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TECHNICAL NOTE

ASSESSMENT OF IN-PLACE SOLUTION METHANE IN TERTIARY SANDSTONES--TEXAS GULF COAST[1]

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ABSTRACT

The higher prices obtained for commercial natural gas in recent years have stimulated interest in methane-saturated formation waters of sandstone reservoirs in the Texas Gulf Coast as a potential alternative source of energy.

The objective of this project was to appraise the total volume of in-place methane dissolved in formation waters of deep sandstone reservoirs of the onshore Texas Gulf Coast within the stratigraphic section extending from the base of significant hydrocarbon production (8,000 ft) to the deepest significant sandstone occurrence. Factors that must be evaluated to determine the total methane resource are reservoir bulk volume, porosity, and methane solubility. The latter is controlled by the temperature, pressure, and salinity of formation waters.

Regional assessment of the volume and distribution of potential sandstone reservoirs was made from a data base of 880 electrical well logs, from which a grid of 24 structural dip cross sections and 4 strike cross sections was constructed. These cross sections extend from near the Wilcox outcrop to the coastline. Reservoir bulk volume was determined by mapping the structural and stratigraphic framework of Tertiary sandstone units. Structural and stratigraphic boundaries were used to divide the Texas Gulf Coast into 24 subdivisions. Methane content in each of nine formations or divisions of formations was determined for each subdivision.

The total in-place methane for Tertiary sandstones below 8,000 ft in the Texas Gulf Coast was found to be 690 TCF.[2] The total in-place methane for "effective" Tertiary sandstones (sandstone units greater than 30 ft thick) below 8,000 ft was 325 TCF.

INTRODUCTION

Energy resources contained in geopressured sandstones along the Texas Gulf Coast are (1) thermal energy from hot brines, (2) mechanical energy from high formation fluid pressure, and (3) energy from natural gas (mostly methane) dissolved in formation water. Initial interest focused primarily on heat that could be extracted from hot brines and converted to electrical energy through turbines at the surface. In recent years, the economic climate in the United States has changed substantially because of the energy crisis, and the resulting increase in the price of natural gas has shifted economic interest from hot water to solution methane.

Estimates of the in-place solution methane resource in geopressured sandstones in the northern Gulf of Mexico basin made by other investigators ranged from 3,000 TCF to 49,000 TCF. A USGS assessment (Wallace et al, 1978) estimated a dissolved methane resource of 1,792 TCF for geopressured sandstones in offshore and onshore Texas including the inland upper Cretaceous sandstones. These widely ranging estimates of in-place solution methane indicated that a more detailed analysis of onshore Tertiary sediments in the Texas Gulf Coast was needed.

The main objective of the present study was to appraise the total volume of in-place methane dissolved in formation waters of deep sandstone reservoirs along the onshore Texas Gulf Coast. It was assumed in this study that all formation waters are saturated with methane, under the existing subsurface conditions of pressure, temperature, and salinity.

The top of the zone examined is the average base of oil production in the Texas Gulf Coast, about 8,000 ft below mean sea level. The lower limit of the zone of interest is the base of the Wilcox Group, because it is the deepest significant sandstone unit. Below the Wilcox the stratigraphic section is almost entirely shale. The area of investigation is about 50,000 square miles.

The areas of significant sandstone development in the Tertiary formations (fig. 1) contain substantial quantities of solution methane. Factors that must be evaluated to determine the total solution methane resource are reservoir bulk volume, porosity, and methane solubility; the latter is controlled by temperature, pressure, and salinity of the formation water. Reservoir bulk volume is determined by mapping the structural and stratigraphic framework of Tertiary sandstone units. Porosity is determined from core analyses or derived from induction and SP logs. Formation fluid pressure is determined from drill stem tests or from shale resistivity log data; salinity is calculated from the spontaneous potential log data; and equilibrium temperature is calculated from well-log header temperatures.

REGIONAL ASSESSMENT

Regional assessment of the volume and distribution of potential reservoirs was made using a

[1]Publication authorized by the Director, Bureau of Economic Geology, The University of Texas at Austin.

[2]TCF = SCF x 10^{12}

CENOZOIC — TEXAS GULF COAST

SYSTEM	SERIES	GROUP / FORMATION
Quaternary	Recent	Undifferentiated
	Pleistocene	Houston
Tertiary	Pliocene	Goliad
	Miocene	Fleming
	—?—?—	Anahuac
	Oligocene	Frio
		Vicksburg
	Eocene	Jackson
		Claiborne
		Wilcox
		Midway

Fig. 1. *Cenozoic stratigraphic section, Texas Gulf Coast.*

data base of 880 electrical well logs, from which a grid of cross sections was constructed (fig. 2). Twenty-four structural dip cross sections, using sea level as the datum, were spaced 15 to 20 miles apart along the Texas Coast, extending from near the Wilcox outcrop to the coastline. Four structural strike cross sections tied to wells on dip sections were constructed to ensure consistency of correlation.

The Gulf Coast was segmented into 24 subdivisions (fig. 2) for detailed mapping and calculation of the in-place methane resource. Locations of Wilcox, Vicksburg, and Frio fault zones, as determined on each dip cross section, delineated four bands paralleling the coast. These bands encompass (1) the area updip of the Wilcox fault zone, including Subdivisions 19 through 24, (2) the Wilcox fault zone, including Subdivisions 13 through 18, (3) the area between the Wilcox fault zone and the Vicksburg and Frio fault zones, including Subdivisions 7 through 12, and (4) the area between the Vicksburg and Frio fault zones and the coast, including Subdivisions 1 through 6. Boundary lines perpendicular to the coast were drawn to separate and bisect the three structural provinces. For ease of calculation, the latter boundaries were drawn along nearest county lines. Each formation in each subdivision, therefore, may be characterized by its structural as well as its depositional setting.

EVALUATION OF FORMATION PARAMETERS

Reservoir bulk volume was determined by mapping the structural and stratigraphic framework of Tertiary sandstone units. Porosity was determined from core analyses or derived from induction and SP well logs. The porosity at the midpoint of formations of interest in each well was determined by using porosity versus depth relationships established for each subdivision shown in Figure 2. Fluid pressure at the midpoint of formations was determined from drill stem test measurements or from shale resistivity data. Formation equilibrium temperatures were obtained at the midpoint of formations by correcting well-log-header temperatures to equilibrium values. Salinity was derived from water resistivity obtained from the SP log using mud filtrate resistivity values from well log headers. The improved method (Dunlap and Dorfman, 1981) devised for determining salinity in deep hot wells drilled with lignosulfonate mud was not available in time to be used in this study.

The empirical equation of Blount et al (1979) was used for calculating methane solubility. The ranges of methane solubility were calculated for the average values of pressure, temperature, and salinity that represent Tertiary net sandstones and effective sandstones that occur below 8,000 ft for each of 9 formations in each of 24 subdivisions, onshore Texas Gulf Coast. Values of methane solubility in formation waters of Tertiary sandstones range from 10 to 120 SCF/bbl. The new equations of Blount et al (1981) give lower values of methane solubility but were not available in time to be used in this work.

EVALUATION OF METHANE IN-PLACE RESOURCE

A regional net sandstone distribution map of each of 9 formations[3] (or divisions of formations) was prepared using available well control and striving for a minimum of one well log per Tobin grid. Sandstone bulk volume, pore volume, median temperature, pressure, salinity, and methane solubility, were tabulated (Gregory et al, 1980) by formation for each well on cross sections within the 24 subdivisions shown in Figure 2. The total solution methane in-place resource for all Tertiary net sandstones below 8,000 ft in the Texas Gulf Coast was determined to be 690 TCF. A resource estimate of 325 TCF was determined for all effective sandstones (sandstones greater than 30 ft thick). All pore spaces were assumed to be filled completely with methane-saturated water.

DISTRIBUTION OF METHANE IN-PLACE RESOURCE

More than 75 percent of the solution methane resource occurs in the Wilcox and Vicksburg-Frio fault zones; 50 percent of the resource occurs in the Vicksburg-Frio fault zone alone, where Tertiary sand depocenters are concentrated (Table 1). Significant sand development occurs updip of the Wilcox fault zone, but vertical accumulation of sand is less relative to that within the fault zones due to lack of growth faulting. Also, where sand has accumulated at shallower depths, methane solubility is lower because of lower pressures and temperatures. In subdivisions downdip of the Wilcox fault zone and updip of the Vicksburg-Frio fault zone only minor, thin sands were deposited in prodelta and shelf muds since Claiborne and Jackson deltas did not prograde out to the shelf margins. The Wilcox and Vicksburg-Frio fault zones, therefore, are of primary interest in evaluating the solution methane resource.

[3]Upper Frio, lower Frio, Vicksburg-Jackson, upper Claiborne (Yegua), lower Claiborne, upper Wilcox, middle Wilcox, lower Wilcox, and upper Oligocene-Pleistocene Formations.

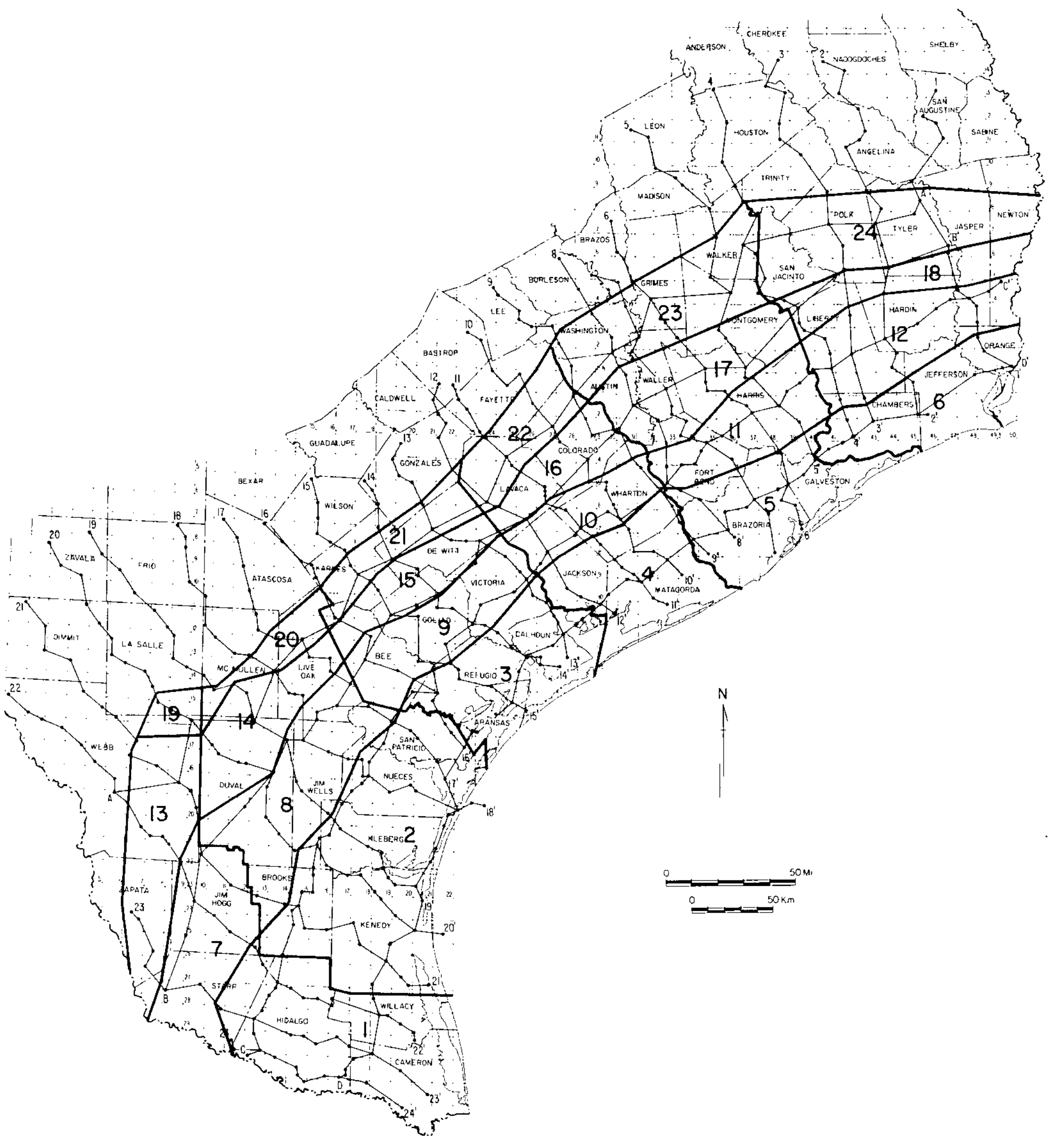

Fig. 2. Subdivisions delineated for detailed mapping and calculation of in-place solution methane resource.

Table 1. Distribution of in-place methane dissolved in formation waters, Tertiary sandstones below 8,000 ft, onshore Texas Gulf Coast.

	Net Sandstone		Effective Sandstone*	
	Methane (10^{12} SCF)	% Total methane	Methane (10^{12} SCF)	% Total methane
Vicksburg-Frio fault zone (Subdivisions 1-6)	348	50.4	142	43.7
Updip of Vicksburg-Frio fault zone (Subdivisions 7-12)	33	4.8	13	4.0
Wilcox fault zone (Subdivisions 13-18)	183	26.5	92	28.3
Updip of Wilcox fault zone (Subdivisions 19-24)	126	18.3	78	24.0
Total	690	100.0	325	100.0

*Sandstones more than 30 ft thick.

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SI METRIC CONVERSION FACTORS

ft	x	0.3048	=	m
SCF	x	0.02831685	=	m^3
SCF/bbl	x	0.1801175	=	std m^3/m^3
sq mile	x	2.589988	=	km^2

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