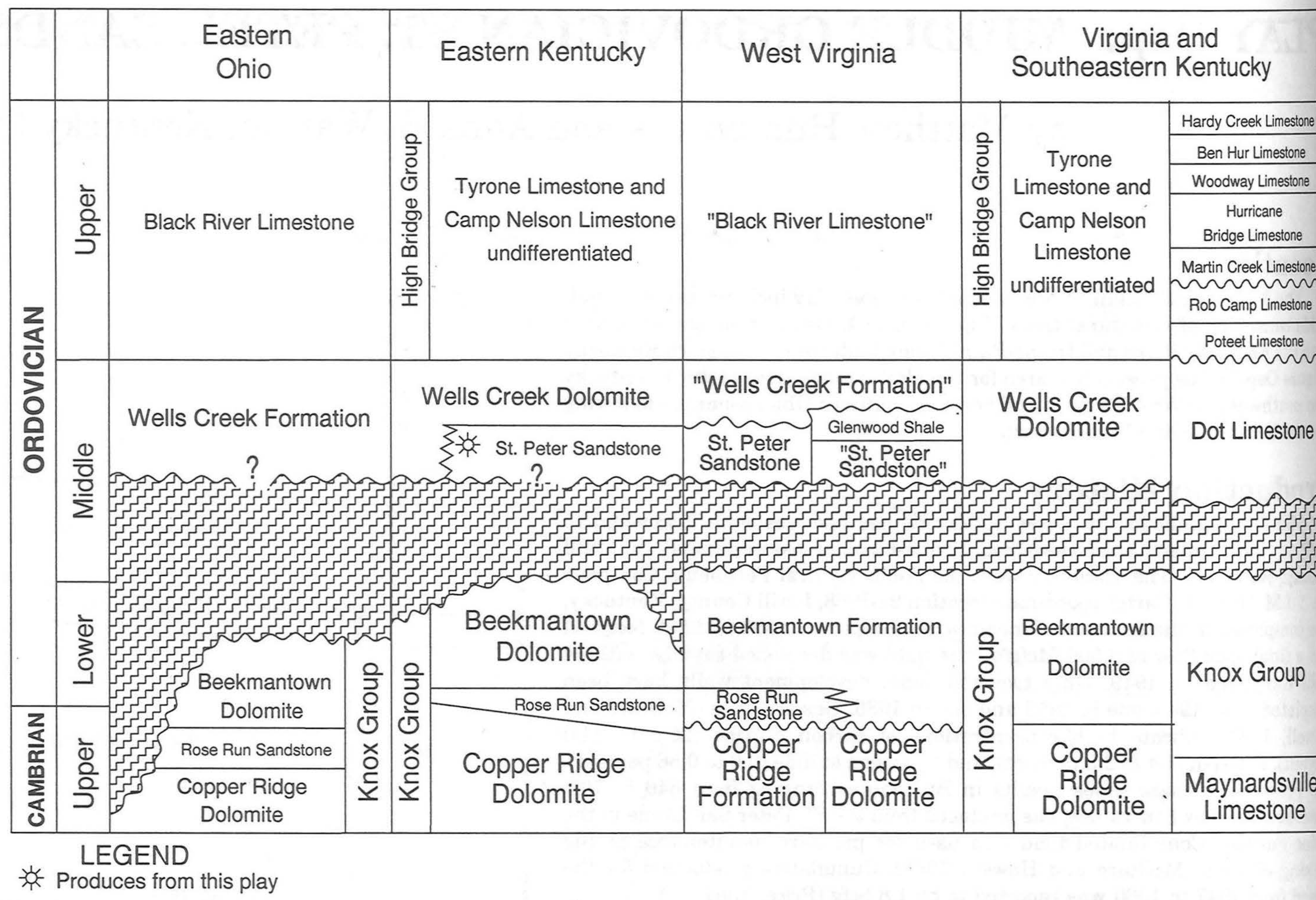


Figure Osp-4. Stratigraphic correlation chart for the St. Peter Sandstone. Modified from Anderson (1984), Noger and others (1984), Patchen and Avary (1984), and Rader (1984).

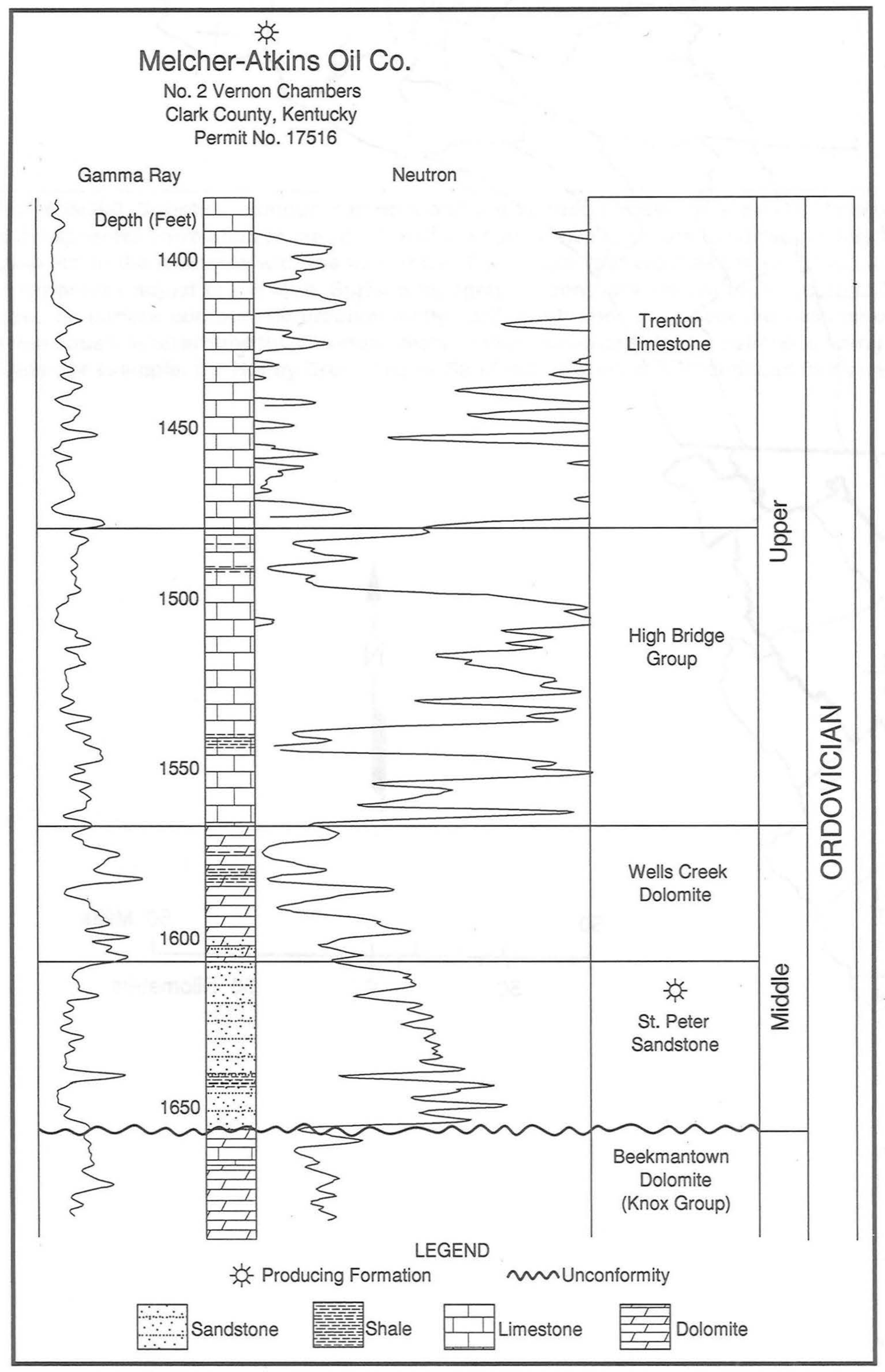


Figure Osp-5. Type log from the Melcher-Atkins Oil Company, No. 2 Vernon Chambers, Clark County, Kentucky, showing the gamma-ray and neutron curves and the interpreted lithologies based on samples of the St. Peter Sandstone. The St. Peter Sandstone has an unconformable lower contact with the Beekmantown Dolomite and a gradational upper contact with the Wells Creek Dolomite.

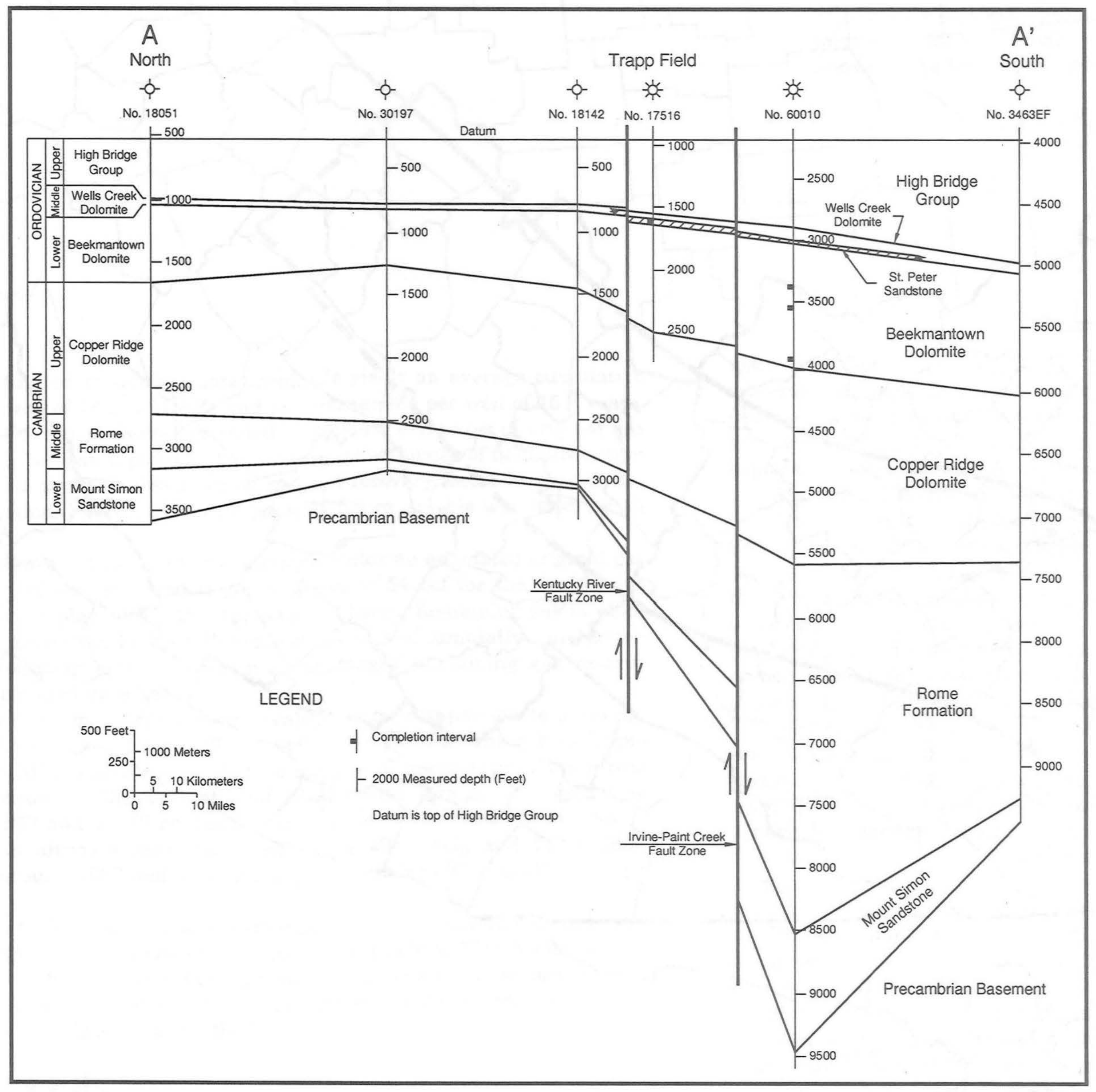


Figure Osp-6. Regional stratigraphic cross section A-A', illustrating the effect of faulting on deposition of the Cambrian and Ordovician formations. Datum is top of the Ordovician High Bridge Group. Line of cross section is shown in Figure Osp-3.

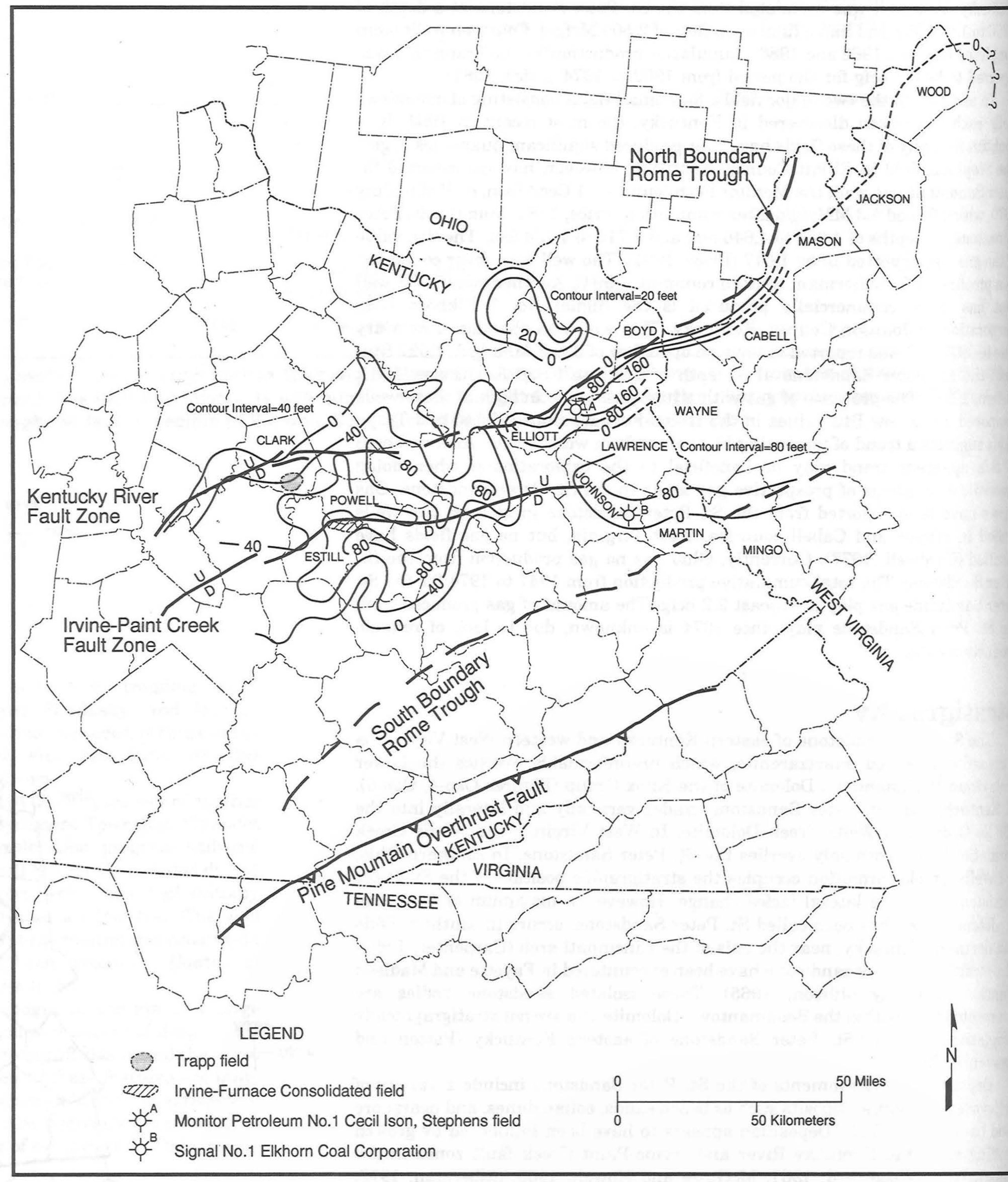
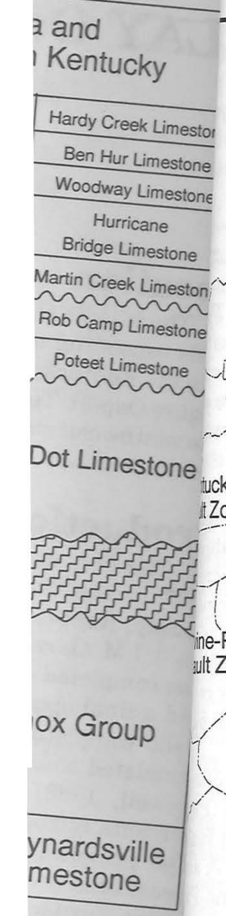
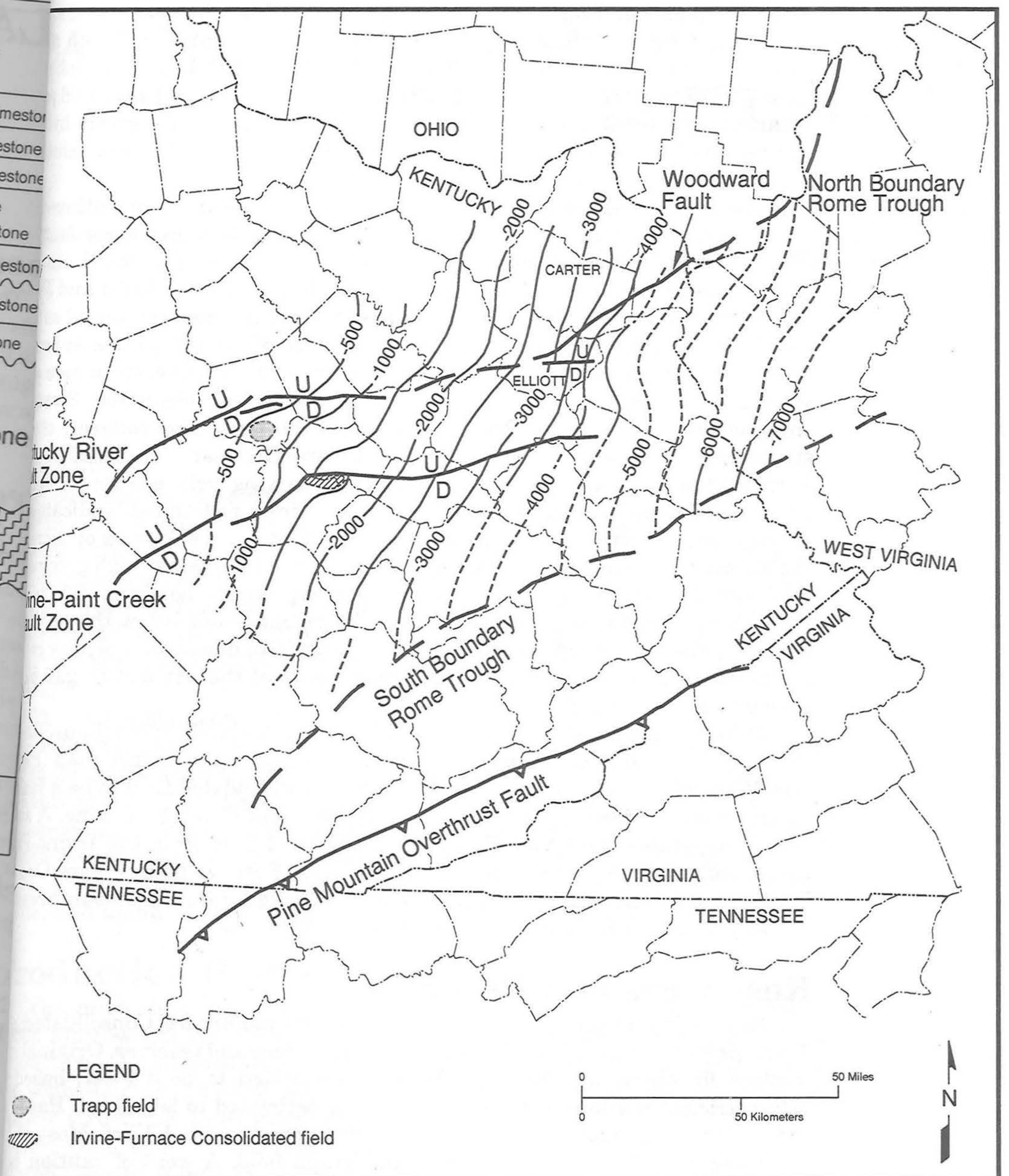


Figure Osp-7. Isopach map showing regional distribution of the St. Peter Sandstone. Modified from Price (1981). Isopach contours are dashed in areas of sparse well control. Major fault zones and county names referred to in text are shown. Contour interval is variable (20, 40, or 80 feet).





...gure Osp-8. Regional structure map contoured on top of the St. Peter Sandstone. Modified from ...ice (1981). Structure contours are dashed in areas of sparse well control. Contour interval = ...0 feet. Datum is sea level. Major fault zones and county names referred to in text are shown.

...o. 1 Cecil Ison drilled in the Stephens field, Elliott County, Kentucky, is located ...this depocenter, downthrown to the Woodward fault zone (Silberman, 1981), ...hich locally forms the northern boundary of the Rome trough. This depositional ...end may extend as far northeast as Jackson and Wood counties, West Virginia ...ardwell, 1977; Price, 1981; Ryder, 1992). In these counties, an unnamed ...ndstone on top of the Knox unconformity occurs at depths below 10,000 feet ...yder, 1992). This unnamed sandstone is probably the stratigraphic equivalent ...f the St. Peter Sandstone of eastern Kentucky. Due to sparse well control, the ...mits of this unnamed sandstone were not mapped in detail in Figure Osp-7. ...nother depocenter is located on the downthrown side of the Irvine-Paint Creek ...ault zone, in Estill and Powell counties, Kentucky. The St. Peter Sandstone is ...reater than 80 feet thick immediately south of the Irvine-Furnace Consolidated ...as field. In southern Clark County, Kentucky, the Trapp gas field is situated in ...a depocenter that reaches a thickness of 40 feet downthrown to the Kentucky ...River fault zone. Limited well control suggests a thick (80 feet) development of St. Peter Sandstone in Johnson and Martin counties, Kentucky, and adjacent Mingo County, West Virginia. The Signal No. 1 Elkhorn Coal Corporation well in Johnson County, Kentucky is located in this depocenter. This well had a significant show of gas from the St. Peter Sandstone.

In the past, the St. Peter Sandstone in eastern Kentucky has been interpreted to be erosional remnants that are laterally equivalent to the St. Peter Sandstone of the Upper Mississippi Valley and Midcontinent Region (Dapples, 1955). However, Price (1981) did a comprehensive study of the regional distribution of the St. Peter Sandstone in eastern Kentucky and concluded that the St. Peter Sandstone in the Rome trough is not stratigraphically related to the Upper Mississippi Valley formation described by Dapples (1955). Freeman (1953) suggested that the St. Peter Sandstone was a transgressive sheet sand derived from erosion of the sandy Knox Dolomite and older dolomites of the Ozark uplift and possibly from the Laurentian uplift in the east. According to this interpretation, the St. Peter Sandstone was deposited in erosional lows on the unconformity surface of the Knox Dolomite. More recent studies (Silberman, 1972; Price, 1981; Cable and Beardsley, 1984) conclude that fault-controlled subsidence during the Middle Ordovician resulted in localized deposition of the St. Peter Sandstone in the Rome trough. Price (1981) described the lithology of the St. Peter Sandstone as a dolomite-cemented quartzarenite with a distinct bimodal distribution of grain sizes. The samples studied typically contained at least 60 percent fine-grained, well-sorted, subrounded sand grains and 15 to 40 percent medium-grained, well-rounded, frosted grains (Price, 1981). Price pointed out that the St. Peter Sandstone of the Upper Mississippi Valley is typically well rounded, extremely well sorted, and not bimodal. He interpreted the St. Peter Sandstone of eastern Kentucky to be a hinge-line, regressive deposit, rather than a transgressive deposit. He suggested sediment from the eroded Rose Run Sandstone and Beekmantown Formation in southern Ohio is a source of texturally mature sand.

Structure

The structure of the prospective area for gas exploration is characterized by regional southeastern dip intersected by the major east-west trending fault zones associated with the Rome trough (Figure Osp-8). Drilling depths for the St. Peter Sandstone are approximately 1,600 feet in the west near Trapp field and 7,500 feet in the east near the border of Kentucky and West Virginia.

	TABLE Osp-1	Irvine-Furnace Consolidated KY	Trapp KY	Crooked Creek KY	Holly Creek Consolidated KY	Hargett KY	Stephens KY
BASIC RESERVOIR DATA	POOL NUMBER	1601029 365 STPR	1601997 365 STPR	1600507 365 STPR	1600977 365 STPR	1600887 365 STPR	1601894 365 STPR
	DISCOVERED	1947	1962	1984	1957	1967	1970
	DEPTH TO TOP RESERVOIR	2,527	1,598	1,670	3,787	1,797	4,634
	AGE OF RESERVOIR	Ordovician	Ordovician	Ordovician	Ordovician	Ordovician	Ordovician
	FORMATION	St. Peter Sandstone	St. Peter Sandstone	St. Peter Sandstone	St. Peter Sandstone	St. Peter Sandstone	St. Peter Sandstone
	PRODUCING RESERVOIR	St. Peter Sandstone	St. Peter Sandstone	St. Peter Sandstone	St. Peter Sandstone	St. Peter Sandstone	St. Peter Sandstone
	LITHOLOGY	sandstone	sandstone	sandstone	sandstone	sandstone	sandstone
	TRAP TYPE	structural	structural	structural	structural	structural	structural
	DEPOSITIONAL ENVIRONMENT	marine-shoreline	marine-shoreline	marine-shoreline	marine-shoreline	marine-shoreline	marine-shoreline
	DISCOVERY WELL IP (Mcf)	8,500	2,500	10	622		5,300
	DRIVE MECHANISM	water	water	water			
	NO. PRODUCING WELLS	0	0	0	0	0	0
	NO. ABANDONED WELLS	16	14	2	1	1	1
	AREA (acreage)	880	1,000	40	20	20	20
	OLDEST FORMATION PENETRATED	Knox	Copper Ridge	St. Peter Sandstone	Copper Ridge	Knox	Cambrian
	EXPECTED HETEROGENEITY DUE TO:	structure diagenesis	structure diagenesis	structure diagenesis	structure diagenesis	structure diagenesis	structure diagenesis
RESERVOIR PARAMETERS	AVERAGE PAY THICKNESS (ft.)	20	23	15	10		14
	AVERAGE COMPLETION THICKNESS (ft.)	23	40	18	10	13	34
	AVERAGE POROSITY–LOG (%)	10	13	11			7
	MINIMUM POROSITY–LOG (%)	8	7	8			6
	MAXIMUM POROSITY–LOG (%)	12	19	14			8
	NO. DATA POINTS	1	9	2			1
	POROSITY FEET						
	RESERVOIR TEMPERATURE (°F)		81				97
	INITIAL RESERVOIR PRESSURE (psi)	780	600	640			
	PRODUCING INTERVAL DEPTHS (ft.)	2,200-2,657	1,436-1,664	1,664-1,674	3,787-3,797	1,797-1,810	4,634-4,646 4,712-4,734
	PRESENT RESERVOIR PRESSURE (psi) / DATE	100/1960	250/1986	640/1984			
FLUID & GAS PROPERTIES	Rw (Ωm)						
	GAS GRAVITY (g/cc)	0.8325	0.626				
	GAS SATURATION (%)		59				53
	WATER SATURATION (%)		41				47
	COMMINGLED	no	no	no			no
	ASSOCIATED OR NONASSOCIATED	nonassociated	nonassociated	nonassociated	nonassociated	nonassociated	nonassociated
	Btu/scf	765	955				1,017
VOLUMETRIC DATA	STATUS (producing, abandoned, storage)	abandoned	abandoned	abandoned	abandoned	abandoned	abandoned
	ORIGINAL GAS IN PLACE (Mcf)	2,400,000	1,700,000				
	ORIGINAL GAS RESERVES (Mcf)	1,900,000	1,400,000				
	PRODUCTION YEARS	1947-1960	1962-1974				
	REPORTED CUMULATIVE PRODUCTION (Mcf)	1,800,000	400,000				
	NO. WELLS REPORTED						
	ESTIMATED CUMULATIVE PRODUCTION (Mcf)						
	REMAINING GAS IN PLACE (Mcf)/DATE	600,000/1993	1,300,000/1993				
	REMAINING GAS RESERVES (Mcf)/DATE	100,000/1993	1,000,000/1993				
	RECOVERY FACTOR (%)	79	82				
	INITIAL OPEN FLOW (Mcf/d)						
	FINAL OPEN FLOW (Mcf/d)	7,818	1,399	15	622		5,300

Structure influenced deposition during Cambrian through Middle Ordovician time in eastern Kentucky, western West Virginia, and southern Ohio. Structurally dominant features controlling sand deposition and gas entrapment in the resulting reservoirs are the Kentucky River and Irvine-Paint Creek fault zones (Figure Osp-8). These fault zones in the Rome trough were episodically active from Late Precambrian time through the end of the Paleozoic. Regional stratigraphic thickening of the Cambrian section on the downthrown side of these major faults suggests a type of growth faulting, related to the tensional rifting of the Rome trough. The moderate thickening observed in the Middle Ordovician section may be a result of reactivation of subsidence along the major fault zones. Silberman (1972) did a detailed study of the Woodward fault along the northern boundary of the Rome trough in Elliott and Carter counties, Kentucky. He suggested penecontemporaneous or post-Knox movement as a controlling factor in the deposition of an abnormal thickness of St. Peter Sandstone.

The Waverly arch (Figure Osp-3) also influenced depositional patterns of the St. Peter Sandstone in eastern Kentucky. Cable and Beardsley (1984) constructed a series of regional isopach maps that indicate the Waverly arch, as depicted by Woodward (1961), primarily influenced the deposition of the Early Ordovician Beekmantown Group. However, this arch appears to have migrated across the region from east to west, beginning in the Early Cambrian and continuing until the Middle Ordovician. The migrating arch resulted in thinning or absence of St. Peter Sandstone near the arch axis, and thick deposition on the flanks. Rejuvenated fault activity along the Kentucky River fault zone accentuated depositional subsidence (Cable and Beardsley, 1984).

TABLE Osp-2	Irvine-Furnace Consolidated KY	Trapp KY
AVERAGE POROSITY–CORE (%)	8	12
MINIMUM POROSITY–CORE (%)	4	7
MAXIMUM POROSITY–CORE (%)	12	19
NO. DATA POINTS	1	2
AVERAGE PERMEABILITY (md)	14	14.1

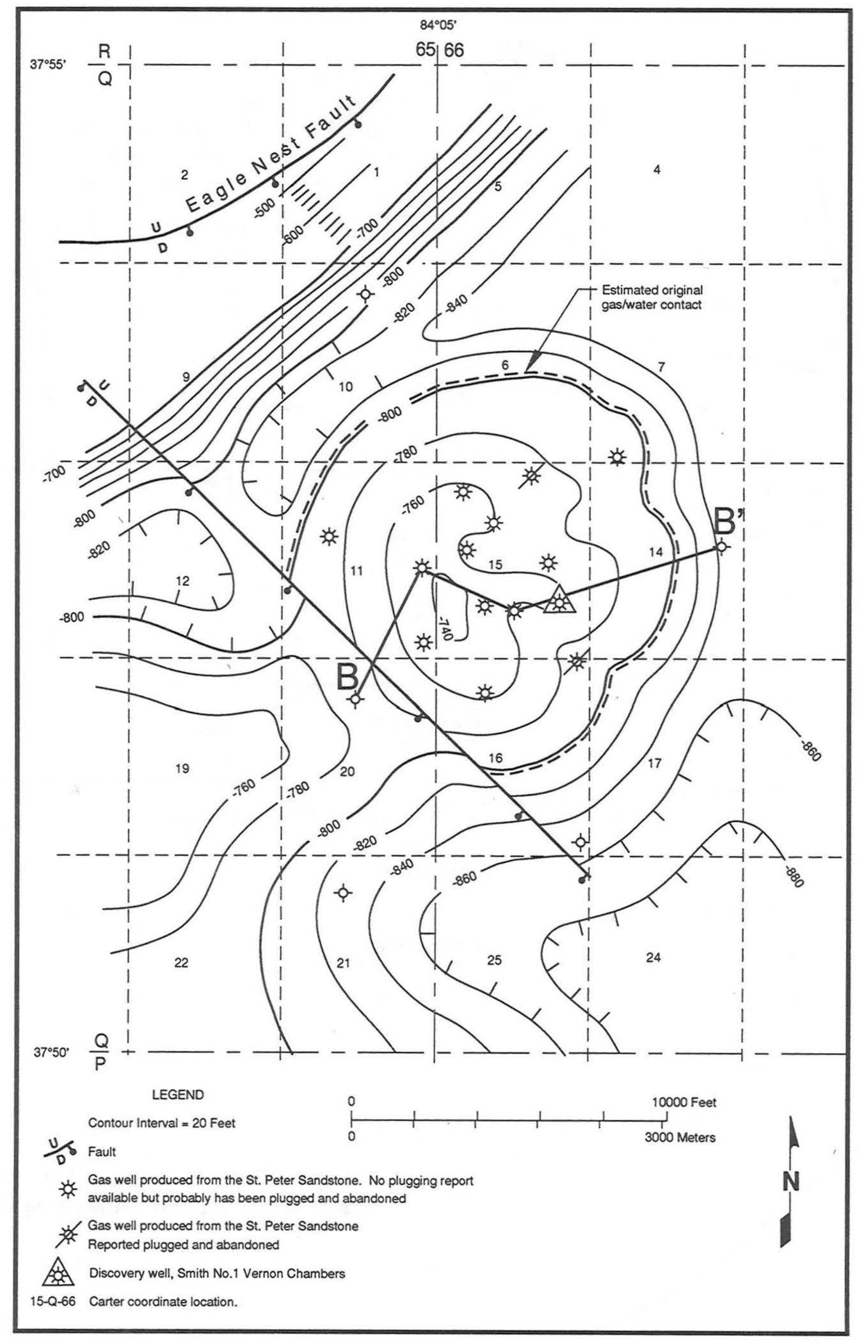


Figure Osp-9. Structure map of the Trapp field, Clark County, Kentucky, contoured on top of the St. Peter Sandstone. Contour interval = 20 feet. Datum is sea level. Line of cross section B-B' (Figure Osp-10) is also shown.

Reservoir

Typical trap types in the St. Peter Sandstone include faulted anticlines, domal anticlines, and possibly fault traps. These localized structural features formed as a result of differential uplift of basement blocks along the Kentucky River and Irvine-Paint Creek fault zones. The seal for gas entrapment is provided by the overlying Wells Creek Dolomite, which has low porosity and permeability. The source rock for gas in the St. Peter Sandstone may be the Devonian Ohio Shale, although organic-rich Ordovician shales should not be overlooked as potential source rocks. Ryder and others (1991) identified the Middle and Upper Ordovician Antes Shale as the most probable source for 15 Cambrian and Ordovician oil samples from Ohio. Cole and others (1987) concluded that the Upper Ordovician Point Pleasant Formation was the probable source of oil for some Cambrian, Ordovician, and Silurian reservoirs in Ohio. Migration of gas may have occurred along the Knox unconformity and along the major fault zones of the Rome trough.

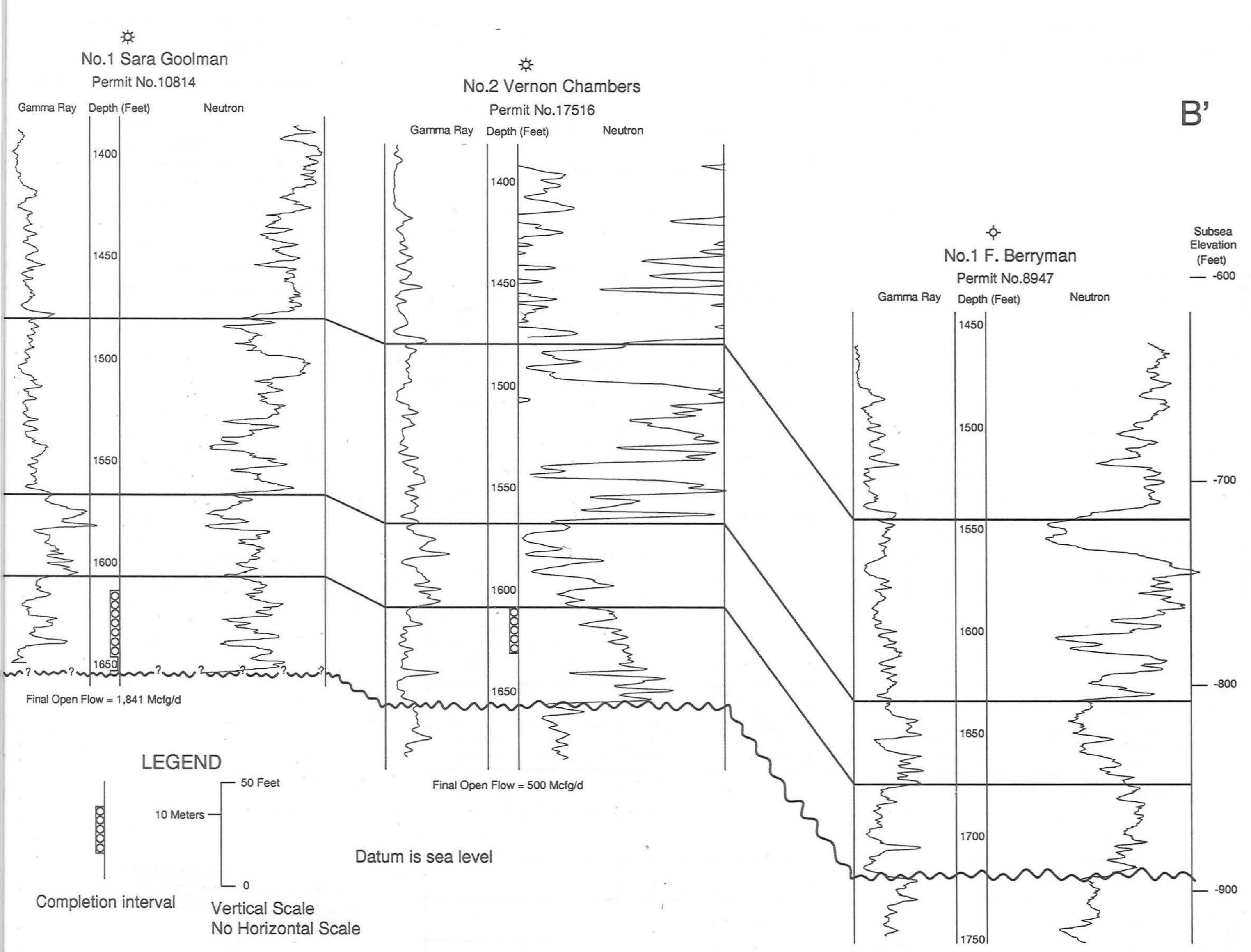
The average depth to the top of the reservoirs (Tables Osp-1, Osp-2) in the St. Peter Sandstone is 2,669 feet and ranges from 1,598 to 4,634 feet. Average pay thickness is 15 feet and ranges from 10 to 23 feet. Completion intervals average 23 feet and range from 10 to 40 feet. Average final open flow is 3,031 Mcfg/d and ranges from 10 to 20,000 Mcfg/d. Three of the St. Peter Sandstone gas reservoirs studied are underpressured, with a pressure gradient of about 0.344 psi/foot. However, the Monitor Petroleum No. 1 Cecil Ison in the Stephens field, Elliott County, Kentucky, had shut-in pressure of 1,998 psi from a drill stem test interval of 4,620 to 4,694 feet (J.D. Silberman, written commun., 1994). The pressure gradient for this well is 0.426 psi/foot, indicating near normal pressure. The maximum initial shut-in pressure reported from the three other St. Peter Sandstone reservoirs was 780 psi at 2,639 feet, and the minimum was 600 psi at 1,694 feet. The average initial shut-in pressure for these fields is 673 psi at 2,005 feet. Gas analyses from several fields, including the Irvine-Furnace Consolidated and Trapp fields, indicate high concentrations of carbon dioxide and nitrogen, which lowers the Btu value of the gas.

In most of the St. Peter Sandstone gas fields, reservoir porosity is dominantly intergranular, with heterogeneity caused by reduction in grain sizes near the upper and lower contacts, variation in the volume of dolomite cementation, and minor occurrences of shale clasts. However, secondary fracture porosity occurs and is important in the St. Peter Sandstone reservoir at Stephens field in Elliott County, Kentucky. When exploring for gas in the St. Peter Sandstone, consideration must be given to potential enhancement of reservoir porosity due to fracturing caused by post depositional faulting. The St. Peter Sandstone has an average log porosity of 10 percent and ranges from 6 to 19 percent. Horizontal permeability averages 14.1 md and ranges from 1 to 160 md, based on three core analyses. Reservoir drive is a combination of gas expansion and partial water drive.

Completion practices since 1962 include acidizing and sand-water fracturing through 4.5-inch casing or open hole. Wells completed in the last 10 years utilize nitrogen foam fracturing. Completions in the 1940s and 1950s were natural or shot with nitroglycerin.

Description of Key Field

Trapp field: The Trapp field in Clark County, Kentucky, was selected to illustrate a typical St. Peter Sandstone gas accumulation, because it has more



ross the Trapp field, Clark County, Kentucky. Completion intervals for the two gas productive wells (No. 1 Sara Goolman
of cross section is shown in Figure Osp-9.

geophysical logs and cores than any of the other fields. The field was discovered in 1962 and has produced 0.4 bcfg from 14 wells, at an average depth of 1,598 feet. Net pay thickness averages 23 feet. Porosity averages 13 percent and ranges from 7 to 19 percent. Gas analyses indicate 88.25 percent methane, 1.66 percent ethane, 5.96 percent nitrogen, 2.96 percent carbon dioxide, 0.15 percent hydrogen sulfide, and 1.02 percent miscellaneous heavy hydrocarbons. The Btu value of the gas is 955, and specific gravity is 0.626.

The Trapp field is a faulted domal anticline situated on the downthrown side of the Eagle Nest fault, which forms a portion of the Kentucky River fault zone (Figure Osp-9). Surface mapping reveals the presence of a small anticlinal feature designated as the Mina dome on the Hedges (Black, 1975) and Palmer (Simmons, 1967) geologic quadrangle maps. A structure map contoured on top of the St. Peter Sandstone indicates about 60 feet of closure in the subsurface (Figure Osp-9). A small, vertical, normal fault on the southwestern side of the structural closure is mapped at the surface and in the subsurface. Structural cross section B-B' (Figure Osp-10) illustrates the structural rollover; the two structurally highest wells (Melcher No. 1 Sara Goolman and Melcher No. 2 Vernon Chambers) are gas productive and the flanking wells are nonproductive. Changes in gamma-ray character of the wells in cross section B-B' indicate some stratigraphic variability. Unpublished sample studies reveal zones of increased shaliness and increased dolomite cementation in the intervals of high gamma-ray readings. The original gas/water contact is interpreted to be about -800 to -810 feet subsea. Wells that penetrated the St. Peter Sandstone below the gas/water contact either produced water or were nonproductive due to low porosity caused by increased grain cementation. An isopach map of the net feet of gas pay is shown in Figure Osp-11.

Only one geophysical log is available for the Irvine-Furnace Consolidated field in Estill and Powell counties, Kentucky. A regional structure map (Figure Osp-12) depicts the trap at the Irvine-Furnace Consolidated field to be a faulted anticline on the downthrown side of the Irvine-Paint Creek fault zone. A small graben separates the Irvine-Furnace Consolidated field from the Irvine-Paint Creek fault zone. A decline curve for the original Furnace field (Figure Osp-13) indicates a 10-year producing life for the field, with an initial shut-in pressure of 740 psi and a near-abandonment pressure of 180 psi.

Resources and Reserves

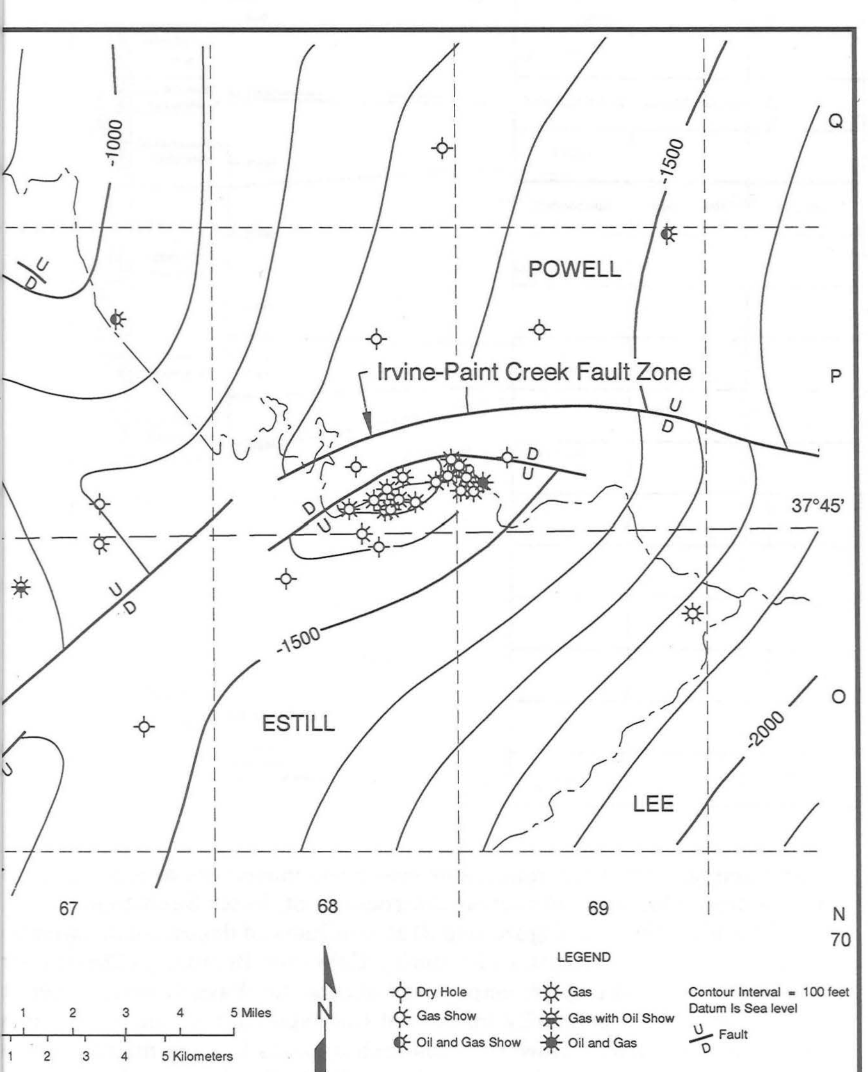
Reservoir and production data from the Irvine-Furnace Consolidated and Trapp fields were used to make estimates of resources and reserves. Original gas-in-place for these two fields combined is estimated to be 4.1 bcf, based on volumetric calculations. Original reserves are estimated to be 3.3 bcf. Based on limited production data, estimated remaining reserves are 1.1 bcf. Most of the calculated remaining reserves are in the Trapp field. A word of caution is in order, because the actual cumulative production for the Trapp field could be significantly higher than the last known figure of 0.4 bcf reported in 1974.

Future resources for the St. Peter Sandstone are estimated to be 10 to 32 bcf of gas over the next 40 years, based on historical drilling results and volumetric estimates. Since 1947, exploration drilling in eastern Kentucky has resulted in the discovery of only two significant St. Peter Sandstone gas fields: Trapp and Irvine-Furnace Consolidated fields. Approximately 144 wells have been drilled through the base of the St. Peter Sandstone in the 20-county area considered to be prospective in eastern Kentucky. The resulting success ratio is 1.4 percent. Several cases were examined with a range of success ratios from 1 to 10 percent. An average annual drilling rate of four wildcat wells per year for the next 40 years was assumed, based on the historical average annual drilling rate for 1947 to 1991. Each new field discovered was assigned ultimate reserves of 2 bcfg, based on the average size of the Trapp and Irvine-Furnace Consolidated fields. A low case was selected that is more optimistic (success ratio of 3 percent) than historical drilling results, based on the assumption that many of the early wildcat wells may not have been valid St. Peter Sandstone prospects. The high case was calculated using a success ratio of 10 percent and assumed that some of the future exploration would employ new technology, which could possibly reduce the number of dry holes. These numbers are highly speculative and are based on very limited data from the St. Peter Sandstone play area in eastern Kentucky only.

Future Trends

The most promising areas for future exploration in the St. Peter Sandstone should be in regions where major fault trends coincide with areas of thick sandstone development, and where the reported Btu value of the gas is high, such as Elliott, Lawrence, Johnson, and Martin counties, Kentucky, and Mingo, Wayne, and Cabell counties, West Virginia. The St. Peter Sandstone gas play trends northeastward beyond these counties into deeper portions of the Appalachian basin. The future limit of the play in a northeasterly direction will be determined by the economics of deep drilling depths (greater than 10,000 feet) and sparse well control.

The southwestern limit of the St. Peter Sandstone gas play is defined by the depositional extent of the prospective reservoir facies. The porous St. Peter Sandstone undergoes a lateral facies change into the nonporous Wells Creek Dolomite near the western end of the Kentucky River and Irvine-Paint Creek fault zones. Unfortunately, the high concentrations of carbon dioxide and nitrogen gas are of economic concern in established producing areas such as Estill, Powell, and Clark counties, Kentucky. However, these low-Btu gases may have value as a resource for other uses, such as secondary recovery in oil fields (for example, gas from the Irvine-Furnace Consolidated field was injected into oil reservoirs in Big Sinking field, Estill County, Kentucky).



Osp-12. Structure map of the Irvine-Furnace Consolidated field, Estill and counties, Kentucky, contoured on top of the Knox Group. Modified from and Howell (1963).

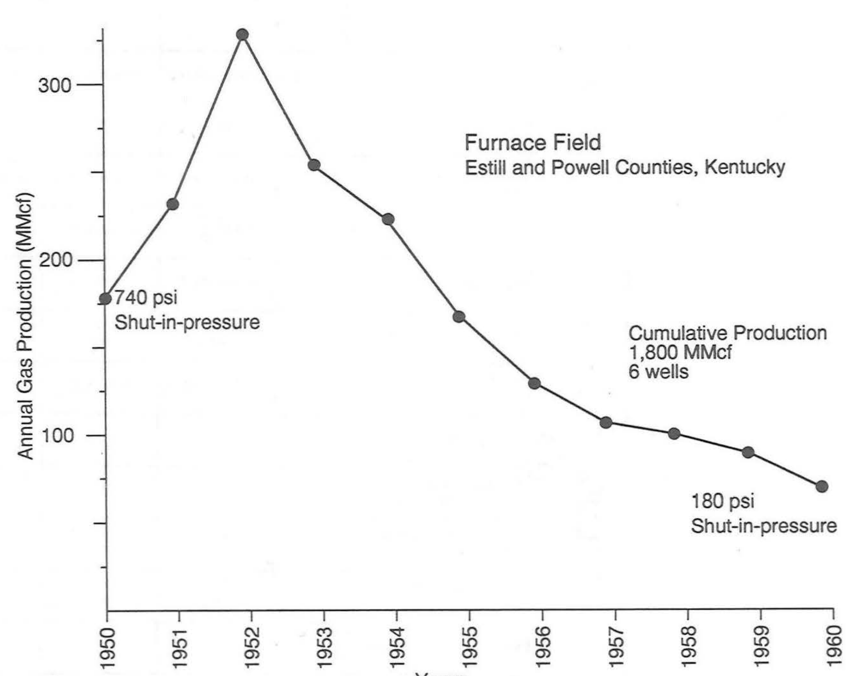


Figure Osp-13. Decline curve for St. Peter Sandstone gas production at the Furnace field (renamed Irvine-Furnace Consolidated), Estill and Powell counties, Kentucky. Modified from McGuire and Howell (1963).