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**Geochemistry of Liquids,
Gases, and Rocks
From the Smackover Formation**

By A. Gene Collins

Bartlesville Energy Research Center, Bartlesville, Okla.



UNITED STATES DEPARTMENT OF THE INTERIOR
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GEOCHEMISTRY OF LIQUIDS, GASES, AND ROCKS FROM THE SMACKOVER FORMATION

by

A. Gene Collins¹

ABSTRACT

The Bureau of Mines conducted a research study of the geochemistry of the Smackover Formation to determine what geochemical relationships are useful in exploration for and production of oil and gas. Samples of oil, gas, brine, and rock were collected and analyzed. The oilfied brines were analyzed by methods recommended by the American Petroleum Institute and by tentative methods of the American Society for Testing and Materials. The crude oils were analyzed by Bureau of Mines methods; the gas, by Bureau of Mines methods; and the rocks, by wet-chemical, atomic absorption, and neutron activation methods. The results were correlated and interpreted, and several geochemical relationships useful in exploration and production were found. These include the type and class of brine, organic constituents in the brine, redox potential, in situ temperature and pressure of brine, degree of sulfate and carbonate saturation of brine, and halide concentrations in the brine.

INTRODUCTION

The Bureau of Mines conducts research related to exploration, production, and conservation of petroleum, natural gas, and other minerals. The objective of this study was to determine some of the geochemical relationships that exist between the waters in a petroleum reservoir and the associated rock, oil, and gas. Knowledge of these relationships should aid exploration and production.

No reports describing the geochemistry of the brine, oil, or gas produced from the Smackover Formation were found; however, several publications concerned with the geology of the Smackover Formation were consulted. Bishop (7)² evaluated the environmental controls of the upper Smackover porosity; Dickinson (28-29) described some of the Jurassic stratigraphy, including the Smackover, of Arkansas, Louisiana, and Texas; Rainwater (70) described the geological history of the gulf coast and the potential for oil and gas; and Imlay (52-54) described some of the geology and paleontology of gulf coast Jurassic formations.

¹Project leader.

²Underlined numbers in parentheses refer to items in the list of references at the end of this report.

Numerous geochemical studies of oilfield brines and subsurface waters from various formations have been made, and 19 papers on the geochemistry of subsurface brines were published in a volume edited by Angino and Billings (3). Hitchon (40-42), Hitchon and Friedman (43), and Hitchon and Hays (44) studied the geochemistry and hydrodynamics of subsurface brines in the western Canada basin and the Surat basin. White (81) explored various theories concerning the origin of subsurface saline waters. Rittenhouse (71) studied the geochemistry of bromide in brines and its use in determining their origin. Van Everdingen (79-80) studied the geochemistry and hydrodynamics of formation waters in western Canada and theories of the origin of subsurface brines. Dickey (27) considered the patterns of the chemical compositions of deep formation waters. Chave (16) concluded that the origin of subsurface brines is best explained with respect to their reactions with formation rock. The origin of formation waters in the Illinois basin was studied by Graf (35-36), Clayton (17), and Bond (9). Collins (18-19, 21-23) and Collins and Egleson (24) studied the composition of various formation brines or associated rocks. Many other studies related to the origin of subsurface brines have been reported; for example, those by Bredehoeft (12), Young and Low (83), Egleson and Querio (32), and Schmidt (73).

Numerous studies related to the origin of petroleum also have been made. Some of the trends were outlined by Hodgson (46-47). Hunt published some data concerning hydrocarbons in sedimentary rocks (49) and the origin of petroleum in carbonate rocks (50).

None of the above studies were of brines from the Smackover Formation or of brines that contained the high concentrations of bromide and lithium found in the Smackover. In addition, most of the above studies did not include data for the associated oil, gas, and rock. In this research, the Smackover brines were classified by methods described by Collins (18). The classification indicates that numerous characteristics of the brines are useful genetic indicators of oil and gas accumulations that can be used in exploration.

The concentrations of some constituents in the Smackover brines such as calcium, strontium, barium, bicarbonate, and sulfate indicate that precipitates can form and cause production problems. Pressure drops in the formation or at the wellhead could cause calcium sulfate to precipitate. Mixing the Smackover brine with a waterflood makeup water containing appreciable amounts of sulfate could cause calcium, strontium, and barium sulfates to precipitate.

GENERAL GEOLOGY OF THE SMACKOVER FORMATION

According to Imlay (54), the Smackover Formation was named after the Smackover field in Arkansas. In that area it is composed of 700 feet of oolitic limestone. Smackover time equivalents have been identified in Mexico, Texas, Arkansas, Louisiana, Mississippi, and Alabama and found to be definitely Jurassic age (52) with good paleontological correlations with the late Jurassic Argovian strata in England. Figure 1 illustrates the age of the Smackover with reference to some of the other formations that it overlies or underlies.

		FORMATIONS	
System	Euro-pean Stages	North Mexico	North Texas, South Arkansas, North Louisiana, Mississippi, Alabama, North Florida
Jurassic	Port-landian	La Casita	Cotton Valley Group
	Kimmeridgian	Olivido	Buckner
	Oxfordian	Zuloaga	Smackover
		Middle Jurassic	Minas Viejas
	Norphlet		
Louann			
		Werner	
		Morehouse	
		Eagle Mills	

The Smackover Formation is the equivalent of the Zuloaga Formation in Mexico (fig. 1). The Zuloaga carbonate outcrops west of the Tamaulipas Peninsula in northwest Mexico. The Smackover in the United States covers a salt dome basin in the western part of the Rio Grande embayment in southwest Texas. It crosses the crest of the San Marcos arch, the northwest part of the east Texas salt basin, the northern portion of the north Louisiana-Arkansas salt basin, then southeast over the north area of the central Mississippi salt basin, and under the Florida panhandle and offshore areas, as illustrated in figure 2. The Smackover Formation does not outcrop anywhere within the continental United States.

FIGURE 1. - Correlation chart of Jurassic age formations in Mexico, Texas, Arkansas, Louisiana, Mississippi, Alabama, and Florida.

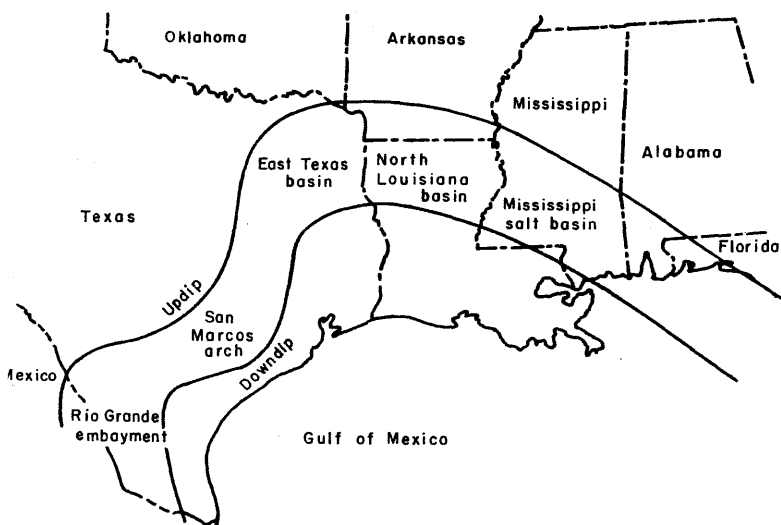


FIGURE 2. - Approximate geographic location of the Smackover Formation.

The northward boundary of the Smackover Formation follows the approximate updip edge of subcrop of the Jurassic rocks. Regional and local subsidence in the gulf coast geosyncline has caused thousands of fault trends associated with slumpage and folding. Structural deformation of the Smackover also has been caused by tectonics related to flow of the underlying Louann salt.

The Smackover (Zuloaga) equivalent lies below Cotton Valley (La Casita) or Buckner (Olivido) equivalents in northwest Mexico (fig. 1). The updip limits of the Zuloaga are west of

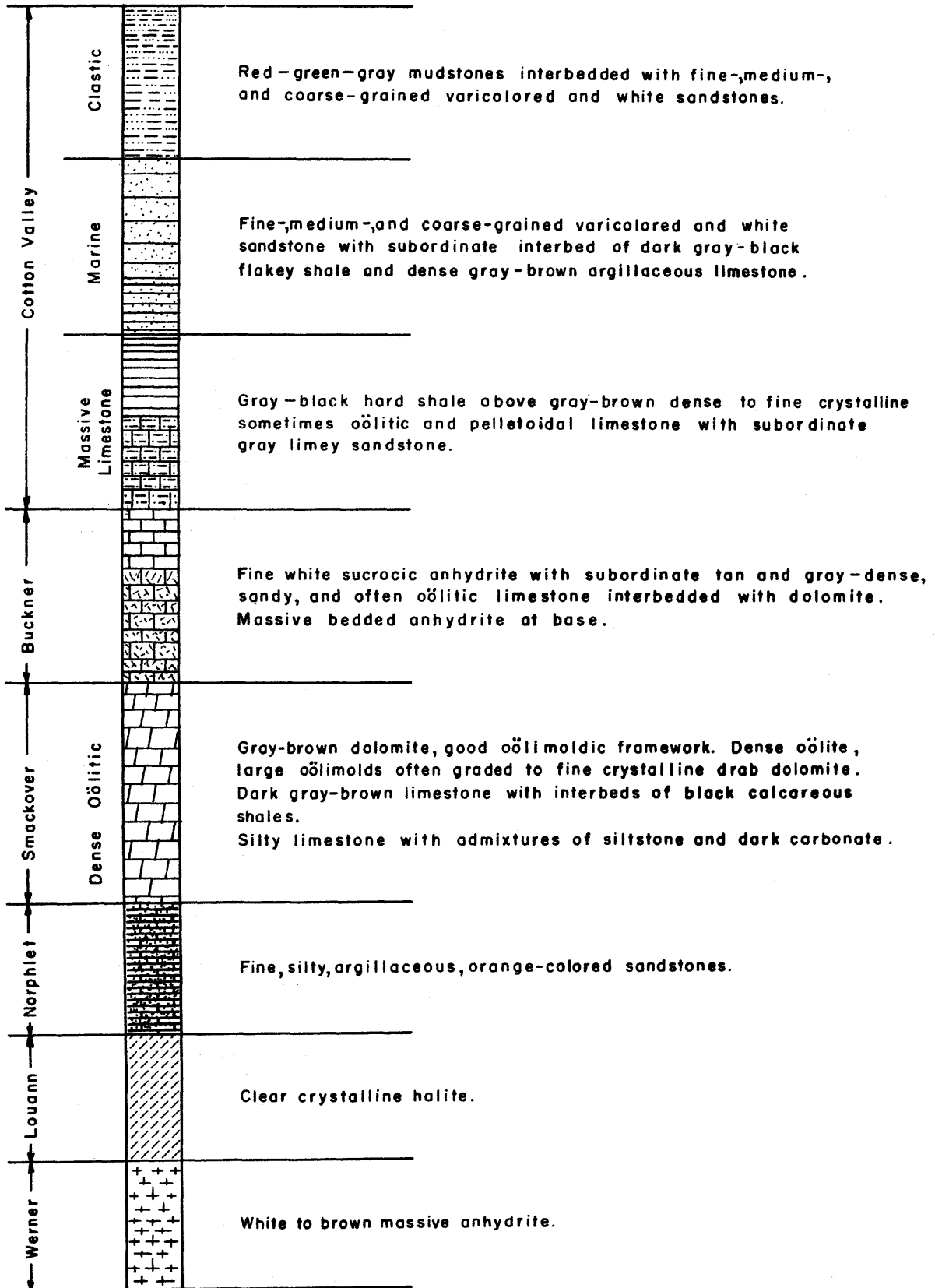


FIGURE 3. - Jurassic section in northeast Texas.

and parallel to the Tamaulipas Peninsula. Surface exposures of Norphlet equivalents (Minas Viejas) are found in the Galena area south of Monterrey and northwest of the Garcia Caves anticline of Sierra del Fraile (30). More than 3,000 feet of anhydrite, salt, and gypsum are found below the 1,400-foot-thick Zuloaga carbonates in the Sabinas basin. The Zuloaga thins northeastward or near the northern updip limit of Jurassic sedimentation. The top of the Zuloaga is about 9,600 feet deep near the Mexico-United States border, and the formation is about 600 feet thick.

A pure coarsely crystalline salt (Louann Formation) is found below the Jurassic sediments in Milam County, Tex. The Smackover Formation in Texas usually consists of an arenaceous base, a microcrystalline middle zone, and a top zone of oolitic limestone or dolomite. Figure 3 illustrates types of rocks found in strata in the Werner, Louann, Norphlet, Smackover, Buckner, and Cotton Valley Formations in northeast Texas (30). The upper oolitic zone is recognizable along most of the Upper Gulf Coastal Plain from northwest Texas to Florida and offshore. Giant oilfields probably remain to be found in the southeast Smackover trend including the offshore area (25).

Bishop (7) divided the Smackover into two members: (1) an upper one, deposited in shallow water with various types of agitation and composed of different types of nonskeletal carbonate and mud; and (2) a lower one deposited in a quiet, toxic environment, composed primarily of carbonate mud with pyrite and abundant carbonaceous material. Dickinson (29) divided the Smackover into three informal members, a lower, middle, and upper. In this scheme, the upper member is predominantly oolitic limestone, the middle is usually a dense limestone, while the lower member is predominantly a dark-brown, silty to argillaceous, commonly laminated limestone.

All members of the Smackover are not present in all areas of the formation from northwest Mexico to Florida. The updip areas often are eroded because of uplifting west of the Tamaulipas Peninsula, uplift of the Peninsular arch, and land to the north before the close of the Jurassic period.

ORIGIN OF THE SMACKOVER FORMATION

Near the end of the Triassic period, tectonics produced a trough near southern Mexico and northern Central America, north of an emerging land mass in the regions of Honduras and southern Guatemala, Chiapas, and Oaxaca. Marine waters (Tethys Sea?) spread westward, and an arm of the sea entered the Gulf of Mexico basin. Highly saline water extended into subsiding grabens, and with arid conditions, salt precipitated (70).

The trough, which was the western part of the Antillean geosyncline, received from 2,000 to 3,000 feet of continental deposits along its southern margin during the Lower Jurassic and early Middle Jurassic. Contemporaneously, farther north in the region of eastern Hidalgo and adjoining parts of Veracruz and Puebla, about 1,300 feet of marine clay was deposited (53).

During the Middle Jurassic period, the sedimentation changed from dominantly carbonaceous or coarse littoral to sublittoral and normal marine in the

upper part in western Oaxaca and northeastern Guerrero. The littoral and sublittoral character of most of the sediments and the preservation of the flora in them indicate that marine waters occupied little area, occurring mainly as bays and lagoons. The climate during the Lower and Middle Jurassic was hot and humid, at least seasonally, as indicated by the richness of the flora, the presence of considerable coal, and the dark color of the marine sediments (53).

The marine waters covered the southern United States, the northern Antilles, and much of Mexico. Thousands of feet of sediments was deposited during Upper Jurassic time ranging from 3,000 to 7,000 feet in the southern United States; 2,600 to 4,800 feet in northern Mexico; 5,000 feet in southern Mexico; and from 10,000 to 30,000 feet in Cuba.

Marine waters of late Upper Jurassic time were limited landward by highlands formed during the orogeny. The sediments ranged in thickness from a few hundred feet to nearly 4,000 feet and were composed primarily of clays and organic matter, but near shore considerable amounts of terrestrial-derived gravel and sand were deposited.

The climate of the later Upper Jurassic probably was more moist than that earlier in the Upper Jurassic because the sediments are much darker and contain more organic matter. At the end of Jurassic time, the marine waters retreated basinward along the northern margins of the Gulf of Mexico and the Mexican geosyncline.

Principal rocks formed during the Upper Jurassic age are sandstone, limestone, dolomite, and evaporites. These suggest that deposition occurred under a variety of environments. As indicated in figure 1, the Smackover Formation overlies the Norphlet Formation in most areas and underlies the Buckner Formation. Generally the Smackover Formation thickens gulfward because of tilting or subsiding of the basin. Unconformities indicate uplifting and erosion occurred later.

On the Arkansas shelf, the upper Smackover primarily is the "Reynolds Oolite," a "blanket" calcarenite thinning southward toward the shelf slope near the Arkansas-Louisiana border. Active structural growth in the deeper water-shelf slope region gave rise to calcarenite deposition in positive areas in Arkansas and east Texas.

Thin units of calcarenite or sandy limestone interbedded with some shale and sandstone are found in eastern Arkansas and Louisiana and in western Mississippi. A massive clean sandstone was deposited above the shelf in western Mississippi by a stream that probably supplied terrigenous detritus to the Smackover sea.

Massive limestone deposition occurred along a tectonic hingeline on the southern portion of the shelf slope. Gray marine shale is found south of the hingeline in the Smackover.

The Smackover Formation resembles a giant crescent, as illustrated in figure 2. In general, the downdip Smackover thickens, but the precise downdip

limits have not been determined because they probably are several miles deep. During Smackover time, the deposition in the deep basin was primarily clays and shales with limestones deposited shelfward.

Several papers have been written in which the main purpose is to compare ancient limestone deposition with the contemporary Bahaman environment (4). Some investigators are certain that significant volumes of carbonate sediments are forming on the Bahama banks by chemical precipitation; others believe that most carbonates are biogenic with only a small portion formed by chemical precipitation. The Reynolds oolites of the upper Smackover were deposited in an environment similar to that of the Bahama Islands (51). On the Bahama banks, oolites, pisolites, pellets, algal lumps, grapestone, and clastic shell material are formed and deposited. The principal deposition is "bahamite" (4), a fine-grained carbonate sand or friable aggregates.

The three principal updip to downdip upper Smackover depositional facies, with respect to decreasing energy level are reservoir, mixed, and pellet-mud (7). According to Bishop (7), the Smackover sea was hypersaline; therefore, the allochems were almost entirely nonskeletal. Deltaic sediments deposited in the eastern area of the Apalachicola embayment probably are the source of the hydrocarbons found in the deep Smackover fields in Florida, Alabama, and offshore. Giant fields probably remain to be found in this area in Jurassic and younger rocks.

ANALYSIS OF SMACKOVER OILFIELD BRINES

Sampling Method

Oilfield brine samples were taken only from wells where reasonable assurance was evident that the formation brine was not contaminated by intrusion of water from other formations. Some drill-stem test samples were taken; however, care was exercised to insure that only bottom samples containing no mud filtrate were used. All of the samples were collected and contained in good-quality polyethylene bottles before transport to the laboratory. Duplicate samples were taken in the field; one sample was not acidified and one sample was acidified to a pH of about 1.5 with reagent-grade hydrochloric acid. The acidified sample was used in the determination of the cations, and the unacidified sample was used in the determination of pH, alkalinity, and the anions.

Analytical Methods

The distances between the points of sampling and the laboratory were several hundred miles; therefore, the time between sampling and analysis often exceeded 3 days. No analyses were made in the field. As soon as the samples reached the laboratory, they were analyzed for pH, alkalinity, and resistivity; therefore, the pH and alkalinity values can be considered only relative and not absolute.

The specific gravity of each sample was determined, so that a correct aliquot size could be estimated for each specific ion determination. A pH meter was used to determine the pH, and a standard acid was used to titrate the carbonate and bicarbonate to a specific pH end point monitored with the pH meter.

Lithium, sodium, potassium, magnesium, calcium, strontium, barium, manganese, iron, copper, zinc, and lead were determined by flame emission or atomic absorption spectroscopy (33). Boron, ammonium, chloride, bromide, and iodide were determined by titrimetric methods, and sulfate was determined by a gravimetric method (1). The organic acids were determined by titration and calculated as acetic acid.

Analyses

Location information is given in table 1 for each sample, and the data are arranged in alphabetical order with reference to the sedimentary basin from which the sample was taken. The number shown in the left column is the sample number, and if oil, brine, and core samples were taken from the same well, the numbers will be the same for all three. Table 1 shows the sample location with respect to State, county, section, township, range, latitude, longitude, and sedimentary basin. Also shown in table 1 is the elevation of the well in feet above sea level, depth of the well in feet, corrected top depth in feet, bottom-hole temperature in ° F, and bottom-hole pressure in pounds per square inch (psi). Subsequent tables in this report show the sample number but not the locations.

The analytical data that were obtained by analyzing brines from the Smackover Formation are shown in table 2. Not all of the Smackover brine samples shown in table 2 were analyzed by the Bureau of Mines; the analytical data for several of the samples were obtained from oil companies. Table 1 indicates where each brine sample was analyzed.

TABLE 1. - Sampling locations, depths, and bottom-hole temperatures and pressures of Smackover samples

Sample	State	County	Section, township, range	Latitude	Longitude	Basin	Elevation, feet	Depth, feet	Corrected depth, feet	Bottom-hole temperature, °F	Bottom-hole pressure, psi
* 1	Mississippi	Smith	4-1N-9E	315800	0892300	East Gulf	370	16,845-17,033	16,475	(1/)	(1/)
* 2	...do....	Wayne	26-10N-6W	314900	0883400	...do.....	233	12,688-13,488	12,455	(1/)	(1/)
* 3	...do....	Smith	9-1N-9E	315700	0892300	...do.....	490	15,860-16,845	15,370	284	3,701
* 4	Alabama	Choctaw	35-11N-4W	315300	0882100	Hatchetigbee	156	11,967-11,918	11,811	190	4,694
* 5	...do....	...do...	4-11N-3W	315700	0881700	...do.....	278	10,486-11,000	10,208	180	3,441
* 6	...do....	...do...	4-11N-3W	315700	0881700	...do.....	241	10,455-10,480	10,214	180	3,298
* 7	...do....	...do...	35-11N-4W	315300	0881500	...do.....	155	11,974-11,997	11,819	188	5,014
* 8	Texas	Vanzandt	NAP	324100	0955200	Mexia Talco	394	12,784-12,818	12,390	275	3,520
* 9	Arkansas	Lafayette	9-16S-24W	332300	0993500	Monroe uplift	295	7,030-7,072	6,735	(1/)	2,974
*10	...do....	Union	30-17S-12W	331300	0922300	...do.....	190	6,049-6,058	5,859	(1/)	(1/)
*11	...do....	...do...	8-16S-17W	332100	0925300	...do.....	220	6,317-6,479	6,097	(1/)	(1/)
*12	...do....	Nevada	1-15S-20W	322800	0930800	...do.....	331	5,891-5,897	5,560	(1/)	(1/)
f13	...do....	Union	15-17S-18W	331600	0925800	North Louisiana	277	7,196-7,200	6,919	(1/)	(1/)
f14	...do....	...do...	14-15S-24W	332700	0933400	...do.....	244	7,184-7,186	6,940	200	2,700
f15	...do....	...do...	10-17S-18W	331700	0925700	...do.....	330	7,138-7,143	6,808	200	2,700
f16	...do....	Lafayette	7-15S-24W	332800	0933800	...do.....	247	7,158-7,282	6,911	200	2,700
f17	...do....	Union	10-17S-18W	331700	0925700	...do.....	272	7,159-7,165	6,887	200	2,700
f18	...do....	...do...	10-17S-18W	331700	0925700	...do.....	289	7,184-7,186	6,895	200	2,700
f19	...do....	...do...	10-17S-18W	331700	0925700	...do.....	244	7,184-7,186	6,940	200	2,700
f20	...do....	...do...	10-17S-18W	331700	0925700	...do.....	300	7,144-7,186	6,844	200	2,700
f21	...do....	...do...	15-17S-18W	331600	0925800	...do.....	272	7,788-7,792	7,516	200	2,700
f22	...do....	...do...	10-17S-18W	331700	0925700	...do.....	283	7,165-7,168	6,882	200	2,700
f23	...do....	...do...	10-17S-18W	331700	0925700	...do.....	245	7,189-7,191	6,944	200	2,700
f24	...do....	...do...	10-17S-18W	331700	0925700	...do.....	262	7,140-7,146	6,878	200	2,700
f25	...do....	...do...	10-17S-18W	331700	0925700	...do.....	282	7,184-7,191	6,902	200	2,700
f26	...do....	...do...	10-17S-18W	331700	0925700	...do.....	286	7,166-7,194	6,880	200	2,700
f27	...do....	...do...	10-17S-18W	331700	0925700	...do.....	282	7,184-7,186	6,902	200	2,700
*28	...do....	...do...	17-17S-17W	331500	0925300	...do.....	215	7,012-7,045	6,797	164	2,724
*29	...do....	Ouachita	22-15S-18W	332500	0925700	...do.....	209	5,188-5,314	4,979	(1/)	5,314
*30	...do....	Hemstead	28-14S-23W	333000	0933000	...do.....	279	5,860-5,876	5,581	(1/)	2,132
*31	...do....	Ouachita	28-15S-15W	332300	0923900	...do.....	129	4,821-4,961	4,692	(1/)	(1/)
*32	...do....	...do...	13-15S-19W	332600	0930100	...do.....	217	5,837-5,862	5,620	(1/)	(1/)
*33	...do....	Union	13-17S-13W	331500	0922400	...do.....	263	6,224-6,232	5,961	(1/)	(1/)
*34	...do....	...do...	28-19S-18W	330300	0925900	...do.....	226	9,287-9,316	9,061	(1/)	2,441
f35	...do....	Lafayette	18-15S-23W	332700	0933200	Sabine uplift	288	6,450-6,482	6,162	185	2,710
f36	...do....	...do...	18-15S-23W	332700	0933200	...do.....	310	6,388-6,430	6,078	190	2,710
f37	...do....	...do...	18-15S-23W	332700	0933200	...do.....	284	6,471-6,489	6,187	180	2,710
f38	...do....	...do...	18-15S-23W	332700	0933200	...do.....	320	6,372-6,388	6,052	180	2,720
f39	...do....	...do...	7-15S-25W	332800	0934500	...do.....	302	6,430-6,457	6,128	185	2,710
f40	...do....	...do...	7-15S-25W	332800	0934500	...do.....	284	6,430-6,457	6,146	185	2,710
f41	...do....	...do...	7-15S-25W	332800	0934500	...do.....	302	6,430-6,457	6,128	185	2,710
f42	...do....	...do...	7-15S-25W	332800	0934500	...do.....	288	6,430-6,457	6,142	185	2,710
f43	...do....	Columbia	15-17S-18W	331600	0925800	...do.....	330	7,138-7,143	6,808	200	2,700
f44	...do....	...do...	10-17S-18W	331700	0925800	...do.....	275	7,136-7,166	6,861	210	2,700
f45	...do....	...do...	24-17S-20W	331500	0930800	...do.....	272	7,515-7,525	7,243	210	2,770
f46	...do....	...do...	23-17S-20W	331500	0930900	...do.....	346	7,626-7,641	7,280	210	2,770
f47	...do....	...do...	18-15S-23W	332700	0933200	...do.....	266	6,471-6,489	6,205	210	2,770
f48	...do....	...do...	18-15S-23W	332700	0933200	...do.....	267	6,372-6,388	6,105	210	2,700
f49	...do....	...do...	18-15S-23W	332700	0933200	...do.....	269	6,388-6,488	6,119	210	2,700
f50	...do....	...do...	18-15S-23W	332700	0933200	...do.....	266	6,356-6,406	6,090	210	2,700

See footnotes at end of table.

TABLE 1. - Sampling locations, depths, and bottom-hole temperatures and pressures of Smackover samples --Continued

Sample	State	County	Section, township, range	Latitude	Longitude	Basin	Elevation, feet	Depth, feet	Corrected depth, feet	Bottom-hole temperature, °F	Bottom-hole pressure, psi
f51	Arkansas	Columbia	10-18S-20W	331200	0931000	Sabine uplift	297	4,283-4,292	3,986	210	2,700
f52	...do....	...do...	24-17S-20W	331500	0930800	...do.....	311	7,603-7,630	7,292	210	2,770
f53	...do....	...do...	22-17S-20W	331500	0931000	...do.....	340	7,536-7,600	7,196	210	2,770
f54	...do....	...do...	13-17S-20W	331600	0930800	...do.....	327	7,602-7,620	7,275	210	2,720
f55	...do....	...do...	20-18S-19W	331000	0930600	...do.....	320	7,500-7,503	7,180	(1/)	(1/)
f56	...do....	...do...	7-15S-23W	332800	0933200	...do.....	264	6,300-6,314	6,036	(1/)	(1/)
f57	...do....	...do...	13-15S-24W	332700	0933300	...do.....	260	6,258-6,262	5,998	(1/)	(1/)
f58	...do....	...do...	10-15S-24W	332800	0933500	...do.....	265	6,309-6,315	6,044	182	2,429
f59	...do....	...do...	9-15S-24W	332800	0933600	...do.....	268	6,309-6,318	6,041	188	2,748
f60	...do....	...do...	10-15S-24W	332800	0933500	...do.....	264	6,100-6,146	5,836	180	2,963
f61	...do....	...do...	22-17S-20W	331500	0931000	...do.....	354	7,608-7,621	7,254	(1/)	(1/)
f62	...do....	...do...	22-17S-20W	331500	0931000	...do.....	345	7,618-7,626	7,273	(1/)	(1/)
f63	...do....	...do...	22-17S-20W	331500	0931000	...do.....	312	7,573-7,564	7,261	(1/)	(1/)
f64	...do....	Lafayette	7-15S-25W	332800	0934500	...do.....	267	6,430-6,457	6,163	(1/)	(1/)
f65	...do....	Columbia	23-17S-20W	331500	0930900	...do.....	343	7,615-7,645	7,272	210	2,705
f66	...do....	...do...	18-17S-19W	331600	0930700	...do.....	304	7,534-7,550	7,230	210	2,770
f67	...do....	...do...	4-18S-20W	331300	0931100	...do.....	293	8,426-8,72	8,133	225	2,800
f68	...do....	...do...	15-17S-20W	331600	0931000	...do.....	272	7,628-7,630	7,356	210	2,700
f69	...do....	...do...	16-17S-20W	331600	0931100	...do.....	275	7,624-7,634	7,349	210	2,700
f70	...do....	...do...	19-17S-20W	331500	0931300	...do.....	316	7,533-7,594	7,217	210	2,700
f71	...do....	...do...	24-17S-20W	331500	0930800	...do.....	290	7,630-7,620	7,340	210	2,700
f72	...do....	...do...	23-17S-20W	331500	0930900	...do.....	269	6,183-6,186	5,914	210	2,705
f73	...do....	...do...	23-17S-20W	331500	0930900	...do.....	287	6,750-6,754	6,463	210	2,700
f74	...do....	...do...	23-17S-20W	331500	0930900	...do.....	283	6,238-6,240	5,955	210	2,700
f75	...do....	...do...	21-17S-20W	331500	0931100	...do.....	264	7,614-7,630	7,350	210	2,700
f76	...do....	...do...	21-17S-20W	331500	0931100	...do.....	364	7,619-7,621	7,255	210	2,700
f77	...do....	...do...	22-17S-20W	331500	0931000	...do.....	290	6,190-6,198	5,900	210	2,760
f78	...do....	...do...	22-17S-20W	331500	0931000	...do.....	303	6,470-6,476	6,167	210	2,700
f79	...do....	...do...	22-17S-20W	331500	0931000	...do.....	289	6,232-6,238	5,943	210	2,700
f80	...do....	Lafayette	18-15S-23W	332700	0933200	...do.....	280	6,356-6,364	6,076	180	2,720
f81	...do....	Columbia	18-17S-19W	331600	0930700	...do.....	298	7,534-7,550	7,236	210	2,700
f82	...do....	...do...	13-17S-20W	331600	0930800	...do.....	318	7,602-7,628	7,284	210	2,720
f83	...do....	...do...	13-17S-20W	331600	0930800	...do.....	334	7,575-7,602	7,241	210	2,700
f84	...do....	...do...	19-17S-19W	331500	0930700	...do.....	271	7,530-7,573	7,259	210	2,700
f85	...do....	...do...	18-17S-19W	331600	0930700	...do.....	308	7,534-7,791	7,226	210	2,770
f86	...do....	Lafayette	18-15S-23W	332700	0933200	...do.....	312	6,388-6,430	6,076	180	2,710
f87	...do....	...do...	18-15S-23W	332700	0933200	...do.....	306	6,372-6,388	6,066	180	2,710
f88	...do....	...do...	18-15S-23W	332700	0933200	...do.....	300	6,356-6,406	6,056	180	2,710
f89	...do....	...do...	18-15S-23W	332700	0933200	...do.....	298	6,471-6,489	6,173	180	2,720
f90	...do....	...do...	18-15S-23W	332700	0933200	...do.....	324	6,388-6,430	6,064	180	2,710
f91	...do....	...do...	18-15S-23W	332700	0933200	...do.....	318	6,450-6,482	6,132	185	2,710
f92	...do....	...do...	18-15S-23W	332700	0933200	...do.....	318	6,388-6,430	6,070	180	2,710
f93	...do....	...do...	18-15S-23W	332700	0933200	...do.....	318	6,388-6,430	6,070	180	2,700
f94	...do....	Columbia	23-17S-20W	331500	0930900	...do.....	361	7,614-7,642	7,253	210	2,720
f95	...do....	...do...	23-17S-20W	331500	0930900	...do.....	361	7,446-7,622	7,085	210	2,700
f96	...do....	...do...	23-17S-20W	331500	0930900	...do.....	310	7,615-7,645	7,305	210	2,760
f97	...do....	...do...	22-17S-20W	331500	0931000	...do.....	354	7,605-7,613	7,251	210	2,770
f98	...do....	...do...	22-17S-20W	331500	0931000	...do.....	340	7,536-7,600	7,196	210	2,770
f99	...do....	...do...	22-17S-20W	331500	0931000	...do.....	360	7,618-7,626	7,258	210	2,700
f100	...do....	...do...	22-17S-20W	331500	0931000	...do.....	360	7,520-7,534	7,160	210	2,700

See footnotes at end of table.

