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Geopressured-Geothermal Resources in California

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ABSTRACT

Geopressured-geothermal waters exist in California within the Great Valley and Franciscan sequences on the west side of the Central Valley and adjacent Coast Ranges. They are also present in Cenozoic rocks within three deep sedimentary depressions (depocenters) of the Central Valley, and in the Ventura, Los Angeles, and several relatively small offshore basins. The areal extent of geopressured zone in California is about 100,000 km^2.

Geopressured zones may be encountered at very shallow depths (<1,000 m) within the Franciscan and Great Valley sequences, but the depths increase in the Central Valley from west to east reaching depths of 3,000 m or more. Temperature gradients in the normally pressured zones from the Central Valley are generally 18 to 27° C/km (1-1.5°F/100 ft) and range up to 45° C/km (2.5°F/100 ft); temperature gradients in the geopressured zones are higher by a factor of up to two.

Water salinities in the geopressured zones are generally less than 20,000 mg/L total dissolved solids, and in many locations, less than 10,000 mg/L. Lower water salinities in California, compared to the Gulf Coast, result in higher dissolved methane and less environmental and disposal problems. In addition, several areas in San Joaquin Valley may be more attractive because faulting may not be as extensive as in the Gulf Coast.

INTRODUCTION

Geopressured-geothermal waters are present at variable depths in sedimentary rocks that range in age from Paleozoic through Cenozoic in at least 10 major basins in the Conterminous United States. An intensive research and development effort is currently underway to determine the feasibility of using geopressured-geothermal waters, especially those from the northern Gulf of Mexico basin, as a source of energy. Three forms of energy may be extracted from these waters: (1) thermal energy, (2) mechanical (hydraulic) energy, and (3) energy obtained from dissolved gasses, mainly methane. Assessment of these energy resources in the Gulf Coast shows a huge resource base, but the amount of energy recoverable by current technology is still unknown (Wallace et al., 1979).

We are currently involved in an assessment of geopressured-geothermal resources in California. The parameters required for this assessment include subsurface temperatures, hydraulic pressures, sandstone/shale distributions, porosities of the rocks, and salinities of the formation waters. This summary reports on the preliminary results obtained and shows that parts of California may be more attractive than the Gulf Coast for geopressured-geothermal development because of the much lower salinities of formation waters in California.

PRESSURE AND TEMPERATURE DISTRIBUTION

Geopressured waters in California are present in Cenozoic and Mesozoic shales, silstones and sandstones beneath an area of about 100,000 km^2. High fluid pressures are present in a regional band of rocks belonging to the Great Valley and Franciscan sequences on the west side of the Central Valley and adjacent Coast Ranges north of the Garlock and east of the San Andreas faults. They are also present in Cenzoic rocks within three (Button Willow, Maricopa, and Delta) deep sedimentary depressions (depocenters) in the Central Valley, and in the Ventura, Los Angeles and several small offshore basins. The depths to the top of the geopressured zones (Figure 1) are variable: they may be encountered at very shallow depths (<500 m) within the Franciscan/ Great Valley sequences, but the depths increase in the Central Valley from west to east reaching depths of 3,000 m or more.

Abnormally high-fluid pressures result from a number of processes that in California are related directly or indirectly to its late Cenozoic tectonic history (Berry, 1973). Tectonic compression of the Franciscan and Great Valley rocks between the granitic Sierran-Klamath and Salinas block is probably responsible for the regional high pressures. This compression is probably caused by the westward movement of the

Sierran-Central Valley basement resulting from late Cenozoic back-arc spreading in the Great Basin. Local compression caused by vertical diapirism (folds along the west side of the Central Valley), opposing lateral thrusts (Ventura anticline), or thrust faults (White Wolf, Santa Monica, and others) have also caused the development of geopressure.

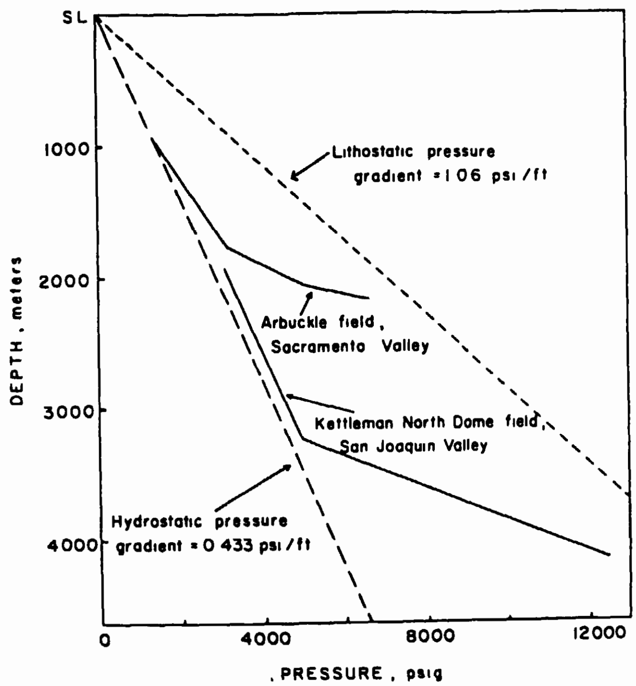

Fig 1. Distribution of the original bottom-hole pressures from the Central Valley, California.

The origins of the high pressures in the three structural depressions (depocenters) are similar to those of the Gulf Coast. Ziegler and Spotts (1978) have shown that the depressions experienced rapid subsidence and deposition (up to 8,000 m of post-Cretaceous sediments) especially since early Miocene time. Compaction of shales and siltstones by the rapidly deposited overburden and the rapid thermal expansion of the waters and the generated organic fluids at higher rates than that of the enclosing sediments are probably the main processes responsible for the high pressures. Recent experiments (Kharaka and Bischoff, unpublished data) indicate that clay transformations are probably not an important mechanism for the generation of high pressures.

Preliminary data show that temperature gradients in the normally pressured zones from the Central Valley of California are generally 18 to 27°C/km (1-1.5°F/100 ft) and range up to 45°C/km (2.5°F/100 ft); temperature gradients in the geopressured zones are higher by a factor of up to two. The higher temperature gradients generally are present in the west and south sides of San Joaquin Valley and in the Coast Ranges. The higher temperature gradients in the geopressured zones of a given area are due mainly to the lower thermal conductivities of shale and siltstones that predominate in these zones.

CHEMICAL COMPOSITION OF WATER

Knowledge of the chemical composition of the geopressured waters is very important in evaluating them as a source of energy. Solubility of methane in these waters decreases substantially as the salinity of water increases. Experimental data on methane solubility (Haas 1978; and others) show that the solubility of methane in water at 150°C (302°F) and 69 megapascals (MPa) (10,000 pounds per inch^2 (psi), for example, is about 8.9m^3 of gas at standard conditions per m^3 of water (50 SCF of gas/barrel of water) if the salinity is zero. The solubility of methane is decreased to about 3/4, 1/2, and 1/4 of the above total where the salinity of water is about 75,000 milligrams per Liter (mg/L), 140,000 mg/L, and 215,000 mg/L, respectively. Detailed knowledge of the chemistry of the geopressured waters is important also in determining potential pollution and disposal problems associated with energy development.

Chemical analyses from geopressured and normally pressured zones from about 100 petroleum wells in the Central Valley (typical analyses shown in Table 1) show that the salinities of formation waters from the geopressured zones are generally less than 20,000 mg/L dissolved solids. Salinities from many wells are less than 10,000 mg/L, but the salinities reach about 70,000 mg/L in a few wells. These values are much lower than the salinities (generally >100,000 mg/L) of geopressured geothermal wells in the Gulf Coast tested by the Department of Energy.

Table 1. Chemical composition (mg/L) of formation waters from Sacramento and San Joaquin Valleys, California

Area	Sacramento		San Joaquin		
Field	Grimes	Malton-Black Butte	San Emidio Nose	Wheeler Ridge	Kettleman North Dome
Sample Number	81-NSV-15	81-NSV-1	74-SEN-3	75-WR-5	912-1
Well name	G.O.U. #4 Well #2	19-1	21-15	21-28	323-21J
Production zone	Forbes	Forbes	Reef Ridge	Tejon	Lower McAdams
Depth (m)	2074	1524	3337	2691	3520
Fluids O/W/G	0/5.6/18.4	0/5.6/2.8	44.2/0.3/2.0	2.2/2.1/4.5	10.3/2.9/0
TDS	18,600	21,400	10,900	44,300	10,000
Li	0.32	0.35	1.95	1.95	3.05
Na	6,830	7,510	4,000	7,450	3,760
K	35.5	28.4	620	135	92.4
Mg	72	148	7.0	27	3.4
Ca	182	331	67	5,550	30.7
Sr	14.3	18.8	8.0	187	4.4
Ba	6.4	4.6	4.2	12	3.98
Fe	0.58	54	0.36	2.8	0.31
NH_3	34	30	73	32	8.9
F	-	-	3.0	2.0	0.3
Cl	11,000	12,700	3,460	21,450	4,680
Br	44	74	57	80	45
I	30	66	14	46	27
HCO_3	359	417	2,870	2,210	1,190
SO_4	<0.5	0.9	38	50	0.5
H_2S	0.07	<0.1	0.02	0.11	3.02
SiO_2	31	18	109	46	128
B	-	-	92	60	43
pH	7.6	7.6	7.7	6.9	7.4

NOTE: Depth is depth below sea level of midpoint of perforation. Liquid production is in m^3/day, gas in 1000 m^3/day. Producing zones are those used by oil companies. TDS is calculated total dissolved solids. HCO_3 is field titrated alkalinity.

Formation waters from the geopressured zones are of the Na-Cl-type in which Na and Cl generally constitute more than 80 percent of the total cations and inorganic anions, respectively. Ca concentrations generally increase with salinity, and bicarbonate alkalinity increases with decreasing Ca concentrations. Sulfate and magnesium concentrations are generally low, but concentrations of B and NH_3 are relatively high. Membrane-squeezing properties of shales and dehydration reactions of clays probably account for the low salinities in California (Berry, 1973; Kharaka and Berry, 1980). Interactions of the waters with minerals and organic matter present in the enclosing rocks and membrane filtration properties of shales are also responsible for modifying the compositions of the waters

GEOPRESSURED-GEOTHERMAL RESOURCE

The available data on sandstone distribution within the geopressured zones in the Central Valley are inadequate for a quantitive assessment of the geopressured-geothermal resource. Also, there is no information on whether the formation waters are saturated with methane. Information on sandstone distribution (Ziegler and Spotts, 1978; Berry, 1980; Garcia, 1981; Webb, 1981; and others) and our preliminary data show the presence of extensive and thick sandstones within the geopressured zones in the San Joaquin and parts of Sacramento Valleys. Also, the presence of numerous oil and gas fields in the Central Valley indicates organic rich source rocks and may indicate that the waters may be saturated with methane. Combining all the parameters required for resource assessment that are available to us at this time and using gross comparisons with similar parameters for the Gulf Coast (Wallace et al., 1979) indicate a large geopressured-geothermal resource in California. These data also indicate that several areas in California have potential for geopressured-geothermal development. Because of higher temperature gradients and larger sandstone distribution, areas in south and areas southwest San Joaquin Valley have the highest potential for this resource.

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