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Correlation of Wireline Log Characteristics with Hydrothermal Alteration and Other Reservoir Properties of the Salton Sea and Westmorland Geothermal Fields, Imperial Valley, California, USA

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LIST OF SYMBOLS

<u>Symbol</u>	<u>Definition</u>
a	Constant in $F = a\phi^{-m}$ equation
a_{mf}	Activity of the mud filtrate
a_w	Activity of the formation water
DIL	Dual Induction-Laterolog
F	Formation resistivity factor
GR	Natural gamma ray
IES	Induction Electrical Survey
N	Neutron porosity divided by density
R, R_{11d}	Resistivity from deep induction log (ohm-m)
R_{11m}	Resistivity from medium induction log (ohm-m)
R_{LL8}	Resistivity from laterolog 8 (ohm-m)
R_m	Resistivity of the mud (ohm-m)
R_{mf}	Resistivity of the mud filtrate (ohm-m)
R_0	Resistivity of a non-shaly formation 100% saturated with brine (ohm-m)
R_{sd}	Resistivity of sandstone from deep induction log (ohm-m)
R_{sh}	Resistivity of shale from deep induction log (ohm-m)
R_t	True resistivity of formation (ohm-m)

LIST OF SYMBOLS (continued)

<u>Symbol</u>	<u>Definition</u>
R_T	Resistivity of formation at temperature T (ohm-m)
R_w	Resistivity of the formation water (ohm-m)
R_{wT}	Resistivity of formation water at temperature T (ohm-m)
R_{xo}	Resistivity of invaded zone (ohm-m)
SP	Spontaneous Potential (millivolts [mv])
SSP	Static Spontaneous Potential (mv)
T	Temperature in °F
T_c	Temperature in °C
ϕ	Porosity measured in laboratory
ϕ_{ch}	Porosity calculated from chlorite zone
ϕ_{fl}	Porosity calculated from feldspar zone
ϕ_{log}	Porosity calculated from gamma-gamma density
ϕ_t	True porosity
ρ_B	Bulk density estimated from gamma-gamma density log (gm/cm ³)
ρ_{BL}	Bulk density estimated from laboratory (gm/cm ³)
ρ_{Bsd}	Bulk density of sandstone estimated from gamma-gamma density log (gm/cm ³)
ρ_{Bsh}	Bulk density of shale estimated from gamma-gamma density log (gm/cm ³)

LIST OF SYMBOLS (continued)

<u>Symbol</u>	<u>Definition</u>
ρ_f	Formation fluid density (gm/cm^3)
ρ_{fT}	True formation fluid density (gm/cm^3)
ρ_{gr}	Grain density (gm/cm^3)
ρ_{grch}	Grain density calculated for the chlorite zone (gm/cm^3)
ρ_{grfl}	Grain density calculated for the feldspar zone (gm/cm^3)
ρ_{theo}	Theoretical bulk density due only to compaction (gm/cm^3)

CORRELATION OF WIRELINE LOG CHARACTERISTICS WITH HYDROTHERMAL
ALTERATION AND OTHER RESERVOIR PROPERTIES OF THE SALTON SEA
AND WESTMORLAND GEOTHERMAL FIELDS, IMPERIAL VALLEY, CALIFORNIA, USA

by

Frank S. Muramoto and Wilfred A. Elders

ABSTRACT

The Salton Sea and Westmorland geothermal systems are developed in the Plio-Pleistocene sediments of the Colorado River delta. In the Salton Sea, field temperatures as high as 365°C are encountered at depths less than 7100 ft (2134 m), and brines contain up to 260,000 parts per million (ppm) of total dissolved solids. In the Westmorland field four miles (6.4 km) to the south, considerably lower temperatures (252°C at 7500 ft [2286 m]) and less saline brine concentrations (maximum salinity approximating 72,000 ppm) are found.

A detailed study of wireline logs from 11 wells in the Salton Sea and Westmorland geothermal systems was undertaken in order to determine the effects of hydrothermal alteration on the response of electrical and gamma-gamma density well logs. For the Salton Sea geothermal field, definite correspondence between log responses and hydrothermal mineralogy is evident, which in turn is related to the physical properties of the rocks. Three hydrothermal and one unaltered zone can be identified from log data on shales. These are: (1) the unaltered "montmorillonite zone" (<100°-190°C); (2) the "illite zone" (100°-190°C to 230°-250°C); (3) the "chlorite zone" (230°-250°C to 290°-300°C); and (4) the "feldspar zone" (>290°-300°C). The characteristic responses on well logs by which these zones are identified result primarily from changes in clay mineralogy of the shales and increases in density with progressive hydrothermal metamorphism.

In the Westmorland geothermal field, differentiating mineral zones from log responses was only partially successful. However, analyses of both well log and petrologic data for wells Landers 1 and Kalin Farms 1 suggest that the former is heating up and the latter is cooling.

Other methods that were found to be effective in delineating mineral zones from log data on shales are the resistivity-density and N-resistivity (where N = neutron porosity/density) crossplots. The latter crossplot distinguishes mineral zones better than the former since another variable, neutron porosity, is used. Both crossplots are, however, unsuccessful in differentiating mineral zones in sandstones.

In addition to the 11 wells, 7 more wells in the Salton Sea geothermal field were studied in order to test the empirical methods developed in this study. It was found that the lack of porosity data inhibited the effectiveness of distinguishing the zones.

Three conditions must be considered in order to interpret log data accurately by the empirical methods in this study. These are a knowledge of the downhole salinity profile, concentrations of resistive minerals in a section of a well, and the presence of thick shale horizons.

Gamma-gamma density logs, petrophysical and petrographic data indicate that net induration of the sandstone and shales has occurred in all altered zones. The gamma-gamma density log was shown to be fairly accurate in recording the true formation density in a hydrothermal environment. Use of Archie's equation to obtain porosity from electric logs was also studied. This method proved unsuccessful in this case, but under different conditions this method may be of value.

Three different methods were used to calculate salinity from wireline logs. The log-derived salinity values are in poor agreement with the actual formation water salinity. Nevertheless, the trend of the log-derived salinity profile may reflect the trend of the true salinity profile.

A comparison of electric log data for the Salton Sea and Cerro Prieto reservoirs indicates that the high salinity in the Salton Sea field (250,000 mg/L) has lowered the overall resistivity responses in all zones in relation to Cerro Prieto (18,000 mg/L).

I. INTRODUCTION

The analysis of downhole wireline logs plays an integral part in the exploration and development of oil and gas fields. The many years of experience gained in log analysis of these fields have led to very sophisticated techniques for evaluation of such energy resources. In contrast, well log analysis of geothermal fields has been much more limited due to several factors. These include the small number of producing fields, the temperature limitations of logging tools, the problems of proprietary data, and logging in nonsedimentary rocks. Recently, however, development of this nonpetroleum energy resource has burgeoned. Therefore, methods such as log interpretation which can aid its development must be more fully investigated.

Because of the similarity in lithologic characteristics to some oil fields, the Salton Sea and Westmorland geothermal fields offer unique opportunities for well log analysis. Certain techniques employed in formation evaluation of petroleum fields can be used in the Westmorland geothermal field, which has moderate temperatures (252°C at 7500 ft [2286 m]) and fluid salinities (maximum concentrations approximating 72,000 parts per million [ppm]). However, the extreme conditions in the Salton Sea geothermal field -- with temperatures greater than 300°C and hypersaline formation fluids approximating 250,000 ppm -- required refinement and development of new techniques in log analysis.

All wells in these two geothermal fields have been drilled by private energy resource companies. Consequently, all data are proprietary in nature. However, through the cooperation of several of these companies, wireline logs, drill-cutting samples, and other relevant data for some of these wells have been released to Dr. W. A. Elders and the Institute of Geophysics and Planetary Physics at the University of California, Riverside (UCR). Electrical logs have been run in all of the wells that have been studied. Unfortunately, only limited log porosity data were available for use.

The purpose of this study is to identify the effects of hydrothermal alteration on wireline log response and to determine the degree of alteration, the porosity changes, and temperature effects from logs. Initially, log curves for 11 wells in the Salton Sea and Westmorland geothermal areas were correlated with mineralogic and temperature data generated in this and a previous study (S. D. McDowell, unpublished data). Later, seven additional wells in the Salton Sea field were studied to test the methods developed in this study. Laboratory petrophysical measurements were then compared with log-derived salinity values to determine the accuracy of the log data in the hydrothermal environment. Log-derived salinities were calculated in order to ascertain the effects of salinity on log response. Furthermore, earlier theories on the nature of the reservoir were tested against these log data.

The hope is to provide an alternative means of determining reservoir parameters such as temperature, porosity, salinity, and patterns of hydrothermal alteration, through use of electric and porosity logs rather than the more costly and time-consuming laboratory procedures of geochemistry, hydrology, petrology, and mineralogy.

II. GEOLOGICAL BACKGROUND

A. Regional Setting

The Salton Sea Geothermal System (SSGS) and the Westmorland Geothermal System (WGS), situated approximately 4 miles (6.4 km) south, are located near the southeastern end of the Salton Sea in the Imperial Valley, California, USA (Figure 1). This valley is part of the physiographic province known as the Salton Trough, the sediment-filled landward extension of the Gulf of California (Elders et al., 1972; Elders, 1979; Muffler and White, 1969).

The Salton Trough is a complex rift valley that is bordered by steep, step-faulted mountains of granitic and metasedimentary rocks of Mesozoic age and older (Dibblee, 1954); it also has a relatively flat basement (Elders et al., 1972; Elders, 1979). The Trough is postulated to have formed by spreading of the oceanic crust to the south and continental crust to the north at a rate of 6 cm/yr (Elders et al., 1972; Menard and Atwater, 1970). These spreading centers or "pull apart basins" are offset by a series of right lateral en echelon transform faults of the San Andreas fault system (Elders et al., 1972;

Figure 1. Location of the Salton Sea, Westmorland, and other geothermal fields in the Imperial Valley and adjacent area of the Salton Trough.

Elders and Biehler, 1975). Elders and Biehler (1975) have termed this system as a leaky transform fault.

Presently, the hot geothermal areas in the Imperial and Mexicali Valleys may be a reflection of these spreading centers (Elders et al., 1972). These areas are characterized by high heat flow (von Herzen, 1963; Lee and Cohen, 1979; Rex, 1966; Lawver and Williams, 1979) and microseismicity (Johnson and Hadley, 1976; Gilpin and Lee, 1978; Albores et al., 1979; Hill et al., 1975), gravity anomalies (Biehler, 1964, 1971; Chase et al., 1979), recent volcanism (Robinson et al., 1976), and surface hydrothermal manifestations.

The sediments that have accumulated in the Trough consist primarily of deltaic and lacustrine deposits forming part of the Colorado River Delta (van de Kamp, 1973). In these sediments, a decrease in volume percent of sand bodies and grain size occurs with increased distance from the apex of the delta (Randall, 1974; van de Kamp, 1973). Consequently, in the distal portions of the delta, lacustrine muds, silts, and beach sands predominate in contrast to the meandering deltaic channel deposits typically near the apex (van de Kamp,

1973). In the SSGS the overall volume percent of lithologic types based on drill cuttings are 70% shales, 5% siltstone, and 25% sandstone (Kendall, 1976). The progradation of the Colorado River Delta normal to the Trough since the mid-Pleistocene (van de Kamp, 1973) has isolated the Salton Basin from the Gulf of California.

The sandstones and shales in the SSGS have undergone extensive hydrothermal alteration to the greenschist facies by temperatures ranging to 365°C at 7117 ft (2170 m) (Muffler and White, 1969; Elders, 1979; McDowell and Elders, 1979). Highly saline brines of concentrations up to 260,000 ppm have also been encountered (Muffler and White, 1969; Helgeson, 1968). Stratigraphically, this geothermal field can be divided into two sections: (1) an upper unconsolidated to poorly consolidated, clay-silt-evaporite lacustrine sequence and (2) a lower moderately to well-consolidated, interbedded sandstone-siltstone-mudstone deltaic sequence (Randall, 1974). The lacustrine sequence acts as an impermeable "caprock" over the interbedded deltaic sediments which constitute the reservoir rocks in this system. At present, the oldest sediments reached by drilling are apparently Pleistocene fluvial and lacustrine deposits (Merriam and Bandy, 1965; Muffler and Doe, 1965).

Recently, McDowell and Elders (1979, 1980) have defined three textural prograde metamorphic zones in the deltaic sediments of the SSGS. Based on petrographic and x-ray examination of sandstone cuttings, these zones with

increasing depth and temperature are: (1) the carbonate cap; (2) the porous or reservoir zone; and (3) the hornfels zone. The carbonate cap zone is characterized by high weight percent (>30 wt. %) of carbonate cement, floating grain contacts, and low porosity as estimated in thin section. The transition into the porous zone is marked by an abrupt increase in porosity to 15-20% and an increase in mutual contacts of detrital quartz and feldspar grains as overgrowths. With increasing depth, the porosity decreases by formation and enlargement of overgrowths on quartz and feldspar grains. The hornfels zone is reached when all visible traces of overgrowths have been removed by recrystallization, producing a dense rock with interlocking granoblastic texture.

Extensive petrologic and geochemical studies have been made recently in the SSGS (Yunker et al., 1982 [review paper]; McDowell and Elders, 1982, 1980a, 1980b; McDowell, 1978; McKibben, 1979; Freckman, 1978; Bird and Norton, 1981; Olson, 1978). Numerous geological and geophysical investigations have also been carried out (Yunker et al., 1982 [review paper]); Humphreys, 1978; Meidav and Howard, 1979; Sigurdson et al., 1971; Biehler, 1964).

In contrast, the Westmorland geothermal area, separated from the SSGS by the Brawley fault (Figure 1) and within its own residual gravity anomaly, shows considerably lower temperatures (252°C at 7500 ft [2286 m]) and less saline brine concentrations (maximum salinity about 72,000 ppm). Hence, less hydrothermal alteration is suggested in the WGS. Olson and Matlick (1978) have studied the geochemical aspects of this field.

B. Drilling History in the Salton Sea and Westmorland Geothermal Areas

In 1927 three wells were drilled by the Pioneer Development Company on Mullet Island to find natural steam (Wynn, 1975) (Figure 2). These wells, the deepest of which was 1473 ft (449 m), encountered steam, hot water, and noncondensable gases; however, the pressure and volume of steam were considered insufficient for commercial production. Consequently, these wells were abandoned (Rook and Williams, 1942).

Figure 2. Location of the wells chosen for study in the Salton Sea and Westmorland geothermal areas (after Geothermal Resources Council, 1981, Geothermal map of the Imperial County, California).

● Geothermal wells studied in this report.
○ Other geothermal wells (not studied in this report).

1 = Britz #3; 2 = River Ranch #1; 3 = Sportsman #1; 4 = I.I.D. #1; 5 = I.I.D. #2; 6 = State of California #1; 7 = Elmore #1; 8 = Magmamax #3; 9 = Magmamax #2; 10 = Magmamax #1; 11 = Woolsey #1; 12 = Sinclair #4; 13 = Sinclair #1; 14 = Sinclair #3; 15 = Landers #1; 16 = Landers #2; 17 = Dearborn Farms; 18 = Kalin Farms.

The abundance of carbon dioxide gas found in these first wells led to renewed interest in drilling. Then in 1932 the Imperial Carbon Dioxide Field was discovered. This field was commercially developed from 1933-1954 (Rook and Williams, 1942) producing over 2.5 billion ft³ of CO₂ gas (McNitt, 1963) from shallow sands 200 to 700 ft deep. Inundation of many wells by the Salton Sea, depletion of production, and development of modern refrigerated transport led to the abandonment of this field (McNitt, 1963).

The Kent Imperial Corporation "Sinclair 1", sec. 10, T12S, R13E, was the first well in the Imperial Valley to produce substantial amounts of steam. Drilled from late 1957 to early 1958 to 4725 ft (1440 m), this well is generally considered to be the discovery well for the SSGS (Lande, 1979). From 1961-1964, 11 more wells were drilled with 8 being completed as steam producers.

A hiatus in drilling occurred between 1965-1971. Since 1972, 22 wells have been drilled. To date a total of 41 wells have been completed. Seven of the wells have been abandoned. Six are injection wells, and one is an observation well (California Division of Oil and Gas, 1981).

In the Westmorland area, all of the wells have been drilled since 1972. A total of seven wells have been completed; four as production wells, two as reinjection wells, and one is abandoned (see Appendix 1 for a complete summary).

C. Previous Well Log Work

Although well log analysis in hydrocarbon reservoirs is highly advanced, geothermal well log interpretation is in a developmental stage. Advancement in use and proper analysis of geothermal well logs requires solutions of problems due to high reservoir temperatures and corrosive brines. These problems may cause both tool breakdown and calibration difficulties (Sanyal et al., 1980). At present, however, high-temperature resistant well tools and calibration pits for calibrating well tools in various fractured and unfractured igneous and metamorphic rocks (Mathews, 1980) are being built.

Applegate and Moens (1980), Keys and Sullivan (1980), Rigby and Zebal (1981), O'Sullivan (1979), and Benoit et al. (1981) have studied well logs from nonsedimentary geothermal systems. These studies were able to distinguish empirically different types of igneous and metamorphic rocks and their altered equivalents by inspection and crossplotting of various log data.

Methods used in well log analysis of petroleum fields have been applied to sedimentary geothermal fields. Randall (1974) and Miller (1980) used electrical logs for parastratigraphic analysis of the SSGS and East Mesa geothermal field, respectively (Figure 1). Ershaghi et al. (1979), using oil field formation evaluation techniques, estimated the formation factor and water resistivity in the Cerro Prieto geothermal field by analyzing electric logs. Littleton and Burnett (1975, 1977) used the spontaneous potential (SP) and dual induction logs to calculate the downhole salinity profiles for ten wells in the East Mesa geothermal field. They found that their computed salinities agreed fairly well with those from chemical analyses of the well fluid. However, the high temperatures encountered in deeper portions of these geothermal reservoirs cause hydrothermal metamorphism, and the sediments lose their clastic texture. Thus, traditional oil-field log interpretation techniques become difficult to apply to hydrothermally altered sediments.

Other problems to overcome are the effects of cooling agents on log parameters and the large temperature gradients between the borehole annulus and the formation. For example, cooling agents such as dry ice are commonly dumped into boreholes in order to prevent tool failure due to high temperatures. These agents may cause mud salinity stratification and can alter the SP curve to a significant degree (Ershaghi et al., 1978). Also, large errors in resistivity

readings may occur because of large temperature gradients between the borehole annulus and the formation. Davis and Sanyal (1979) state that for low-water-loss drilling mud the effect of temperature gradients below 100°C on estimations of true formation resistivity is probably minimal.

In a comprehensive well log study of the Cerro Prieto geothermal field, Seamount (1981) demonstrated that shale log data show good correlation with four mineralogic zones determined by x-ray diffraction. These are defined as: (1) the montmorillonite zone (<150°C); (2) the illite zone (150°C to 230-245°C); (3) the chlorite zone (230-245°C to 300°C); and (4) the feldspar zone (>300°C). He could also recognize these zones on electrical logs by noting the parallelism, convergence, or divergence of the respective curves of sand and shale resistivity. He also found that by crossplotting shale resistivity and density data the mineral zones could be easily identified. Furthermore, his analysis of well logs supports the ideas of fluid flow in the Cerro Prieto reservoir (Seamount and Elders, 1981) developed on the basis of other data.

Previous interpretation of well logs performed in the SSGS dealt mainly with stratigraphic correlation and structure determinations (Randall, 1974; Tewhey, 1977; Chan and Tewhey, 1977). Using SP and resistivity logs combined with the study of well cuttings, Randall (1974) determined that the upper portion of the sedimentary section consists of a wedge-shaped, northward-thickening series of lacustrine clays, silts, and evaporites, while the lower portion consists of intercolated sandstones and shales with a few meters of altered dark-brown rhyolite. Using electric logs, he determined the depth to the top of what he termed the metamorphic zone. By correlation of electric logs between wells, he hypothesized the presence of numerous strike-slip faults to explain the variation in depth of correlatable horizons. From his study of temperature logs, Randall suggested that the geothermal anomaly is not influenced by stratigraphic or structural boundaries. Furthermore, he also proposed that the present shape and size of the Salton Sea reservoir are determined by the distance from a magma intrusion which he supposed caused the anomaly.

Tewhey (1977), on the basis of log correlation and drill-cutting examination, recognized three zones: the upper zone, defined as the caprock which consists of unconsolidated silt, sand, and gravel; the unaltered reservoir zone composed of well-indurated shales, siltstones, and sandstones consisting of dense quartz and feldspar grains cemented with calcite and/or silica; and the lower zone, a hydrothermally altered zone marked by the presence of epidote, which replaced calcite. Later well log correlation suggested that the subsurface structure of the Salton Sea is a structural basin whose axis trends northwest (Chan and Tewhey, 1977).

D. Hydrothermal Mineralogy

The sediments in the SSGS have undergone various degrees of hydrothermal metamorphism with depth caused by high temperatures and hypersaline brines. Greenschist facies metamorphism of these sediments is presently occurring (Muffler and White, 1969; McDowell and Elders, 1979, 1980a, 1980b, 1982). Previous studies of hydrothermal alteration in volcanic and sedimentary geothermal fields have shown that there is a correspondence between certain metamorphic mineral assemblages and temperatures (Browne, 1978 [review paper]; McDowell and Elders, 1979, 1980a). In the SSGS, detailed mineralogic studies have been carried out at UCR (McDowell and Elders, 1979, 1980a, 1982; Kendall, 1976; McKibben, 1979). Figure 3 shows the authigenic mineral assemblages in sandstones for the representative borehole Elmore 1, located near the center of the SSGS (McDowell and McCurry, 1978). When the same authigenic mineral occurs in the sandstones and shales, the mineral appears at a shallower depth and lower

Figure 3. Summary of lithologic, temperature, authigenic mineral variation, and sandstone mineral zones in well Elmore 1. In the lithologic column, clear = shale; solid black = sand; and dots = volcanic material. Temperature from Helgeson (1968). Vertical bars show depth range of authigenic minerals in sandstones: solid where common, dashed where sporadic and in minor quantities. Horizontal lines separate the major metamorphic zones: dolomite/ankerite from <1440 ft (439 m); the calcite/chlorite from 1440-3723 ft (439-1135 m); biotite from 3723-6954 ft (1135-2120 m); garnet from >6954 ft (2155 m). WM = illite and white mica; CH = chlorite; BI = biotite; VM = vermiculite in rare clay fraction; AC = actinolite; TA = talc; CC = calcite; EP = epidote; GA = garnet; OR = orthoclase/microcline; AH = Anhydrite; H = hematite (and dolomite); PY = pyrite; Q = quartz; AB = albite (after McDowell and McCurry, 1978).

temperature in sandstones. Higher original permeability for the sandstones probably causes this difference (McDowell and Elders, 1979; Elders et al., 1979). In this study the mineralogic zones are based on shale x-ray diffraction data since shale mineralogy has a greater effect on resistivity and gamma-gamma density than does the mineralogy of sandstones, as will be shown later. The term "shale" is used here to designate mudstones and other claystones, rather than implying that the rocks have the fissility of true shales. X-ray diffraction data for the shales are included in Appendix 2.

The montmorillonite zone, the coldest of the defined shale mineral zones, is characterized by the presence of the clays, montmorillonite, and kaolinite. Depending upon the location of the wells in the SSGS, this shale zone is correlative with the lacustrine sequence of Randall (1974) or part of the dolomite/ankerite zone in the sandstones (McDowell and Elders, 1980a). The sediments are mostly unconsolidated in this zone.

The calcite-chlorite zone in the sandstones as defined by McDowell and Elders (1980a) occurs at temperatures of 190°C-325°C. They have observed the following major changes in the constitution of the layered silicates

in sandstones in this zone. Between 190°C-275°C the illite/smectite consists of 0-5% expandable layers. At 300°C significant recrystallization of most layer silicates occurs. Throughout this zone the sandstone and shale clay size fraction becomes more chlorite rich and less abundant (McDowell and Elders, 1980a). Also, at approximately 300°C, quartz and feldspar are recrystallized to produce hornfelsic-textured sandstones.

In this study at temperatures corresponding to the calcite-chlorite and to the lower portion of the dolomite/ankerite zones in sandstones, three different shale zones have been defined. These are here termed the illite, chlorite, and feldspar zones.

The illite zone occurs in shales at temperatures from 100°C-190°C to 230°C-250°C. The percentage of illite increases from approximately 13-15% to 20% in this zone; however, montmorillonite is absent. The chlorite zone occurs in shales at 230°C-250°C to 290°C-300°C. A rapid increase in the percentage of chlorite from approximately 9% to 13% characterizes the lower temperature boundary of this zone. Dolomite and kaolinite are mostly absent, and the illite continues to increase to 30% or more throughout this zone. By 300°C the interlayered montmorillonite has usually disappeared.

The feldspar zone occurs above 300°C in shales. A large increase in plagioclase and alkali feldspar is the distinctive mineralogic change. This increase, often greater than 20%, is at the expense of the layered silicates (Appendix 2). Illite decreases in this zone, and calcite is typically absent.

The hottest zone in the shales, defined as the biotite/calc-aluminum silicate zone, occurs where biotite, amphibole, and epidote are initially detected by x-ray diffraction. Only three wells in this study have penetrated this zone. Because of the sparse x-ray data in this zone, an exact temperature range cannot be given. The lack of data precludes detailed interpretation; therefore, this zone will not be mentioned further.

III. COLLECTION AND PROCESSING OF DATA

Logs for the 18 wells examined in this study were made available to UCR by Randall (1974) and Republic Geothermal, Inc. (Table 1). In the SSGS, the criteria used in the selection of seven wells for detailed study were the completeness of well log data and the amount of petrologic and temperature data already available. In addition, these wells were chosen from different areas within the field in order to establish analytical methods for the entire field. Because of the lack of complete well log suites in the other wells of the SSGS, the authors extended the study into the Westmorland area where more complete well log suites were available. Four wells were analyzed in the WGS. Furthermore, a reconnaissance log study of seven additional wells in the SSGS was undertaken to test the empirical methods presented in this report (see pages 34-39). Figure 2 shows the location of all wells studied. Table 1 lists the 18 wells and the data used.

A. Wireline Logs

Electric logs were primarily used in this study. Where available, gamma-gamma density, neutron, and sonic logs were also scrutinized. A summary of the basic principles of these logs types is presented in various log manuals (Schlumberger, 1972; Dresser Atlas, 1974) and in Seamount (1981). Nearly complete electric log coverage was obtained for all wells studied except for Britz 3, Sinclair 3 and 4. These wells, however, do have electric log coverage

TABLE 1

Wireline Log, Mineralogic, and Temperature Data Used in this Study

Field	Well Name	Operating Company	Total Depth (ft)	Elog Data (ft)	Density Data (ft)	Shale X-ray Data (ft)	Temp Data	Date Logged ^a
Salton Sea	Magmamax 1*	Magma Power	2805	1060-2543	1060-2550	---	---	1972
	Magmamax 2*	Magma Power	4368	100-4368	1009-4367	1090-4340	TL	1972
	Magmamax 3*	Magma Power	4000	112-4000	1033-4004	1020-4000	TL	1972
	Woolsey 1*	Magma Power	3490	1084-2397	1800-2380	1575-3468	---	1972
	Sinclair 1*	Geothermal Energy & Mineral Corp.	4725	243-4479	---	---	---	1958
	Sinclair 3*	Geothermal Energy & Mineral Corp.	6922	1365-5329	---	2590-6831	TL	1962
	Sinclair 4*	Geothermal Energy & Mineral Corp.	5300	1768-5309	---	2750-5166	TL, FI, δO^{18}	1964
	Elmore 1*	Imperial Magma	7117	107-7117	---	1349-4920	TL, FI	1964
	River Ranch 1*	Union Oil Company		1576-6550	---	2333-6100	TL	1963
	I.I.D. 1*	Imperial Thermal Products	5230	1624-5234	---	---	---	1962
	I.I.D. 2*	Imperial Thermal Products	5826	100-5826	---	900-5810	TL	1963
	State of California	Imperial Thermal Products	4848	100-4839	---	---	TL	1964
	Sportsman 1*	J. I. O'Neill	4729	1194-4737	---	---	---	1961
	Britz 3	Republic Geothermal, Inc.	10370**	333-8067**	780-3100**	1000-10250**	TL	1980
Westmorland	Landers 1	Republic Geothermal, Inc.	7705	100-7690	3000-7692	3010-7690	TL	1976
	Landers 2	Republic Geothermal, Inc.	7507	96-7398	7488-5990	1020-7470	TL	1976
	Kalin Farms 1	Republic Geothermal, Inc.	8490	546-8190	---	1180-8470	TL	1976
	Dearborn Farms 1	Republic Geothermal, Inc.	8000	85-8000	3000-8000	2000-7970	TL	1976

*From Randall (1974).

**Not true vertical depth.

^a = Old logs (run prior to 1965).

TL = temperature log

FI = fluid inclusion derived temperatures

 δO^{18} = oxygen isotope temperatures

over intervals important to this study. Only five wells have usable and sufficient gamma-gamma density log data.

Careful inspection of each log was undertaken to determine its quality. For the newer logs, e.g., the logs for the Republic wells, several repeat runs were available for examination. These logs were deemed of acceptable quality (Table 1). The older logs do not have appended repeat runs. These logs, however, were assumed to be of acceptable quality. As will be shown later (pages 12-18), this assumption could be proved valid in certain cases as similar trends in log data were observed on older logs as on newer logs.

Additional criteria were employed to select log values presented since most are uncorrected for borehole size and mud temperature. The log values were always picked from lithologic units at least 5 ft (1.52 m) thick and preferably greater than 10 ft (3 m) in order to eliminate errors due to bedding contacts (Schlumberger, 1972). Next, since oversized boreholes particularly affect gamma-gamma density values (Maxant, 1980), data were not generally used from boreholes greater than 15% oversized. However, in order to facilitate greater use of these data, in particular with the gamma-gamma density, compensation curves were applied to correct for oversized hole diameters but only for boreholes >15-20% oversized. In addition, the gamma-gamma density values that are corrected by compensation curves were constrained by not allowing the density values to be corrected to vary more than 0.1 gm/cm³ from those values 100 ft (30.5 m) above and 200 ft (61 m) below (C. Isselhardt, personal communication, 1981). These constraints on log density values were effective, as shown by close agreement between ρ_B and petrophysical data (see pages 46-49). Sand and shale log values were handpicked independently over 50 ft (15 m) intervals and then plotted at a reduced scale of 500 ft/in.

Sands and shales were distinguished on the basis of self potential (SP) deflections. Gamma-ray log readings were also used as a check of lithologic type. Usually low gamma-ray counts and SP deflections to the left indicate sands. Within a given interval, log values were picked opposite maximum and minimum SP and gamma-ray deflections.

After handplotting the data, the curves were machine digitized (although some were hand digitized due to machine breakdown) and run through computer programs which produced most of the figures presented.

B. Petrologic Data

Hydrothermally altered sediments are present in all of the wells studied (McDowell and Elders, 1979, 1980a, 1980b, 1982; Muffler and White, 1969; Kendall, 1976; Freckman, 1978; Olson and Matlick, 1978). The zones of mineral alteration are based exclusively on x-ray diffraction data of cutting samples. The mineralogy of shales affects the log responses to the greatest degree; therefore, the zones defined above are based exclusively on shale mineralogy (Appendix 2). Sand mineralogy will be referred to as needed (Appendix 3).

Problems in contamination of drill cuttings and determination of depth resulting from lag time have been described by Miller (1980), Hoagland (1976), and Kendall (1976). The sampling interval for the x-ray analyses in most wells is approximately 250 ft (76.3 m).

X-ray diffraction data for eight wells were generated in this study (see Appendices 2 and 3). For the x-ray diffraction analyses of shales, representative bulk samples were picked so that biasing the x-ray determined bulk mineralogy by selection of one predominate shale color was eliminated. Three different colors of shales are present in the SSGS and WGS. These are red brown in the upper portions, light gray at intermediate depths, and dark gray near the bottom of the wells. These color zones are transitional and do not appear to

correlate with the previously defined mineral zones in shales. The data for the remaining wells were produced from a previous study (McDowell, unpublished data, Appendix 2).

C. Temperature Profiles

Due to borehole conditions, such as cooling effects of drilling fluids and later heating of upper strata through production, measured temperatures within a well do not always reflect the true formation or reservoir temperature. Under certain conditions, however, measured temperatures may be near formation temperatures. Among these conditions are that the mud should be washed out of the well after the cessation of drilling and that it should be idle, preferably for a period as long as drilling operations existed.

The temperature logs (Figures 4-9, 26, 28) presented in this study were chosen as the best representative in situ temperatures (Randall, 1974, Figures 4, 6, 7, 9, 26; Helgeson, 1968, Figures 5, 6, 9). In addition, fluid inclusion and oxygen isotopic temperatures are included where available.

D. Petrophysical Analyses

Core samples from wells Landers 1, Dearborn Farms 1, and Kalin Farms 1 were analyzed for porosity using a Ruska mercury porometer and Beckman pycnometer in order to compare the results with ρ_B (see pages 43-49).

E. Petrographic Study

Thin sections were examined for well Britz 3 to achieve familiarity with types of rock alteration and porosity that are commonly found. A preliminary petrographic description for Britz 3 is given in Appendix 4.

IV. MINERAL ZONE AND LOG DATA PRESENTATION

This report employs four types of data displays to demonstrate the effects of hydrothermal alteration and temperature on well log data. These are:

1. Well log and temperature data vs. depth.
2. Rsd/Rsh vs. depth.
3. R vs. ρ_B crossplot.
4. R vs. N crossplot.

All four methods readily differentiate in shales the four mineral zones defined in this report. Each method will be discussed and explained separately. The well log and Rsd/Rsh vs. depth show both sandstone and shale data together. Log data for only one lithology are shown on individual crossplots. As shall be shown later, data presentations which display log data for the two lithologies together distinguish the mineral zones best.

A. Well Log and Temperature Data vs. Depth

The mineral zones are plotted on downhole temperature logs in Figures 4-9 and plotted with other well log data versus depth in Figures 10-20. The depths of the various mineral zones are based on shale x-ray diffraction data (Appendix 2).

Well log data versus depth diagrams exhibit the effect of hydrothermal alteration on the sandstones and shales. This effect is shown by: (1) the virtual parallelism of the sandstone and shale curves within certain zones; and (2) the divergence of the curves in other mineral zones. Table 2 and the following discussion summarize the typical log responses in the SSGS:

Figure 4. Temperature data for well Magmamax 3, after Randall (1974). Mineral zones in shales are based on this study.

Figure 5. Temperature data for well I.I.D. 2, after Helgeson (1968).

Figure 6. Temperature data for well Elmore 1, after Randall (1974).

Figure 7. Temperature data for well Sinclair 4 (Randall, 1974) and fluid inclusion homogenization temperatures. Horizontal bar indicates range of homogenization temperatures at a given depth. Triangle indicates the mean homogenization temperatures at a given depth (after Freckman, 1978).

Figure 8. Temperature data for well Britz 3 (Republic Geothermal, Inc.).

Figure 9. Temperature data for well River Ranch 1, after Randall (1974).

The montmorillonite zone that extends below the lacustrine sequence (Randall, 1974) shows a deep induction resistivity of both sandstone (R_{sd}) and shales (R_{sh}) ranging from 0.7 ohm-m to 1.2 ohm-m. The gamma-gamma densities of the sandstone (ρ_{Bsd}) and shale (ρ_{Bsh}) are always low ($<2.2 \text{ gm/cm}^3$). Within the illite zone, highly variable R_{sd} and R_{sh} values are normally present. An overall rise in ρ_{Bsd} and ρ_{Bsh} occurs, although both show some variation. Within the chlorite zone, R and ρ_B for both lithologies generally rise and parallel each other with increasing alteration. The ρ_{Bsh} rises to values between 2.40 gm/cm^3 , while the ρ_{Bsd} reaches values of 2.25 gm/cm^3 to 2.40 gm/cm^3 . The feldspar zone, the hottest zone studied in this report, typically shows resistivities values diverging at the top of this zone -- R_{sd} usually drops and the R_{sh} rises. The ρ_{Bsd} are generally about the same as the chlorite zone (between 2.25-2.35 gm/cm^3). ρ_{Bsd} occasionally rises in this zone.

In the Westmorland geothermal area, only one well shows equivalent well log responses corresponding to mineral zones. An explanation of these different log responses and reasons for the typical log responses in the SSGS and WGS will be given in a later section (see pages 24-33).

Figure 10. Well Magmamax 2, well log data vs. depth.

Figure 11. Well Magmamax 3, well log data vs. depth.

Figure 12. Well I.I.D. 2, well log data vs. depth.

Figure 13. Well Elmore 1, well log data vs. depth.

Figure 14. Well Sinclair 4, well log data vs. depth.

Figure 15. Well Sinclair 3, well log data vs. depth.

Figure 16. Well Britz 3, well log data vs. depth.

Figure 17. Well Landers 1, well log data vs. depth.

Figure 18. Well Kalin Farms 1, well log data vs. depth.

Figure 19. Well Dearborn Farms 1, well log data vs. depth.

Figure 20. Well Landers 2, well log data vs. depth.

Table 2. Characteristic Log Response and Hydrothermal Mineralogy Within the Four Mineral Zones

Zone	Sandstone*	Shale	Most Apparent Mineralogical Change	Typical Effect on Log Data [†]		Stratigraphic Correlation
				Sandstone	Shale	
Montmorillonite 100-190°C	X	X	Montmorillonite and kaolinite are the dominant layered silicates	ρ_{Bsd} - Values usually lower than 2.05 gm/cm ³ Rsd - Where present from .75 to 3.8 ohm-m	ρ_{Bsh} - Rises from 2.00 gm/cm ³ to 2.15 gm/cm ³ Rsh - Varies from 0.1 ohm-m to 2.75 ohm-m SP - good	Easy to Difficult
	X	X	No alteration			
Illite 230-250°C		X	Illite increases; montmorillonite disappears	ρ_{Bsd} - Rises from 2.05 gm/cm ³ to 2.2 gm/cm ³ Rsd - Variable values from 0.3 to fluctuating values (1 ohm-m to 2 ohm-m) SP - Good deflection GR - Good response	ρ_{Bsh} - Overall rise from 2.15 gm/cm ³ to 2.25 gm/cm ³ Rsh - Rapid rise of ~0.5 ohm-m at top of this zone	Difficult
	X		Increase in chlorite			
	X		Dolomite/ankerite usually disappears			
	X		Formation and enlargement of quartz and feldspar overgrowths			
	X		Decrease of interlayered montmorillonite/illite			
Chlorite 290-300°C		X	Increase in chlorite content	ρ_{Bsd} - Rises generally from ~2.2 gm/cm ³ to ~2.40 gm/cm ³ . The highest ρ_{Bsd} values are typically recorded near the base of this zone. Rsd - Rises through this zone - highest at the base of this zone GR - Good response SP - Good response	ρ_{Bsh} - Rises gradually from 2.25 to 2.60 gm/cm ³ Rsh - Typically and steadily rises throughout this zone.	Very Difficult
	X		First occurrence of epidote (optically determined)			
		X	Disappearance of interlayered illite/montmorillonite >50% expandable layers			
	X		Abrupt decrease in mica content			
	X		Epidote is detected by X-ray diffraction			
Feldspar 315-325°C		X	Increase in feldspar content and often quartz at the expense of the layered silicates	ρ_{Bsd} - 2.25 gm/cm ³ to 2.35 gm/cm ³ - variable Rsd - Decreases in this zone from ~1-1.5 ohm-m to less than 0.5 ohm-m SP - Good response GR - Good response	ρ_{Bsh} - 2.5 gm/cm ³ to 2.65 gm/cm ³ Rsh - Rises dramatically by 0.4 to 0.8 ohm-m	Impossible
	X		Abrupt decrease in calcite			
	X		First occurrence of biotite and vermiculite			

*Mineralogy from McDowell and Elders, 1979.

[†]Refers to deep induction resistivity; GR = gamma ray; ρ_B = gamma-gamma density; SP = spontaneous potential.

B. Rsd/Rsh vs. Depth

Another method employed to discriminate between the four mineral zones is the Rsd/Rsh versus depth presentation. This type of plot is constructed by dividing the deep induction resistivity of the sandstones (Rsd) by the deep induction resistivity of the shales (Rsh) and crossplotting this dimensionless ratio against depth (Figures 10-20). The resistivity ratio applies to log data within a 50-ft (15-m) interval. Both lithologies are therefore shown on a two-dimensional display on this plot.

Where the montmorillonite zone extends below the lacustrine sequence in the SSGS, the resistivity ratio ranges from 0.60 to 1.2. The illite zone values found near the center of the field vary from 0.8 to 2.0. The ratio within the chlorite zone normally shows a lower range from 0.3 to 1.5. The scatter of values in the ratio are least in the feldspar zone where the values ordinarily lie between 0.1 to 0.4. The divergence of values from these given ranges are attributed to variations in mineralogy physical properties of the rocks and to variations in fluid salinity which chiefly affect sandstones.

C. Resistivity-Density Crossplot

The resistivity-density crossplot, commonly used in the petroleum industry to determine water saturation (Schlumberger, 1972), also differentiates the mineralogic zones. These crossplots were produced for the wells which had the most complete density data, namely Magmamax 2 (Figure 21) and Magmamax 3 (Figure 22). The crossplot was not applied to wells Landers 1 and Dearborn Farms 1 because of the lack of gamma-gamma density data for the upper portions of these wells where the only mineral zone boundaries exist.

This crossplot functions well in identifying the mineral zones using shale data. Yet, overlap of some plotted zones does occur, for example, in well Magmamax 3. Overlapping of these mineral zones takes place because resistivity is affected not only by mineralogy but also by rock properties and formation

Figure 21. Resistivity-density crossplot for well Magmamax 2.

Figure 22. Resistivity-density crossplot for well Magmamax 3.

Figure 23. N-Resistivity crossplot for well Magmamax 2.

Figure 24. N-Resistivity crossplot for well Magmamax 3.

fluid characteristics. In sandstones, this crossplot is less successful in separating mineral zones (Figures 21, 22). A shortcoming of the resistivity-density crossplot is that only one type of lithology is presented on a given crossplot. To give the best possible correlations, both sandstones and shales should be analyzed together.

D. N-Resistivity Crossplot

The N-resistivity crossplot is a variation of the M-N crossplot of Burke et al. (1969). N is defined as the neutron porosity divided by density. Since porosity usually decreases with increasing alteration, this display takes into account another variable that affects log response. As a result, this method discriminates between mineral zones better than the resistivity-density crossplot (Figures 23, 24). The application of this crossplot was limited to two wells, Magmamax 2 (Figure 23) and Magmamax 3 (Figure 24), since density and/or neutron porosity data are absent over important intervals in the other wells that were studied. In sandstones the crossplot is unsuccessful in separating the zones.

V. MINERAL ZONE IDENTIFICATION ON LOGS

A thorough discussion of the characteristic log responses to varying degrees of hydrothermal alteration is presented in this section. The emphasis will be placed on the reasons for these log responses. In addition, atypical cases will also be discussed.

As previously mentioned, with increasing temperature the sandstones and shales of the Salton Sea and Westmorland geothermal systems show characteristic zones of hydrothermal alteration mineralogy. These sediments, a part of the Colorado River Delta, are heterogeneous in grain size and sorting (van de Kamp, 1973; Muffler and Doe, 1965). There are various lateral and vertical variations in lithology, mineralogy, and formation water salinity within both unaltered and altered sediments. Nevertheless, water-rock reactions at high temperatures are transforming these heterogeneous sediments into characteristic mineral assemblages which vary little between wells at equivalent temperatures. Thus, with increasing alteration the distinction of mineralogy and texture between different sedimentary units becomes less apparent. The log data reflect this tendency towards homogenization. For example, the resistivity ratio (Figures 10-20) for the illite zone generally ranges from 0.8 to 2.0. With increased alteration in the feldspar zone, the range in values is restricted to 0.1 to 0.4.

In the SSGS, hydrothermal alteration has affected all of the logs studied in similar ways, although slight variations in log signatures do exist. These variations probably result from local mineralogic and stratigraphic differences.

Each mineral zone has its own characteristic log response which will be elaborated upon in the following sections. Thus, mapping of the altered zones from log data from well to well is possible.

The primary factor that produces the characteristic log responses in the Salton Sea and Westmorland geothermal areas is the progressive dehydration of clays and their final alteration to feldspars. Johnson and Linke (1977) [cited in Ershaghi et al., 1980, 1981] have classified clays into effective and ineffective types based on resistivity. The clays, montmorillonite and illite, are considered effective because of their high cation exchange capacity and high surface conductivity (Grim, 1953, pages 125-155). This high surface conductivity causes an overall lowering of electrical resistivity. Ineffective clays, such as chlorite and kaolinite, have low cation exchange capacity and thus low conductivity. Furthermore, the general rise in resistivity associated with increased alteration indicates that the lower temperature clays such as montmorillonite and illite have more exchangeable sites than high-temperature, less hydrated clays. Other factors that influence log parameters are changes in porosity caused by induration and mineral precipitation and large changes in formation water salinity in and between wells.

The changes in mineralogy of the shales affect log parameters to a greater degree than the changes in mineralogy of the sandstones. Changes in sandstone mineralogy have a more subtle effect on log responses because of the major influences of the formation fluids within the larger pore spaces of these clastic rocks.

In this study the available logs for examination were the dual induction-laterolog (DIL), the induction electrical survey (IES), gamma-gamma density, and neutron logs. If additional wireline logs had been run in these wells, it would have been likely that the mineral zones could be more easily delineated. For example, the M-N plot (Burke et al., 1969) which incorporates sonic, gamma-gamma density, and neutron porosity data would probably be effective in distinguishing the mineral zones in the Salton Sea and Westmorland areas.

Because of their inherent differences, a discussion of the Salton Sea and Westmorland geothermal systems will be given in separate sections. Problems in log interpretation in the Westmorland field exist which will be addressed separately.

A. Salton Sea Geothermal System

1. Montmorillonite Zone. The montmorillonite zone is postulated to be present in all of the wells studied in the SSGS since montmorillonite, the characteristic mineral of this zone, is a component of the original detrital clay mineralogy (Muffler and White, 1969). However, this zone has been identified by x-ray diffraction studies of shale cuttings (Appendix 2) in only two wells, Sinclair 3 and Britz 3. The major reasons for its absence in cuttings from five other thoroughly studied wells in the SSGS are, firstly, poor sampling of the shallower parts of the wells and, secondly, the removal of expandable clays with repeated washing to remove drilling mud. The authors have, however, defined the lower boundary of the montmorillonite zone in well Sinclair 4 at 2750 ft (838 m) (Figure 14) based on its similarity in log response to well Sinclair 3 (Figure 15). Furthermore, the close proximity of these two wells makes extrapolation of this zone boundary possible. For wells Elmore 1 (Figure 13) and Magmamax 2 and 3 (Figures 13 and 14, respectively), the base of this zone has been correlated with the base of the lacustrine sequence (Randall, 1974). Reasons for this correlation are explained in detail in the following section and on pages 32-33.

The sediments in the montmorillonite zone are mostly unconsolidated. Claystones, the dominant lithology, are generally soft and light brown in color. The deep induction resistivities of these claystones are intermittently greater than those of the sandstones to depths as deep as 2700 ft (823 m) in well Sinclair 3 (Figure 15). The fluctuations of the shale resistivity values with depth are difficult to explain. One possible explanation is that the higher shale resistivities might be the result of the expulsion of more saline pore fluid through compaction and ionic membrane filtration, leaving fresher interstitial water (Englehardt and Gaida, 1963). The fresher interstitial pore water will cause higher R_{sh} values. Another explanation might be due to the conditions under which the clay particles were originally deposited. These conditions include the concentration and acidity of the initial pore solutions, particle size, and rate of deposition (Meade, 1964). For example, in low electrolytic solutions with slow depositional rates, the clay particles will become preferentially arranged in comparison to more random orientation in different conditions, as depicted in Figure 25. The preferentially arranged particles (case A, Figure 25) result in more rapid porosity reduction with burial. Consequently, at equivalent depths the resistivities associated with case A (Figure 25) will probably be higher than case B (Figure 25).

2. Illite Zone. Locating the upper boundary of the illite zone is difficult in many wells of the SSGS. In the central portion of this field near well Elmore 1, the montmorillonite-illite zone boundary presumably lies within the lacustrine sequence, since montmorillonite is not present in the limited shale x-ray diffraction data for the lacustrine sequence (e.g., wells Magmamax 2 and 3, Appendix 2). Because the boundary cannot be precisely located in wells Magmamax 2 and 3 and Elmore 1, the top of the illite zone for these wells has been correlated with the base of the lacustrine sequence (see pages 32-33 for a more detailed explanation).

CASE A

CASE B

Figure 25. A comparison of clay particle orientation for different conditions during sedimentation (after Magara, 1978). Case A: Slow depositional rates and low electrolytic conditions. Case B: Fast depositional rates and high electrolytic conditions.

The ρ_{Bsd} shows a general rise through this zone although considerable density variations do exist with depth. These fluctuations suggest that selective induration of some sandstones takes place, while others are left unconsolidated. This occurrence is probably the result of primary permeability and original density/packing of the sediments.

The ρ_{Bsh} also increases throughout the illite zone. At the top of this zone in wells Magmamax 2 (Figure 10) and Magmamax 3 (Figure 11), the ρ_{Bsh} displays an increase of about 0.1 gm/cm^3 within 200 ft

(70 m). This increase occurs at the interface of the lacustrine sequence and the sand-shale deltaic sequence. Since the permeability of the deltaic sediment sequence is presumably greater than the lacustrine sequence, more extensive water-rock interactions have taken place in the deltaic sequence, which results in sediment induration. This probably causes the increase in density at the top of this zone. Furthermore, for well Britz 3 (Figure 16) a rapid rise in ρ_{Bsh} also occurs at the top of this zone. These wells show inordinately high ρ_{Bsh} ($\sim 2.2 \text{ gm/cm}^3$) for depths as shallow as 1500 ft (457 m). Hydrothermal alteration has indurated these sediments since compaction is insufficient to cause densities this high at such shallow depths in young sediments (Athy, 1930).

In wells Elmore 1 (Figure 13), I.I.D. 2 (Figure 12), and Sinclair 3 and 4 (Figures 15 and 14, respectively) the R_{sd} is often greater than the R_{sh} in this zone. Since density logs are lacking in these wells, a possible correlation of high density with high resistivity due to intense induration cannot be demonstrated. However, in well Sinclair 4 (Figure 14) at 3100 ft (945 m), the high R_{sd} readings correlate with an increase in feldspar content from approximately 10% to 19% (sandstone x-ray diffraction data, Appendix 3).

It is interesting to observe that the illite zone is nearly coincident with the carbonate cap as defined by McDowell and Elders (1979) in wells Magmamax 2 (Figure 10) and Magmamax 3 (Figure 11). In the carbonate cap which extends to 1758 ft (536 m) in Magmamax 2 and 1899 ft (579 m) in Magmamax 3, the sandstones have very low porosities because of the pervasive pore-filling carbonate cement (McDowell and Elders, 1979). Thus, high R_{sd} are expected. The resistivities actually are very low (0.3 ohm-m). The low resistivities can be explained by the presence of illite and mixed layer clays, both effective clay types in respect to resistivity (Appendix 3) and to the very high salinity.

In well Britz 3 anomalously high R_{sd} and R_{sh} values are present between 6400 ft (1951 m) and 7500 ft (2286 m). This high resistivity zone is delineated on the lithologic log (Exlog Smith, 1980, from Republic Geothermal, Inc.) as a possible salt intrusion since an increase in Cl^- concentration within the circulating drilling mud was noted by the logging geologist. Evaporites are not uncommon in the SSGS and leaching of halite, for example, from them may have caused the increase in Cl^- in the drilling mud. If this is the case, then resistive minerals such as anhydrite which are components of evaporites may cause the high resistivities in this zone. Furthermore, examination of thin sections from this zone reveal sandstones of low apparent porosity resulting

from pervasive pore-filling cementation by calcite and anhydrite. Low porosity and resistive minerals such as anhydrite are probable sources for this high resistivity zone. Consequently, close scrutiny of lithologic logs can aid in the identification and cause of anomalous wireline log responses.

The first obvious occurrence of hydrothermal alteration typically occurs at the top of the illite zone. The limited gamma-gamma density data available for this zone indicate that a rapid rise in shale density occurs at the top of this zone. Through this zone, the ρ_{Bsh} increases from approximately 2.15 gm/cm^3 to values near 2.4 gm/cm^3 , and the ρ_{Bsd} rises from 2.0 gm/cm^3 to 2.2 gm/cm^3 . Both Rsd and Rsh show minor variation in this zone.

3. Chlorite Zone. The depth where both Rsd and Rsh curves begin a parallel rise with increasing depth indicates the transition into the chlorite zone. This rise, observed in five of seven wells studied in the SSGS, is typically continuous throughout this mineral zone. At the base of this zone, the Rsd and Rsh curves diverge -- the Rsd drops by 1 ohm-m to 1.5 ohm-m, while the Rsh generally continues to rise. Well Magmamax 3 (Figure 11) displays these effects the best. The maximum sand resistivity values vary considerably at the base of this zone from 0.3 ohm-m in well Magmamax 3 (Figure 11) to 4.4 ohm-m in well Sinclair 4 (Figure 14). In all wells studied, the rise in Rsd is directly related to reduced porosity resulting from quartz-feldspar overgrowth (McDowell and Elders, 1979) and with an increase in sandstone chlorite concentration. Generally, the chlorite concentration in sandstones ranges from 5% to 13% but can rise to 15% as in well Magmamax 2 (Appendix 3).

The Rsd of well Sinclair 4 fluctuates greatly in this zone (Figure 14), exhibiting values from about 0.7 ohm-m to greater than 20 ohm-m. At approximately 3500 ft (1067 m) the Rsd is greater than 2.4 ohm-m, while below 4100 ft (1250 m) the values approximate 0.7 ohm-m. This drastic Rsd reduction is believed to be due to a salinity change within the well. Freckman (1978) examined fluid inclusions in authigenic minerals from this well and determined the salinity in NaCl weight percent equivalent of the entrapped fluid by the depression of the freezing point method. He postulated that two fluids of different brine concentrations, separated by a thick shale layer, are probably present in this well (Figure 26). Since the concentration of the pore fluids has an overriding effect on the resistivity of sandstones, the drastic change in resistivity is most likely related to the presence of two fluids of considerably different formation water salinities.

Figure 26. Average salinity vs. homogenization temperature of fluid inclusion data in well Sinclair 4. These values are compared with Helgeson's (1968) calculated unit isochore for a simulated geothermal brine in the system $\text{KCl}-\text{CaCl}_2-\text{NaCl}-\text{H}_2\text{O}$ ($\text{KCl}:\text{CaCl}_2:\text{NaCl}-1:1.95:3.55$ by weight) (after Freckman, 1978).

In well Magmamax 3 (Figure 11), high Rsd readings occur at approximately 2600 ft (792 m). These high readings are attributed to a 10% increase in muscovite, probably a recrystallized phengitic mica (Appendix 2) (the percentage referred to relates to total bulk rock composition).

The increase in the concentration of non-conductive chlorite (Appendix 2) at the expense of the mixed layer clays most likely causes the rise of Rsh within this zone. Even though the illite concentration increases, the enhancement of conductivity is offset by a greater increase in chlorite content.

The ρ_{Bsd} shows marked fluctuation with depth, but an overall rise in density from 2.05 gm/cm³ to 2.42 gm/cm³ is evident in the two wells that have density data within the chlorite zone. In these wells Magmamax 2 (Figure 10) and Magmamax 3 (Figure 11), anomalously low ρ_{Bsd} readings occur between

Figure 27. Present static temperature profile in Magmamax 2 plotted against the boiling curves for pure water and for 15 and 25 wt. % NaCl solutions (after Kendall, 1976; temperature profile from Randall, 1974; and the curves for the 15 and 25 wt. % NaCl solutions, adjusted to the observed pressure gradient of .0287 bars/ft, are from Haas, 1971).

1950-2050 ft (595-625 m). Three possibilities exist as an explanation of the low ρ_{Bsd} : (1) an enlarged borehole causing low backscatter detection of gamma rays; (2) a boiling zone where steam causes low ρ_{Bsd} ; and (3) a clean sandstone aquifer. The inspection of the caliper log shows no evidence for enlarged boreholes at these depths. Next, a steam zone is highly unlikely since the temperatures at approximately 2000 ft (610 m) are insufficient to cause boiling for brine solutions at 15 or 20 wt. % NaCl (Figure 27). Finally, a low-density, clean sandstone aquifer is the most plausible explanation. Using oxygen isotope minima, Kendall (1976) correlated this horizon between wells Magmamax 2 and 3. Oxygen isotopic minima signify that high water to rock interactions have occurred. Hence, from these minima, Kendall (1976) postulated that this zone is a major horizontal aquifer. Consequently, marked low ρ_{Bsd} readings within specific horizons as shown in Magmamax 2 and 3 within the chlorite zone may qualitatively indicate permeable zones within and between wells.

Typically maximum ρ_{Bsd} are located near the base of the chlorite zone. These high ρ_{Bsd} values may indicate that a type of self-sealed caprock may be forming. Examination of thin sections from this part of the well in Magmamax 2 and 3 shows low apparent porosity as demonstrated by filled pores of quartz-feldspar overgrowths and carbonate cement (S. D. McDowell, personal communication, 1982).

The rise in ρ_{Bsh} is generally continuous through the chlorite zone from approximately 2.25 gm/cm^3 to 2.60 gm/cm^3 . The rise in density is probably caused by an increase in quartz content with concomitant decrease in porosity and low density mixed layer clays.

In summary, the chlorite zone is characterized by an overall rise in both Rsh and Rsd. A gradual increase in ρ_{Bsd} (2.1 gm/cm^3 to 2.4 gm/cm^3) and ρ_{Bsh} (2.2 gm/cm^3 to 2.6 gm/cm^3) also occurs. The increase in concentration of authigenic chlorite and porosity reduction with depth appear to have the greatest effect on log responses. Drastic salinity changes within a well, however, may alter the Rsd curve which may cause errors in the correct identification of mineral zones on logs.

4. Feldspar Zone. Hydrothermal mineralogy has a dominant effect on well log characteristics within the feldspar zone. The high concentration of feldspars in shales correlates directly to Rsh values. Usually at the top of this zone, the Rsh values quickly rise by 0.4 to 0.8 ohm-m (Figure 28). This rise accompanies an increase in content of alkali and plagioclase feldspar from approximately 10% to 25% or greater in the shales. The feldspar concentration comes at the expense of illite and the mixed layer clays. Induration of the shales and dehydration of the clays also occurs.

In well I.I.D. 2 (Figure 12), the log characteristics in a section of the feldspar zone differ from the other wells studied in this field. Generally, the Rsh increases rapidly with depth upon entering the feldspar zone; however, the Rsh decreases in this well. These low Rsh values occur between 2800 ft (854 m) to 4050 ft (1235 ft) (Figure 12). S. D. McDowell (personal communication, 1981) states that in well I.I.D. 2 an unconsolidated zone in sandstones exists between the aforementioned depths. The sandstones in this zone are weakly cemented and consequently have high porosities in the range of 28% to 30% as determined from sidewall and solid core samples (McDowell, unpublished data; also see page 50). (Density, neutron, and sonic logs were not run for this well at the time it was drilled). Because of the unconsolidated nature of this zone, it is believed that the associated shales also have unusually high porosities for the feldspar zone. Hence, these low Rsh values may result from highly saline brines of approximately 250,000 ppm in this well. Furthermore, the clays in this zone may have high cation exchange capacities which can cause low Rsh values. Below 4100 ft

Figure 28. An example of the high shale resistivities in the feldspar zone for well Magmamax 2. Sh = shale and ss = sandstone.

(1250 m) (Figure 12), the Rsh increases dramatically to values normally associated with the feldspar zone.

From 2850 ft (859 m) to 3500 ft (1067 m), well Elmore 1 (Figure 13) displays similar log responses to that observed in well I.I.D. 2 (Figure 12), where Rsh values are abnormally low for the feldspar zone. There are three possible explanations. One is that a young, unconsolidated zone similar to that found in well I.I.D. 2 is present. Confirmation of the existence of this zone is impossible because of the lack of porosity data from either wireline logs or cores. Another is that this interval is a "cold zone." Inspection of the static temperature profile for this well (Figure 6) shows no evidence for a temperature reversal. The shale mineralogy (Appendix 2), however, indicates an increase in calcite concentration (from ~5% to 15% within this zone). (Shale mineralogy is not as reliable an indicator of present temperatures in a well as sandstone mineralogy because the reaction kinetics of mineral transformation are slower due to low permeability and porosity of the shales.) This increase may imply a slight temperature depression. Lastly, this zone consists predominantly of shale (Figure 3, see lithology log). The lack of sandstones, a permeable medium, inhibits the hydrothermal fluids from interacting with the shales in this zone. The lack of interaction of the shales with the fluids may preserve a more pristine shale mineralogy. Therefore, the shale mineralogy may be in disequilibrium with the present temperatures, and the cation exchange capacity of the clays may not be destroyed. At present, this latter explanation appears to be the most plausible since the Rsh values and Rsd/Rsh ratio return to those normally associated with the feldspar zone below this interval (Figure 13).

At the chlorite zone/feldspar zone boundary, the Rsd decreases abruptly from 1-2 ohm-m to less than 0.5 ohm-m. The drop in resistivity is probably due to an increase in formation water salinity. Mineral transformations that occur from the chlorite to the feldspar zone of the sandstones may release ions into solutions, thus increasing the formation water salinity (Muffler and White, 1969) and lowering the sand resistivity in the feldspar zone as compared to the chlorite zone.

The ρ_{Bsh} within this zone typically increases from 2.40 gm/cm³ to 2.62 gm/cm³. (Note that higher ρ_{Bsh} values appear on Figures 10 and 11, but these values are attributed to the presence of silicic dike rocks. See section on Detection of Igneous Rocks, pages 33-34.) These high ρ_{Bsh} values are uncommon for shallow depths of 3000-4000 ft (915-1219 m) in areas of normal heat flow and recent sedimentation. For example, in the oil fields of the San Joaquin Valley in California, similar ρ_{Bsh} values occur at depths greater than 12,000 ft (3658 m) (Seamount, 1981).

The ρ_{Bsh} values in the feldspar zone are generally more uniform and have density values similar to the lower portions of the chlorite zone. Deviations from these trends occur as ρ_{Bsd} is higher, hence, probably more indurated.

In conclusion, the main effects on resistivity in the feldspar zone come from large, authigenic concentrations of feldspars in shales. In sandstones, salinity increases possibly caused by release of ions in the transformation of the chlorite mineralogy to the feldspar mineralogy chiefly aids in the reduction of Rsd. The Rsh normally rises by 0.4 ohm-m to 0.8 ohm-m at the top of this zone, and the ρ_{Bsh} can increase from 2.4 gm/cm³ to 2.62 gm/cm³. The Rsd is typically less than 0.5 ohm-m with ρ_{Bsd} between 2.35 gm/cm³ to 2.55 gm/cm³. The ρ_{Bsh} values are higher than those normally expected from compaction alone.

B. The Westmorland Geothermal Field

In the study of four Westmorland geothermal wells, only Kalin Farms 1 (Figure 18) displays log responses characteristic of the mineralogic zones

defined by shale x-ray diffraction data. These log responses are similar to those found in the SSGS; hence, only a brief discussion of the responses will be given. An explanation of the different log characteristics in this field will then follow.

In well Kalin Farms 1 (Figure 18), only the montmorillonite, the illite, and the chlorite mineralogic zones are present. Within the montmorillonite zone, Rsd and Rsh values vary, and below 2000 ft (610 m) the Rsh is consistently less than Rsd. The alignment of clay particles and resultant expulsion of water from the interlayers of the clays through compaction probably causes the Rsh to become less than Rsd. The top of the illite zone is distinguished by a 0.5 ohm-m rise in Rsh. This increase is attributed to approximately 4% loss in the effective clay, montmorillonite (Appendix 2). (The percentage referred to relates to total bulk rock composition.) The Rsh values in this zone fluctuate tremendously and possibly result from varying degrees of cementation as suggested by the lack of dolomite and ankerite in low resistivity zones. The transition into the chlorite zone is identified by a nearly parallel rise in both Rsd and Rsh curves, although Rsd shows large fluctuations. A 4% increase in chlorite content accompanied by a 1% rise in illite concentration contributes to the Rsh rise. (The percentages referred to relate to total bulk rock composition.) The Rsd rise most likely results from an increase in feldspar and quartz content together with a decrease in porosity.

In comparison, difficulties arise in correlating log responses to mineral zones in shales in wells Landers 1 (Figure 17), Landers 2 (Figure 20), and Dearborn Farms 1 (Figure 19). The examination of the shale x-ray diffraction data for lower portions of those wells suggests an illite zone mineralogy (Appendix 2); however at approximately 5500 ft (1676 m), 6300 ft (1920 m), and 7600 ft (2317 m) in wells Landers 1 and 2 and Dearborn Farms 1, respectively, apparent chlorite zone log responses are signaled by an overall rise in Rsh. The rise in Rsd is probably not seen because of a change in water salinity (see pages 39-44). In these cases, the rise in Rsh is presumably related to greater induration of the sediments and/or to less conductive clay minerals in the lower portions of this well.

From detailed study of these wells, discrepancies are found to exist between measured, isotopic, and log mineral-zone-derived temperatures. According to static temperature profiles, well Landers 1 is hotter than well Kalin Farms 1 (Figure 29). Yet, isotopic temperatures calculated using the calcite most nearly in isotopic equilibrium (lightest $\delta^{18}\text{O}$) and the water $\delta^{18}\text{O}$ for each well show that Kalin Farms 1 is considerably hotter than Landers 1 (Olson and Matlick, 1977, from Table 3):

Well	Depth Sampled	Temperature (°C)	
		Measured	Isotopic*
Landers 1	6880 ft (2097 m)	227	165
Kalin Farms 1	7115 ft (2196 m)	216	259

Furthermore, estimate of temperatures from the illite-chlorite mineral zone transition indicates well Kalin Farms 1 had temperatures greater than 230°C. The illite zone mineralogy of well Landers 1 signifies temperatures less than 230°C.

*Calculated using the equation $10^3 \ln_{\text{H}_2\text{O}}^{\text{ct}} = 2.78 \times 10^6 (T^{-2}) - 2.89$ where T = temperature (°C) (O'Neil et al., 1969; modified by Friedman and O'Neil, 1977).

Figure 29. Comparison of temperature data for wells Landers 1 and Kalin Farms 1. Isotopic temperatures are from Olson and Matlick (1978).

There are two possible reasons to explain the above disagreement. First, the static temperature profiles, the reported best representative temperatures for these wells (C. Isselhardt, personal communication, 1981), are inaccurate. Second, if the static temperature profile reflects present conditions, the recorded isotopic temperatures could be the result of prior thermal regimes. Therefore, this argues that well Landers 1 is presently heating up, and well Kalin Farms 1 is cooling. Moreover, the comparison of sandstone and shale x-ray diffraction data between each well further substantiates the latter agreement (Appendices 2 and 3). The shale x-ray data clearly show Kalin Farms 1 is hotter than Landers 1 by the disappearance of the minerals dolomite, ankerite, kaolinite, mixed layers, and siderite. As stated pre-

viously, shale mineralogy may not reflect present conditions in a well. Thus, sandstone x-ray diffraction data were compared. The indication is that Kalin Farms 1 is slightly hotter than Landers 1. This argument also assumes that the original detrital content of the sediments for both wells is basically the same. From the data presented it appears that well Landers 1 is heating up while Kalin Farms 1 is cooling.

C. Problems in the Delineation of Mineral Zones on Logs

Even though mineral zones are delineated in most cases on wireline logs by log signatures, physical characteristics of the reservoir which affect log responses may occasionally mask mineral zone boundaries. Figure 30 shows a cross section through the SSGS displaying the mineralogic zones of shales

Figure 30. A cross section through the Salton Sea geothermal field depicting the mineral zones of selected wells to the general stratigraphy of the subsurface. Base of zones derived almost exclusively from x-ray examination of cuttings (Appendix 2).

defined in this report. As depicted on this diagram, the montmorillonite zone can be either entirely within the lacustrine sequence or in the interstratified sandstone and shale portion of the reservoir. In the former case, the boundary between the montmorillonite and illite zone is difficult to locate in that the lacustrine sequence generally shows fairly constant resistivity response throughout, and only a single lithology (shale) is normally present (Figures 10-13). In order to circumvent the difficulties in defining the montmorillonite-illite zone boundary within the lacustrine sequence, the boundary was placed at the interface of the lacustrine and sandstone-shale deltaic sequence for wells Magmamax 2 and 3 and Elmore 1. This boundary is easily recognized on well logs. It has been shown that the montmorillonite-illite zone boundary can be located within the intercolated sandstone-shale sequence of the field (Figures 14-15).

Portions of the illite and chlorite zone can also be present within the lacustrine sequence. As in well I.I.D. 2 (Figure 12), the differentiation of these zones is possible on logs because of the presence of sand bodies within the lacustrine sequence. This gives Rsd and Rsh curves upon which mineral zone determinations can be made.

As stated previously, a high resistivity zone due to the presence of a resistive mineral such as anhydrite lies between 6400-7500 ft (1951-2286 m) in well Britz 3. The high resistivities may lead to errors in interpreting mineral zone boundaries. Consequently, close scrutiny of lithologic logs is mandatory in order to be cognizant of high concentrations of resistive minerals.

Major salinity changes in a well may also cause problems in delineating mineral zones. In well Sinclair 4, a divergence in sandstone and shale resistivity values occurs at approximately 4100 ft (1250 m) (Figure 14). This divergence, the result of a drop in Rsd due to an increase in water salinity, is similar to that found at the top of the feldspar zone; however, temperatures and shale mineralogy indicate the chlorite mineralogic zone. If drastic changes in formation water salinity are not taken into account, misinterpretation of log data may result. Furthermore, salinity changes in well Landers 1 (Figure 17) have hindered mineral zone identification by log responses (see pages 41-43).

D. Detection of Igneous Rocks

Subsurface igneous rock has been reported from four wells in the SSGS: Magmamax 2, Magmamax 3, I.I.D. 2, and Elmore 1 (Robinson et al., 1976; Randall, 1974; McDowell and Elders, 1980). Robinson et al. (1976) have divided these subsurface igneous rocks into two groups based on chemical and petrologic data: (1) dark-gray to black, fine-grained to porphyritic basalt; and (2) light-gray, fine-to medium-grained silicic rock. These subsurface rocks are believed to be the result of intrusion of dikes.

In well Magmamax 3, Randall (1974) reported the presence of 10 zones of silicic dike rocks each up to 10 ft (3 m) thick between 3591-4000 ft (1095-1220 m). He based his findings on drill cutting examination and electric log interpretation. A more detailed log evaluation of these dike rocks will be given.

These silicic dike rocks have certain log characteristics similar to sandstones (Figure 31). The natural gamma-ray count for these dike rocks is approximately 75 API units. In comparison, the sandstone baseline at these depths is approximately 55 API units. This relationship for a sediment would be a shaly sandstone. On the other hand, the dike rocks have some shale characteristics, such as an SP deflection toward the shale baseline and densities as high as 2.7 gm/cm³. But the resistivities are abnormally high (between 3.0 ohm-m to 4.7 ohm-m) for shales. Consequently, these silicic dike rocks are

Figure 31. Dike rock locations and characteristics in well Magmamax 3 (data from Randall, 1974). D = dikes; S = sediments.

characterized by high resistivity, relatively high radioactivity (Adams, 1954; Barsukov et al., 1965), and high density. Probable dike rock locations in well Magmamax 2 are shown in Figure 10.

The identification and characterization of the basaltic dike rock found in well I.I.D. 2 (Robinson et al., 1976) based solely on electric log information is fortuitous at best. Additional log data such as gamma-gamma density is needed for a more unequivocal interpretation.

VI. USE OF THE EMPIRICAL RELATIONSHIPS TO IDENTIFY MINERAL ZONES ON LOGS

In order to test the empirical relationships developed in this study, a total of seven additional wells from the SSGS were scrutinized. These wells, listed below, are from diverse locations within the field (Figure 2):

<u>Well</u>	<u>Operator</u>
River Ranch 1	Union Oil Co.
State of California 1	Shell Oil Co.
Magmamax 1	Magma Power Co.
Woolsey 1	Magma Power Co.
Sinclair 1	Kent Imperial Co.
I.I.D. 1	J. I. O'Neill, Jr.
Sportsman 1	J. I. O'Neill, Jr.

The characteristic log responses, previously elaborated upon in detail (see pages 24-30), are used to identify mineral zones in each of these wells (Figures 32-38). In summary, the montmorillonite zone is characterized by fairly constant Rsd and Rsh responses. The transition into the illite zone is marked

Figure 32. Well River Ranch .1, well log data vs. depth.

Figure 33. Well Magmamax 1, well log data vs. depth.

Figure 34. Well Woolsey 1, well log data vs. depth.

Figure 37. Well I.I.D. 1, well log data vs. depth.

Figure 38. Well Sportsman 1, well log data vs. depth.

by slight rise in Rsh caused by the loss of the effective clay, montmorillonite. The resistivity response of both sandstone and shale is fairly constant within this zone. A nearly parallel rise in both Rsd and Rsh signals the entrance into the chlorite zone. Lastly, the top of the feldspar zone is demarcated by the divergence in Rsd and Rsh curves with the sandstone resistivity decreasing and the shale resistivity increasing rapidly. In order to verify the interpreted mineral zones from log responses, shale x-ray diffraction data for one well, River Ranch 1, were generated, but other x-ray data in existence were also used.

Figure 32 shows the interpreted mineral zone boundary locations from log responses for well River Ranch 1. Note the log responses for both Rsd and Rsh fluctuate greatly within the chlorite zone. Inspection of the shale x-ray diffraction data for this well (Appendix 2) shows that between 2843-3880 ft (867-1183 m) anomalously high alkali feldspar concentrations are present. Also, illite and chlorite are extremely depleted. In addition, the sandstones are extensively altered in this zone (Cox, 1977). An explanation for the unusual mineral contents is difficult to make without supplementary density, porosity, and petrologic data. In any case, if the anomalously high alkali feldspar concentrations are disregarded, the shale x-ray diffraction data substantiate the interpreted zone boundaries.

The interpretation of wells Magmamax 1 (Figure 33), Woolsey 1 (Figure 34) (shale x-ray diffraction data for this well substantiates the interpreted zone boundary locations - see Appendix 2), and Sinclair 1 (Figure 35) is rather straightforward and has been aided by the similarity in log responses to other nearby wells. Wells State of California 1 (Figure 36), I.I.D. 1 (Figure 37), and Sportsman 1 (Figure 38) do not show the same systematic log responses. The absence of sharp contrasts in physical properties of the rocks in the northeast fringes of the field is a likely cause of these uncharacteristic log responses. In order to locate these mineral zones within these wells more accurately, porosity and/or density data are needed.

VII. LOG-DERIVED SALINITY

Estimation of salinity profiles in geothermal wells is important in planning well completions, subsurface mapping, and environmental impact considerations (Gobran et al., 1981). Moreover, because of the marked effects that salinity has on resistivity and, hence, interpretation of log data, attempts have been made to estimate salinity from well logs. Only wireline logs from the WGS were studied rather than attempting to do so in the SSGS with its extremely high temperatures and hypersaline fluids. In addition, the wireline logs from the Westmorland area are more modern, are of good quality, and have accurate records of drilling mud types and properties.

Two methods primarily used in the petroleum industry to estimate R_w , the resistivity of the formation water, from well logs have application in sedimentary-type geothermal fields. These are an analysis of the spontaneous potential (SP) curve and the interpretation of sandstone resistivity and porosity data (Littleton and Burnett, 1975, 1977; Ershaghi et al., 1979). The following is a brief synopsis of the methods used in this study to determine the formation water salinity.

The SP curve method entails use of the equation

$$SSP = -K \log_{10} \left(\frac{a_w}{a_{mf}} \right) , \quad (1)$$

where a_w and a_{mf} are respectively the activities of the formation water and the mud filtrate, K is a function of temperature ($K = 60 + 0.133T$, in °F; Dresser Atlas, 1977), SSP is the static spontaneous potential [millivolts (mv)]. For brines below 60,000 ppm, the activities are inversely proportional to their respective resistivities (Schlumberger, 1972; Ershaghi et al., 1978):

$$SSP = -K \log_{10} \left(\frac{R_{mf}}{R_w} \right) \quad (2)$$

R_w can then be easily found if R_{mf} at formation temperature* is known, together with the magnitude of the SSP :

$$R_w = (R_{mf}) 10^{\left(\frac{SSP}{K} \right)} \quad (3)$$

A second method combines electric and porosity log data to determine R_w . Archie (1942) showed that the formation resistivity factor, F , may be computed by the following empirical relationship

$$F = \frac{a}{\phi^m} = \frac{R_o}{R_w} \quad (4)$$

where a and m are lithology-dependent parameters, ϕ is porosity, R_o is the resistivity of a nonshaly formation 100% saturated with brine of resistivity R_w . If R_o is obtained from a deep investigating tool, ϕ from porosity logs, and for this study $a = 0.81$ and $m = 2$ (Schlumberger, 1972), then R_w may be calculated by

$$R_w = \frac{(R_o) (\phi^2)}{.81} \quad (5)$$

Another method employs the resistivity of the flushed zone, R_{xo} , and the true resistivity of the formation, R_t . Appendix 5 (Bateman and Konen, 1977b) shows a summary of the equations used in the computation to obtain R_t and R_{xo} . Thus,

$$R_w = \left(\frac{R_t}{R_{xo}} \right) R_{mf} \quad (\text{variables defined previously}). \quad (6)$$

*Arps equation (Arps, 1953) corrects resistivities at a given temperature to those at another temperature. For example, $R_{mf2} = R_{mf1} \left[\frac{T_1 + 6.77}{T_2 + 6.77} \right]$ where temperatures are in °F.

After R_w is obtained from the above methods, the total dissolved solids (TDS) in equivalent sodium chloride concentration can be found by applying the following equations:

For salinity data at 75°F (23.9°C) ,

$$\text{NaCl}_{\text{eq}} = 10^x \quad (\text{Bateman and Konen, 1977a})$$

$$\text{where } x = \frac{3.562 - \log_{10}(R_{75} - 0.0123)}{0.955}$$

$$\text{and } R = R_T \left[\frac{T + 6.77}{75 + 6.77} \right]$$

For salinity data at formation temperature (°F) ,

$$\text{NaCl}_{\text{eq}} = y^{1.05} \quad (\text{Bateman and Konen, 1977a})$$

$$\text{where } y = \frac{300,000}{R_{wT}(T + 7) - 1}$$

To calculate R_w from the above methods, borehole temperatures which were acquired from the bottom-hole temperature recorded on the log heading and deep formation temperatures obtained from temperature logs were used separately as estimates of the formation temperatures. However, the formation temperatures used in the computation of salinity on Figures 39-41 are from temperature logs (Figure 29 and Appendix 6) since the computed salinities are in closer (but still poor) agreement with the actual salinities, as explained below.

A. Application to the Westmorland Wells

Figures 39-41 are the salinity profiles generated by the above methods (see Appendix 6 for a summary of the data used in the salinity calculations). Also indicated on these figures are the actual salinities determined from chemical analyses of the well fluid and the location of the sampling interval. Clearly, a lack of agreement between the well fluid analyses and log-derived salinities is evident. The log-derived salinities are lower than the actual salinities. This probably results from several factors. First, Equations 2, 5, and 6 are

Figure 39. Log-derived salinity profile for well Landers 1 at 75°F (23.7°C).

Figure 41. Log-derived salinity profile for well Dearborn Farms 1 at 75°F (23.7°C).

Figure 40. Log-derived salinity profile for well Landers 2 at 75°F (23.7°C).

empirical relationships developed for petroleum fields to obtain R_w ; hence, these equations may be invalid for use in sedimentary-type geothermal systems where high temperatures and hydrothermally altered sediments are encountered. For example, the constants used in Equation 5, $a = 0.81$ and $m = 2$, apply in the shallower portions of the wells but are probably erroneous in the more hydrothermally altered sections. Second, the true R_{mf} and R_m at formation temperature are not accurately known. Ershaghi et al. (1979, 1981) state that the log-heading values of R_{mf} and R_m are probably unreliable due to likely changes in mud or mud filtrate characteristics. These changes result from extreme conditions in the borehole. Third, there are problems in determining the magnitude of the SP deflection (Equation 2), i.e., in several of the wells studied, shifts in shale baseline and streaming potentials made accurate estimation of the SP magnitude difficult. Furthermore, at elevated temperatures the validity of the magnitude of the SP deflection is questioned (Ershaghi et al., 1978).

Detailed examination of Figures 39-41 shows that the SP-derived salinity curves are consistently lower in value than the other curves. This occurrence is difficult to explain; however, a reduction in magnitude of the SP can result if the reference electrode is attached to the survey cable instead of being placed in the mud pit at the surface, which is the common practice (M. Mathews, personal communication, 1982). This procedure may alter the SP and, hence, R_w appreciably.

Even though discrepancies exist between the log-derived and actual downhole salinity, the trend of the log-derived salinity data barring the SP-derived salinity data in this case is believed to mirror the actual downhole salinity. For example, in well Landers 1 (Figure 38) the salinity appears to increase at approximately 5300 ft (1423 m). This apparent rise in salinity may explain the low-sandstone resistivities in this zone (Figure 17).

The lack of agreement between actual and log-derived salinity has deterred the use of a resistivity-salinity crossplot. This crossplot should in principle correct sandstone resistivity for changes in formation water salinity.

Figure 42 displays the actual brine concentrations encountered in several wells of the SSGS and WGS (Helgeson, 1968; California Department of Water Resources, 1970; Olson and Matlick, 1977; Needham et al., 1980; Republic Geothermal, Inc., personal communication, 1981. Note that the brine concentrations are corrected for steam loss). As shown on this figure, high-brine salinities are present in the central portion of the SSGS, while on the flanks the brines are less concentrated.

VIII. RESERVOIR POROSITY

An important aspect of reservoir analysis in sedimentary geothermal fields is the determination of porosity. In the SSGS previous petrographic studies have shown that a reduction in porosity resulting from hydrothermal mineral alteration and precipitation typically occurs with increasing depth (McDowell and Elders, 1979, 1980b). Measurements of porosity from thin sections, however, are tedious, time consuming, and occasionally inaccurate. Also, only the porosities of sandstones can be routinely measured. Therefore, a combination of log data and petrophysical measurements on cores have been used to resolve the effects of hydrothermal alteration on porosity in the Salton Sea and Westmorland geothermal reservoirs.

Figure 42. Fence diagram showing well depth, perforated interval, and formation fluid salinity for selected wells in the Salton Sea and Westmorland geothermal areas. Location of perforation horizon from Palmer (1975).

- a = Helgeson (1968)
- b = California Department of Water Resources (1970)
- c = Olson and Matlick (1977)
- d = Needham et al. (1980)
- e = Republic Geothermal (1981, personal communication)

Porosity is normally estimated from density using the equation

$$\phi = (\rho_{gr} - \rho_B) / (\rho_{gr} - \rho_f) ,$$

where ρ_{gr} is the grain density (normally 2.65 gm/cm^3 for quartz), ρ_B is the bulk density estimated from the gamma-gamma density log, and ρ_f is the fluid density. Scrutiny of the above equation in its application to geothermal fields reveals two possible sources of error when calculating porosity: (1) assuming that the fluid density is unity; and (2) assuming that grain density has not changed with authigenic mineral transformations occurring with increasing alteration. In the former case, the fluid density is usually not equal to 1 gm/cm^3 for highly saline fluids (e.g., for 20 wt. % NaCl solution at 20°C , $\rho_B = 1.19 \text{ gm/cm}^3$ [Wolf et al., 1974]). Furthermore, a decrease in fluid density occurs with rising temperature; consequently, assuming a ρ_f of 1.0 gm/cm^3 may lead to erroneous estimates of porosity. For example, Table 3 shows the varying densities of pure water and 5.7 molal (20 wt. %) NaCl solution at increasing temperatures (Helgeson and Kirkham, 1974; Haas, 1970; Wolf et al., 1974) together with the associated porosity computation. Clearly, ϕ will change depending upon the ρ_f used. The percent error can then be calculated as

$$\text{Percent Error} = (\phi - \phi_t)100 = \left[\frac{2.65 - \rho_B}{2.65 - 1} - \frac{2.65 - \rho_B}{2.65 - \rho_{fT}} \right] 100$$

(modified from Seamount, 1981)

TABLE 3

Fluid Density Variation with Temperature of Pure Water
and 20 wt. % NaCl Solution and Their Associated Porosity Calculation

Temperature	Pressure (bars) (Helgeson and Kirkham, 1974)	ρ_f Pure water (Helgeson and Kirkham)	Calculated ϕ^*	ρ_f 5.7 molal (20 wt. %) NaCl Solution (Haas, 1971, Fig. 1; Wolf and others, 1974)	Calculated ϕ^*
0°C	.006	1.00	.152	--	--
20°C	.023	.998	.151	1.19	.171
200°C	15.54	.865	.140	1.06	.157
300°C	85.81	.713	.129	0.82	.137

* $\phi = (\rho_{gr} - \rho_B) / (\rho_{gr} - \rho_f)$ where $\rho_{gr} = 2.65 \text{ gm/cm}^3$ and $\rho_B = 2.40 \text{ gm/cm}^3$.

where ϕ_t is the true porosity, ρ_{ft} is the true fluid density, and ρ_{gr} is assumed to be 2.65 gm/cm^3 . It is obvious from the above equation that if ρ_f is not chosen carefully, errors in the calculation of sandstone porosity may be incurred.

In the SSGS, however, Helgeson (1968) states that the brine must have a fluid density of 1.0 gm/cm^3 to at least 7000 ft (2134 m) in order to satisfy the observed hydrostatic gradient (0.0295 atmospheres/ft) in this field. Hence, the error in the calculation of porosity caused by decreasing fluid density with increasing temperature may be negated by the increase of salinity counteracting the effect of increasing temperatures.

In the other case, an increase in grain density resulting from authigenic mineral transformations occurs with increasing alteration. This increase in grain density may introduce an additional error in calculating porosity. For example, in the SSGS the average density of the sandstones from the chlorite zone is found to be 2.68 gm/cm^3 ; for the feldspar zone of the sandstones, the average density is 2.81 gm/cm^3 . These values are calculated using average mineral concentrations by weight, converting weight percent to volume percent (McDowell, unpublished, Appendix 3), estimating mineral densities, determining volumetric contributions of each mineral per unit area of the rock, and the summation of all contributions (Table 4).

In order to compute the effect of grain density variation on porosity, the following equation can be employed, assuming that there is no loss or gain of material in transforming a rock, for example, from the chlorite to the feldspar zone:

$$\Delta\phi_{fl-ch} = \phi_{fl} - \phi_{ch} = \frac{\rho_{grfl} - \rho_{grch}}{\rho_{grfl}} \quad (\text{from Seamount, 1981})$$

where ϕ_{fl} = porosity estimated using the ρ_{gr} of the feldspar zone

ϕ_{ch} = porosity estimated using the ρ_{gr} of the chlorite zone

ρ_{grfl} = grain density of the feldspar zone

ρ_{grch} = grain density of the chlorite zone

assuming:

$$\rho_{grfl} = 2.81 \text{ gm/cm}^3$$

$$\rho_{grch} = 2.68 \text{ gm/cm}^3$$

therefore:

$$\Delta\phi_{fl-ch} = \phi_{fl} - \phi_{ch} = 0.046$$

A minute change in porosity probably occurs with the variation in grain density from the chlorite zone to the feldspar zone; however, this change appears to have little effect on porosity. Furthermore, assuming that ρ_{gr} is equal to 2.65 gm/cm^3 will lead to slightly low estimates of porosity.

Porosity of core samples measured in the lab by petrophysical techniques was compared with ρ_B (Table 5) using the equations:

$$\rho_{BL} = \phi\rho_f + (1 - \phi)\rho_{gr}$$

$$\phi_{log} = (\rho_{gr} - \rho_B)/(\rho_{gr} - \rho_f)$$

TABLE 4

Calculation of ρ_{gr} for Average Sandstones of the Chlorite and Feldspar Zone

Mineral	Chlorite Zone					Feldspar Zone				
	Wt % [*]	ρ_{gr}^{**} (gm/cm ³)	Wt %/ ρ_{gr}	Vol % ^t	Den contr./Unit vol (gm/cm ³) ^a	Wt %	ρ_{gr} (gm/cm ³)	Wt %/ ρ_{gr}	Vol %	Den contr./Unit vol (gm/cm ³)
Quartz	.413	2.65	.156	.399	1.06	46.5	2.65	.175	.385	1.02
Plagioclase	.085	2.65	.032	.077	.20	16.6	2.65	.063	.139	.37
Alkali feldspar	.069	2.57	.027	.058	.15	9.5	2.57	.037	.081	.21
Mica	.051	2.80	.020	.051	.14	6.6	2.80	.026	.053	.15
Illite	.055	2.80	.019	.049	.14	7.6	2.80	.027	.059	.17
Vermiculite	.095	2.76	.034	.087	.24	3.0	2.76	.011	.024	.07
Chlorite	.096	2.80	.034	.087	.24	8.1	2.80	.029	.064	.18
Calcite	.103	2.72	.038	.097	.26	4.1	2.72	.015	.033	.09
Pyrite	.011	5.02	.002	.005	.03	1.8	5.02	.004	.009	.05
Amphibole	.000	3.28	.00	.00	.00	2.3	3.28	.007	.015	.05
Epidote	.047	3.60	.013	.033	.12	15.5	3.60	.043	.095	.34
Anhydrite	.014	2.96	.005	.013	.04	5.0	2.96	.017	.037	.11
Zeolite ^β	.025	2.26	.011	.028	.06	.00	2.26	0	0	0
TOTAL			.391		2.68 gm/cm ³			.454		2.81 gm/cm ³

^{*} from McDowell, unpublished (see Appendix 3).^{**} from Birch and others (1942).^t Vol % = (wt %/ ρ_{gr})/(Σ wt %/ ρ_{gr}).^a Density contribution per unit volume = Vol % $\times$ ρ_{gr} .^β Assumed wairakite as zeolite.

TABLE 5

Porosity and Density Measurements from Petrophysical Analysis of Cores and Density Logs

		Lab Measurements			Log Measurements	
Well	Depth (ft)	Measured ϕ (at UCR)	ρ_{BL}^* from Lab Data (gm/cm ³)	Measured Grain Density (ρ_{gr}) (gm/cm ³) (at UCR)	ρ_B	ϕ_{log}^+ from Log Data
Dearborn Farms 1	5758	19.5	2.34	2.66	2.32	20.0
Dearborn Farms 1	7420	19.2	2.34	2.66	2.40	15.2
Landers 1 ^{α}	6352	4.2	2.56	2.63	2.61	2.4
Kalin Farms 1 ^{β}	7114	14.2	2.40	2.63	2.50	9.1
Kalin Farms 1 ^{β}	5374	4.7	2.45	2.52	2.10	33.3

* $\rho_{BL} = \phi \rho_f + (1 - \phi) \rho_{gr}$ where $\rho_f = 1.00$ gm/cm³.

† $\phi_{log} = (\rho_{gr} - \rho_B) / (\rho_{gr} - \rho_f)$ $\rho_f = 1.00$ gm/cm³, $\rho_{gr} = 2.65$ gm/cm³.

α Lithology red-brown shale.

β Because of borehole rugosity greater than 20%, these calculated and log ϕ values are in poor agreement; hence, ρ_B are not shown on Figure 18.

where ϕ is the lab-measured porosity and ρ_{BL} is the bulk density calculated from ϕ . In this calculation ρ_f is assumed to be unity, and its decrease with increasing temperature is not accounted for. Thus, ϕ_{log} may be higher than the actual case.

Only core samples from the Westmorland geothermal area were analyzed since log porosity data and/or core samples are lacking for the wells examined in the SSGS. Close agreement between the lab-measured porosities and the log values is evident even though ρ_f is assumed to equal 1 gm/cm³. Consequently, the density logs of the WGS (Figures 17, 19, 20) are representative of the actual densities encountered in these wells. In contrast, M. Mathews (personal communication, 1982) states that his attempts to check the accuracy of the density logs with core measurements in the East Mesa geothermal field were unsuccessful.

The densities of the shales and sandstones from the illite, chlorite, and feldspar are higher than those expected from normal compaction. Figure 43 shows the shale density curves from wells Magmamax 2, Magmamax 3, Landers 1, and Dearborn Farms 1 in relation to the unaltered shales of Cerro Prieto (Seamount, 1981), shallow young oceanic sediments (from sonic data, Nafe and Drake, 1957), Gulf Coast shales (gravity and petrophysical data, Nettleton, 1934; petrophysical and density log data, Dickinson, 1953). The shale log density curves of the Salton Sea and Westmorland geothermal areas show marked deviations from the compaction curves of recent, unaltered sediments. This indicates that induration greater than that expected from compaction alone has occurred.

An attempt was made to obtain porosity from electric logs by utilizing Archie's equation (1942):

$$F = a\phi^{-m} = R_t/R_w \quad (\text{symbols previously defined}).$$

Figure 43. A comparison of densities of unaltered and altered shale vs. depth in wells Magmamax 2, Magmamax 3, Landers 1, and Dearborn Farms 1.

By taking the logarithm of the above equation and rearranging the terms, one obtains the following equation:

$$\log R_t = -m \log \phi + \log (aR_w) . \quad (7)$$

Therefore, if both R_t and ϕ are known, linear regression analysis will give the quantity, m , which is needed for the porosity calculation. The porosity data were acquired from gamma-gamma density logs of wells Magmamax 2 (Figure 11) and Magmamax 3 (Figure 12), the only wells that have porosity data within the feldspar zone in the Salton Sea field. Note, however, that in order to use this equation, R_w has to be fairly constant in the zone of interest. The relatively constant R_{sd} within the feldspar zone of these wells satisfies the latter requirements with omission of some anomalous data. The following m values were obtained.

<u>Well</u>	<u>m</u>	<u>Correlation Coefficient</u>
Magmamax 2	1.10	0.36
Magmamax 3	1.92	0.35
Magmamax 2 and 3	0.84	0.29

These low correlation coefficients signify a poor linear regression fit of data points (Figure 44). Nevertheless, these m values were used in order to compute porosities for well I.I.D. 2. This well was chosen for this study to acquire valuable log porosity data for the anomalous zone between approximately 2900-4000 ft (915-1220 m) (Figure 12). In using Equation 7, R_w was obtained from graphs given by Ucock et al. (1980)* for 20 wt. % NaCl solution** at a formation temperature of 305°C acquired from temperature logs (Figure 6, Helgeson, 1968). Furthermore, the constant, a , is assumed to be unity. The calculated porosities are shown below and are compared to core data at equivalent depths and lithology.

<u>Depth (ft)</u>	<u>m</u>	<u>Calculated ϕ</u>	<u>Laboratory Measurement (McDowell, unpublished)</u>	<u>Lithology</u>
3504	1.92	13%	32.9%	siltstone
3504	1.10	2.85%	32.9%	siltstone

Although the calculated porosities are in poor agreement with the laboratory-measured values, it is believed that this method might still be useful if applied to wells that are more closely spaced so that inter-well differences such as lithology, salinity, and porosity are minimized.

*Ucock et al.'s (1980) graph was used since maximum temperatures published on Schlumberger's and Dresser Atlas's nomographs for R_w computation are only 230°C.

**One limitation of using the graph of Ucock et al. (1980) is that the maximum-calculated R_w is for 20 wt. % NaCl solutions when the TDS for I.I.D. 2 is actually near 250,000 TDS (25 wt. % TDS).

IX. A COMPARISON BETWEEN THE SALTON SEA AND CERRO PRIETO GEOTHERMAL FIELDS

The method of correlating mineral zones defined by shale x-ray diffraction data with log responses has been applied successfully by Seamount (1981) to wells in the Cerro Prieto geothermal field, located approximately 85 km to the south-southeast of the SSGS (Figure 1). Even though both fields are situated within the deltaic sediments of the Colorado River and have temperatures in excess of 300°C at drilled depths, intrinsic and extrinsic characteristics of these fields make each distinct from one another. In this section a discussion of these characteristics, their effect on log responses, and other relevant data is given.

Figure 44. Crossplot of resistivity-porosity (R_T - ϕ) for the feldspar zone in two wells, showing linear regression of the data. A = Magma-max 3; B = Magma-max 2; C = combined data of A and B.

The intrinsic features which differentiate these fields are salinity and to a lesser extent, stratigraphy. The maximum reported salinities from the SSGS are greater than 250,000 TDS which is an order of magnitude higher than that at Cerro Prieto. Figure 45 compares the resistivity vs. temperature curves for well Elmore 1 in the SSGS and well T366 in Cerro Prieto. This crossplot is used to show the effects of salinity on overall log response, assuming that equivalent mineral assemblages have virtually identical effects on resistivity between the two wells. Clearly, the resistivity-temperature curve for well Elmore 1 is lower than for well T366. The higher salinity in the SSGS presumably causes the overall lowering of resistivity responses in all mineralogic zones as compared to Cerro Prieto.

Stratigraphically, the lacustrine sequence present in the SSGS is absent at Cerro Prieto. As stated earlier, the existence of this clay-silt-evaporite sequence causes problems in demarcating mineral zones in the upper portions of the wells (see pages 32-33).

Extrinsically, the number and spacing of geothermal wells with complementary wireline log data differ widely between these two fields. At Cerro Prieto more than 110 wells have been drilled by the La Comisión Federal de Electricidad de Mexico (CFE). Several different wireline logs are available for each of these wells and all data are in the public domain. In comparison,

fewer wells have been drilled in the SSGS. Much of the old and new data gathered on this field are held proprietary by the operating companies. Also, since many of the wells in the SSGS were drilled in the early 1960's, the induction electrical log was commonly the only wireline log run. The study of wireline logs in the SSGS has not shown any distinguishable fluid flow patterns as in Cerro Prieto, where wireline log responses reaffirmed the reservoir dynamics based previously on petrologic data (Seamount and Elders, 1981).

X. SUMMARY AND CONCLUSION

This study has confirmed that wireline logs run in sedimentary geothermal fields can be used to determine various reservoir properties. In addition, from analysis of log data, qualitative estimates of temperature and alteration mineralogy can also be made.

Figure 45. A resistivity-temperature crossplot showing wells Elmore 1 (SSGS) and T366 in the Cerro Prieto geothermal field. Temperature data for well T366 are from Barker (1979). Temperature data for well Elmore 1 are from Helgeson (1968).

For the Salton Sea geothermal system, definite correspondence between log responses and mineralogy of shales is observed. Four mineralogic zones in which one is unaltered and three are hydrothermal can be identified from log data of shale. The zones, correlated with temperature, are:

Montmorillonite zone (unaltered) - <100°C to 190°C.

Illite zone - 100°-190°C to 230°-250°C.

Chlorite zone - 230°-250°C to 290°-300°C.

Feldspar zone - >290°-300°C.

Both sandstone and shale log data should be compared in order to identify the log responses of these mineral zones.

The characteristic log responses from which these mineralogic zones are determined result primarily from changes in clay mineralogy of the shales. These mineralogic changes are the conversion of montmorillonite and mixed layer clays to illite and chlorite and then finally to feldspars and quartz. In sandstones, both clay mineralogy and formation water salinity affect log responses; hence, analysis of sandstone data is more difficult.

The montmorillonite zone, the shallowest of the mineral zones studied and the most poorly controlled mineralogically because of sampling problems, is characterized by fairly constant resistivity

responses of shale and sandstone (if present). The gamma-gamma density is typically less than 2.2 gm/cm^3 . The exact location of the base of the montmorillonite zone, however, is difficult to locate in several wells of the SSGS because of the masking effects of the clay-silt-evaporite lacustrine sequence. The top of the illite zone is indicated by a rise in shale resistivity probably caused by the loss of montmorillonite and a decrease in the cation exchange capacity of the clays. From the limited gamma-gamma density data available, it also appears that a rapid rise in shale density occurs at the top of the illite zone. This rapid rise probably indicates induration of the sediments. The chlorite zone is distinguished by an increase in both sandstone and shale deep induction resistivity (R). The maximum ρ_B values in this zone are 2.40 gm/cm^3 for sandstones and 2.60 gm/cm^3 for shales. The log response of the feldspar zone is a rise in shale resistivity accompanied by a decrease in sand resistivity.

For the Westmorland geothermal field, only limited success was obtained in identifying mineral zones from log responses. The analysis of well log and petrologic data for wells Landers 1 and Kalin Farms 1 in this field suggests that Landers 1 is heating up while Kalin Farms is cooling.

Other methods were also shown to be effective in delineating mineral zones. The Rsd/Rsh ratio method calculated in 50-ft (15-m) intervals shows a decrease from approximately 0.8 to 2.0 in the illite zone to less than 0.4 in the feldspar zone. Another useful method is the crossplotting of gamma-gamma density (ρ_B) data against resistivity (R). This crossplot distinguishes mineral zones in shales readily. Lastly, crossplotting the neutron porosity divided by density against resistivity proved more effective in separating the zones than the other crossplot. Both crossplots were, however, unsuccessful in delineating zones from sandstone data.

Testing of certain empirical methods used in this study to identify mineral zones was of limited success. It was concluded that for wells on the fringes of the SSGS, supplementary porosity data are needed to locate zone boundaries more accurately.

Certain reservoir characteristics must be taken into account in order to make accurate interpretations of log data. First, knowledge of the salinity profile in a well is advantageous since changes in salinity can affect log data of porous rocks. Second, highly resistive zones caused by minerals such as anhydrite must be recognized. This can be accomplished by detailed inspection of lithologic logs in many cases. Third, thick shale horizons in a well which may alter log responses, as demonstrated in well Elmore 1, must be considered.

Petrophysical, ρ_B , and petrographic data indicate that induration of the sandstone and shale has occurred within all altered zones. The gamma-gamma density log has been shown to be fairly accurate in recording true formation density values in a hydrothermal environment. Porosity derivation from electric logs was unsuccessful; however, it is believed that this method may be valuable if the wells being studied were more closely spaced so that inter-well differences such as salinity and lithology could be allowed for.

The log-derived salinity values are in poor agreement with the actual observed formation water salinity. Nevertheless, the trend of the log-derived salinity data probably reflects the trend of the actual salinity profile in the well.

Until high-temperature resistant tools and calibration data for the unusual lithologies encountered in geothermal reservoirs are available to provide better quantification and interpretation, the empirical methods used in this study can be employed to assess various reservoir parameters in sedimentary-type geothermal systems.

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APPENDICES

- Appendix 1 - Geothermal well status (from Palmer, 1975).
- Appendix 2 - Shale x-ray diffraction data.
- Appendix 3 - Sandstone x-ray diffraction data.
- Appendix 4 - Reconnaissance petrographic description of well Britz #3.
- Appendix 5 - Computation of R_t and R_{xo} from the Dual Induction-Laterolog (from Bateman and Konen, 1977b).
- Appendix 6 - Summary of log data from Landers 1, Landers 2, and Dearborn Farms 1 used in salinity calculation together with temperature logs for Landers 2 and Dearborn Farms 1.

APPENDIX 1 GEOHERMAL WELL STATUS (from Palmer, 1975)

<u>Well name</u>	Sinclair #1	Sinclair #2	Sinclair #3
<u>Status</u>	Completed ^a 1958 Operated ^b 1958 Shut-in ^d 1958	Completed 1961 Abandoned ^c 1965	Completed 1963 Produced 1963 Operated 1975
<u>Depth^e (ft)</u>			
Total height of Kelly Bushing above surface-ft.	4725	2363	6922
Perforations ^f	5 3370 to 3445	5 None	12 3788-5179 5313-6868
Plugs ^g	None	Q-2363	None
<u>Casing^h</u>			
Outside diameter (in.)	10-3/4 3-1/2 open ⁱ	12-3/4 9-7/8	13-3/8 8-5/8 6-5/8 5-1/2 open
Length (ft)	0-280 0-4692 4692-4725	0-304 0-2363	0-1365 0-5326 5272-6913 0-3730 6913-6922
<u>Logs^j</u>	SP, R, C	No information	SP, R, C, L
<u>Well name</u>	Sinclair #4	Magmamax #1	Magmamax #2
<u>Status</u>	Completed 1964 Operator 1975	Completed 1972 Produced 1972 Shut-in 1972	Completed 1972 Shut-in 1972 Operated 1974 Shut-in 1974
<u>Depth (ft)</u>			
Total height of Kelly Bushing above surface-ft.	5300	2805	4368
Perforations ^f	12 4287 to 5060	12 1797-2264	12 3784 to 4360
Plugs	None	2300-2805	None
<u>Casing</u>			
Outside diameter (in.)	13-3/8 9-5/8 7	20 13-3/8 8-5/8	20 13-3/8 9-5/8
Length (ft)	0-1765 0-5260 0-4006	0-110 0-1060 908-2264	0-100 0-1009 0-4360
<u>Logs</u>	SP, R, C, L	SP, R, C, F, T, L	SP, R, C, F, T
<u>Well name</u>	Magmamax #3	Magmamax #4	Woolsey #1
<u>Status</u>	Completed 1972 Shut-in 1972	Completed 1972 Shut-in 1973	Completed 1972 Shut-in 1972
<u>Depth (ft)</u>			
Total height of Kelly Bushing above surface-ft.	4000	2567	2400
Perforations	12 2618 to 3076	12 2376 to 2518	12 1866 to 2375
Plugs	3120 to 4000	None	None
<u>Casing</u>			
Outside diameter (in.)	20 13-3/8 9-5/8	12-3/4 8-5/8 2-7/8	20 13-3/8 8-5/8
Length (ft)	0-100 0-1032 0-3076	0-40 0-516 0-2566	0-105 0-1084 875-2375
<u>Logs</u>	SP, R, C, F, T	SP, R, C, F, L	SP, R, C, F, L

<u>Well name</u>	Elmore #3	Elmore #1	
<u>Status</u>	Completed 1974 Shut-in 1974	Completed 1964 Produced 1964 Shut-in 1965	
<u>Depth (ft)</u>			
Total	2510	7117	
height of Kelly Bushing above surface-ft.	12	15	
Perforations	2007 to 2505	4766 to 7097	
Plugs	None	4307 to 7117	
<u>Casing</u>			
Outside diameter (in.)	16 10-3/4 7	20 13-3/8 8-5/8 6-5/8	
Length (ft)	0-100 0-1068 0-2505	0-107 0-1510 0-4745 0-4307 4633 to 7087	
<u>Logs</u>	SP, R, C, L	SP, R, C, L	
<u>Well name</u>	River Ranch #1	Hudson #1	
<u>Status</u>	Completed 1963 Produced 1963 Abandoned 1971	Completed 1964 Produced 1964 Abandoned 1971	
<u>Depth (ft)</u>			
Total	8100	6141	
height of Kelly Bushing above surface-ft.	15	15	
Perforations	3890 to 6570 6642 to 8093	5812 to 6112	
Plugs	0-8100	0 to 6141	
<u>Casing</u>			
Outside diameter (in.)	20 13-3/8 8-5/8 6-5/8	20 13-3/8 8-5/8 6-5/8	
Length (ft)	0-108 0-1575 0 to 6632 2419-8093	0-97 0-1445 0-5884 5810-6112	
<u>Logs</u>	SP, R, C	SP, R, C, L	
<u>Well name</u>	IID #1	IID #2	IID #3
<u>Status</u>	Completed 1962 Produced 1965 Shut-in 1965	Completed 1963 Produced 1963 Shut-in 1964	Completed 1965 Shut-in 1965
<u>Depth (ft)</u>			
Total	5230	5826	1700
height of Kelly Bushing above surface-ft.	9	12	No information
Perforations	4900-5212	3490-3702	No information
Plugs	5215-5230	5811-5826	None
<u>Casing</u>			
Outside diameter (in.)	20 16 11-3/4 7-5/8	18 11-3/4 9-5/8	No information
Length (ft)	0-67 0-303 0-1672 0-5215	0-90 0-1598 0-5811	No information
<u>Logs</u>	SP, R, C, L	SP, R, C, L	No information
<u>Well name</u>	State of Calif. #1	Sportsman #1	
<u>Status</u>	Completed 1964 Produced 1964 Shut-in 1965	Completed 1961 Produced 1961 Shut-in 1961	
<u>Depth (ft)</u>			
Total	4848	4729	
height of Kelly Bushing above surface-ft.	11	12	
Perforations	4435-4806	3980-4720	
Plugs	4839-4848	4720-4729	
<u>Casing</u>			
Outside diameter (in.)	18 11-3/4 7-5/8	20 16 10-3/4 5-1/2	
Length (ft)	0-102 0-1191 0-4848	0-65 0-283 0-1195 0-4729	
<u>Logs</u>	SP, R, C, T, L	SP, R, L	

<u>Well name</u>	Pioneer Dev. Co. #1	Pioneer Dev. Co. #2	Pioneer Dev. Co. #3
<u>Status</u>	Completed 1927 Abandoned 1928	Completed 1927 Abandoned 1928	Completed 1927 Abandoned 1928
<u>Depth (ft)</u>			
Total	727	1263	1473
height of Kelly Bushing above surface-ft.	No information	No information	No information
Perforations	No information	No information	No information
Plugs	No information	No information	No information
<u>Casing</u>			
Outside diameter (in.)	5" 2-7/8 2-1/4 open	No information	No information
Length (ft)	0-79 0-316 0-452 452-727	No information	No information
<u>Logs</u>	L	L	L

<u>Well name</u>	Salton Sea Chem. Prod. #1	Salton Sea Chem. Prod. #5	J. P. Chandler & Staton #1
<u>Status</u>	Completed 1932 Abandoned 1932	Completed 1933 Abandoned 1933	Completed 1935 Abandoned 1935
<u>Depth (ft)</u>			
Total	1054	960	590
height of Kelly Bushing above surface-ft.	No information	No information	No information
Perforations	No information	450-550	No information
Plugs	No information	550-960	No information
<u>Casing</u>			
Outside diameter (in.)	No information	9" 5"	8-1/4 6-5/8
Length (ft)	No information	0-420 0-550	0-151 0-400
<u>Logs</u>	L	L	L

^aThe drilling has been completed at the intended depth.

^bThe well is or has been flowed within the past year.

^cThe well is inoperative and the borehole is plugged.

^dThe wellhead is closed but the borehole is not plugged.

^eAll depths are reported in feet below Kelly Bushing (KB), a position 9 to 15 ft above local surface level. Height of KB above surface level is listed in the KB section of the table. Surface level in this area is below sea level. A topographic map of the SSGF area is included (Fig. 2).

^fListed by the depth of the perforated section and generally represent production zones for each well.

^gListed by the depth of the plugged section and represent closed sections of the borehole.

^hThe casing refers to the pipe that is lowered into the borehole. The o.d. for each length of casing in the borehole is given. Also the position of each length of casing in the borehole is supplied: 10-3/4", 0-280 ft means that the o.d. is 10-3/4 in. wide and the length of pipe with that diameter extends 280 ft below KB.

ⁱThe word "open" means that the borehole does not have any pipe.

^jLogs available for each borehole: SP - self potential, R - resistivity, C - conductance, L - lithology, P - pressure, T - temperature.

	Well Name	Company	Type of Well	Depth
COMPLETED SINCE 1979	<u>Salton Sea Geothermal System (continued)</u>			
	Sinclair 12	Union Oil Co.	----	----
	Sinclair 13		Completed steam	----
	Sinclair 14		----	----
	Sinclair 15		Completed steam	----
	Sinclair 20		----	----
	Sinclair 25		----	----
	I.I.D. 5		Completed steam	----
	I.I.D. 6		Completed steam	----
	I.I.D. 8		----	----
	I.I.D. 10		----	----
	I.I.D. 12		----	----
	M-8	Imperial Magma	----	----
	M-6		----	----
	I M-5		----	----
	Baretta 1		----	----
	Britz 3	Republic Geothermal, Inc.	Completed steam	10,300 ft
	Fee 1		Completed steam	10,013 ft
<u>Westmorland Geothermal Field</u>				
1976	Landers 1	Republic Geothermal, Inc.	Completed steam	7,705 ft
1976	Landers 2		Completed steam	7,507 ft
1976	Landers 3		Disposal	----
1976	Dearborn Farms 1		Completed steam	8,000 ft
1976	Dearborn Farms 2		Disposal	----
1976	Kalin Farms 1		Completed steam	8,190 ft
1972	Dearborn 1	Magma Power Co.	Abandoned	4,133 ft

APPENDICES 2 AND 3

Note: The identification of discrete minerals in polymineralic bulk samples by x-ray diffraction techniques is often complicated by low mineral quantities and/or major x-ray peak interference. This occurs in the Salton Sea and Westmorland geothermal systems for minerals kaolinite, two undifferentiated chlorite types, anhydrite, and alkali feldspar from $24.95^\circ 2\theta$ to $25.65^\circ 2\theta$. Thus, differentiation between these minerals is difficult and somewhat tenuous in this 2θ range.

X-Ray Diffraction: Mineral and Detection Limits and Standard Errors for Appendices 2 and 3

<u>Symbol</u>	<u>Mineral</u>	<u>True Value, %</u>	<u>Standard Error (1 S.D.), %</u>	<u>Detection Limit, %</u>
QUAR	Quartz	60	± 3.1	<1*
PLAG	Plagioclase	10	± 2.7	<2*
ALKA	Alkali Feldspar	10	± 2.6	<3*
MICA	Biotite and/or muscovite	5	± 1.0	>2
ILLI	Illite	5	± 1.0	>2†
1MIX	Illite/montmorillonite mixed layer clay, 25% expandables	--	---	>5*
2MIX	Illite/montmorillonite mixed layer clay, 50% expandables	--	---	>5*
MONT	2 H ₂ O montmorillonite	--	$\pm 5.5^*$	>5*
KAOL	Kaolinite	5	± 1.0	greater if >2
CHLO	Chlorite	10	± 1.5	both are >1*
CALC	Calcite	10	± 1.9	present >1*
DOLO	Dolomite	5	± 1.5	>2
AKER	Ankerite	--	---	--
ZEOL	Wairakite and/or analcite	5	± 2.7	<1
TALC	Talc and/or pyrophyllite	5	± 1.8	<1
PYRI	Pyrite	5	± 3.7	>4
HEMA	Hematite	--	---	--
PHRR	Pyrrhotite	--	---	--
AMPH	Hornblende	5	± 1.0	<1
EPID	Epidote	5	± 1.0	>4
PREH	Prehnite	5	± 1.0	>4
ANHY	Anhydrite	5	± 2.1	<1
GYPS	Gypsum	5	± 2.0	<1

--- Not determined.

* Value reported in Elders et al., 1977.

† Estimated value.

APPENDIX 2

SHALE X-RAY DIFFRACTION DATA

Well Magmamax 2
Selected Bulk Shales

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	MICA	ILLI	1MIX	2MIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	TALC	PYRI	HEMA	PHRR	COPV	SPHA	ANPH	EPID	AMHY	GYPs	ZEOL
MCSEB 01	1090.0	11.1	1.9	3.0	-	10.9	13.4	6.9	-	3.3	2.5	4.2	-	42.1	-	-	-	-	-	-	-	-	0.7	-	-
MCSEB 02	1240.0	21.2	3.4	3.8	-	19.9	23.4	10.9	-	1.5	2.2	6.3	2.3	2.8	-	0.6	-	-	-	-	-	-	0.5	-	-
MCSEB 03	1430.0	22.9	2.9	3.6	-	14.7	21.0	10.9	-	2.3	4.4	13.4	3.1	-	-	-	-	-	-	-	-	-	0.9	-	-
MCSEB 04	1445.0	26.1	4.5	4.3	-	14.6	21.0	10.7	-	2.0	3.2	9.0	2.3	-	-	1.6	-	-	-	-	-	-	-	-	-
MCSEB 05	1520.0	25.3	3.9	4.8	-	14.2	22.4	10.8	-	1.8	4.1	9.0	2.3	-	-	0.9	-	-	-	-	-	-	0.6	-	-
MCSEB 06	1535.0	20.8	3.2	4.7	-	13.8	24.3	13.0	-	2.1	3.0	8.4	1.8	2.4	-	1.1	-	-	-	-	-	-	0.6	-	-
MCSEB 07	1640.0	38.3	4.6	3.3	-	15.0	13.9	-	-	-	8.4	15.4	-	-	1.1	-	-	-	-	-	-	-	-	-	-
MCSEB 08	1655.0	29.6	3.8	3.1	-	21.3	21.6	-	-	-	6.4	11.9	-	-	-	1.7	-	-	-	-	-	-	0.7	-	-
MCSEB 09	1820.0	31.1	2.8	4.2	-	28.1	12.3	-	-	-	9.5	11.0	-	-	-	1.0	-	-	-	-	-	-	-	-	-
MCSEB 10	1940.0	31.3	5.3	7.2	-	33.5	-	-	-	-	15.0	8.8	-	-	-	-	-	-	-	-	-	-	1.1	-	-
MCSEB 11	1972.6	33.8	6.6	8.0	-	31.1	-	-	-	-	16.2	10.2	-	-	-	-	-	-	-	-	-	-	1.1	-	-
MCSEB 12	2060.0	33.6	5.7	4.5	-	22.3	-	-	-	-	19.5	5.9	-	-	-	-	-	-	-	-	-	-	1.3	-	-
MCSEB 13	2180.0	35.9	5.7	4.5	-	22.3	-	-	-	-	17.4	14.0	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSEB 14	2270.0	33.7	4.4	3.9	-	22.7	-	-	-	-	16.1	19.1	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSEB 15	2320.0	34.2	4.9	3.9	-	28.5	-	-	-	-	16.3	12.1	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSEB 16	2450.0	33.6	5.2	4.9	-	24.5	-	-	-	-	16.1	14.3	-	-	-	-	-	-	-	-	-	-	1.4	-	-
MCSEB 17	2542.0	31.7	4.4	3.9	-	32.2	-	-	-	-	20.5	7.3	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSEB 18	2600.0	33.1	5.5	5.1	-	26.7	-	-	-	-	17.3	8.1	-	-	-	-	-	-	-	-	-	-	1.2	-	-
MCSEB 19	2780.0	33.0	8.1	5.6	-	26.2	-	-	-	-	18.6	11.5	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSEB 20	2990.0	31.6	10.9	5.5	-	25.0	-	-	-	-	19.7	6.4	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSEB 21	3020.0	31.8	10.7	6.7	-	24.4	-	-	-	-	17.7	9.0	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSEB 22	3200.0	35.0	7.0	4.7	-	25.2	-	-	-	-	18.7	9.4	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSEB 23	3290.0	14.6	26.4	16.5	-	12.6	-	-	-	-	22.5	-	-	-	0.8	3.7	-	-	-	-	-	-	3.0	-	-
MCSEB 24	3530.0	5.9	45.1	21.4	-	8.1	-	-	-	-	17.6	-	-	-	-	2.2	-	-	-	-	-	-	5.1	-	-
MCSEB 25	3560.0	16.0	24.9	11.3	-	18.5	-	-	-	-	22.2	-	-	-	0.8	2.1	-	-	-	-	-	-	4.1	-	-
MCSEB 26	3660.0	16.8	23.7	13.1	3.7	8.1	-	-	-	-	22.7	-	-	-	-	2.0	-	-	-	-	-	-	-	-	-
MCSEB 27	3750.0	14.4	24.0	15.7	7.9	3.9	-	-	-	-	21.5	-	-	-	-	1.6	-	-	-	-	-	-	-	-	-
MCSEB 28	3840.0	12.9	24.7	17.2	19.6	-	-	-	-	-	10.8	-	-	-	-	0.7	-	-	-	-	-	4.2	-	-	-
MCSEB 29	3870.0	18.1	20.3	20.7	9.8	-	-	-	-	-	21.7	-	-	-	-	4.1	-	-	-	-	-	-	3.3	-	-
MCSEB 30	3990.0	7.1	21.9	24.3	33.0	-	-	-	-	-	12.6	-	-	-	-	1.1	-	-	-	-	-	-	-	-	-
MCSEB 31	4110.0	8.7	10.9	17.2	24.5	-	-	-	-	-	37.4	-	-	-	-	1.1	-	-	-	-	-	-	-	-	-
MCSEB 32	4230.0	9.5	9.3	32.1	15.0	-	-	-	-	-	33.2	-	-	-	-	0.9	-	-	-	-	-	-	-	-	-
MCSEB 33	4340.0	9.3	13.7	22.1	29.2	-	-	-	-	-	24.7	-	-	-	-	1.0	-	-	-	-	-	-	-	-	-

(McDowell, unpublished data)

Well Magmamax 3
Selected Bulk Shales

SAMPLE NO	DEPT	QUAR	PLAG	ALKA	MICA	ILLI	INIX	ZNIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	SIDE	TALC	PYRI	HEMA	COPY	SPHA	AMPH	EPID	ANNY	GYP	ZEOL
PAG3 01	1020 0	12.0	2.6	2.8	-	18.6	12.6	6.0	-	2.4	-	3.8	12.9	33.1	0.8	-	-	-	-	-	-	-	0.5	-	-
PAG3 02	1120 0	15.6	3.1	3.0	-	19.6	18.9	7.1	-	1.5	3.4	4.9	6.0	16.9	-	-	-	-	-	-	-	-	-	-	-
PAG3 03	1210 0	18.6	2.3	3.7	-	23.8	19.8	5.3	-	2.0	5.8	17.2	1.5	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 04	1300 0	20.0	3.2	6.0	-	22.6	22.3	7.1	-	1.3	4.2	11.4	1.8	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 05	1390 0	19.5	3.8	3.8	-	25.0	23.4	7.0	-	1.8	5.0	7.1	2.6	-	-	-	1.0	-	-	-	-	-	-	-	-
PAG3 06	1495 0	23.0	4.3	3.3	-	21.0	22.4	6.3	-	-	9.0	8.4	2.4	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 07	1590 0	21.1	3.7	3.9	-	24.3	23.4	5.6	-	-	6.9	8.1	1.9	-	-	-	1.2	-	-	-	-	-	-	-	-
PAG3 08	1680 0	23.3	3.5	4.1	-	24.3	19.8	4.5	-	-	9.2	10.3	-	-	-	-	0.9	-	-	-	-	-	-	-	-
PAG3 09	1780 0	24.8	5.6	5.5	-	23.0	18.9	4.0	-	-	9.2	12.6	-	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 10	1900 0	23.9	5.1	4.5	-	26.0	14.9	-	-	-	13.0	8.2	-	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 11	1990 0	31.0	5.6	4.4	-	22.9	12.1	-	-	-	17.6	1.0	5.9	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 12	2080 0	27.4	5.0	5.0	-	25.6	14.6	-	-	-	17.2	4.1	0.9	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 13	2200 0	24.4	3.0	2.9	-	27.7	16.7	-	-	-	14.4	10.0	-	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 14	2305 0	24.6	4.6	2.7	-	28.3	18.7	-	-	-	12.5	8.7	-	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 15	2400 0	25.1	3.5	3.1	-	31.3	11.2	-	-	-	17.3	8.5	-	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 16	2500 0	24.6	3.3	2.6	-	27.5	10.3	-	-	-	18.2	13.6	-	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 17	2590 0	28.5	4.0	3.1	-	27.5	9.8	-	-	-	18.6	9.2	-	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 18	2710 0	28.3	3.7	3.3	-	28.1	8.5	-	-	-	17.7	9.5	-	-	-	-	2.9	-	-	-	-	-	-	-	-
PAG3 19	2800 0	26.4	4.2	3.8	-	28.8	6.1	-	-	-	18.1	12.7	-	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 20	2890 0	21.6	3.3	15.9	-	13.3	-	-	-	-	39.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 21	2980 0	24.6	5.6	10.0	-	17.8	-	-	-	-	37.5	2.6	-	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 22	3100 0	26.1	10.2	18.5	-	13.6	-	-	-	-	20.9	9.7	-	-	-	-	1.2	-	-	-	-	-	-	-	-
PAG3 23	3150 0	23.6	4.6	6.1	-	22.8	8.4	-	-	-	22.2	12.3	-	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 24	3200 0	23.4	9.0	14.9	-	11.2	-	-	-	-	38.7	2.9	-	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 25	3290 0	12.2	13.2	37.5	-	4.7	-	-	-	-	32.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 26	3400 0	11.4	28.8	27.0	-	3.8	-	-	-	-	28.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAG3 27	3610 0	12.9	22.8	18.6	-	3.5	-	-	-	-	31.1	-	-	-	-	-	1.7	-	-	-	-	-	6.1	-	-
PAG3 28	3700 0	10.8	35.4	19.2	-	3.3	-	-	-	-	17.4	7.9	-	-	-	-	1.1	-	-	-	-	-	-	-	-
PAG3 29	3820 0	8.1	34.0	20.6	-	25.4	-	-	-	-	5.0	-	-	-	-	-	1.5	-	-	-	-	4.9	-	-	0.6
PAG3 30	3910 0	11.6	30.6	19.1	-	17.4	-	-	-	-	14.6	3.2	-	-	-	-	3.4	-	-	-	-	-	-	-	-
PAG3 31	4000 0	17.1	36.5	11.0	-	3.8	-	-	-	-	22.2	3.9	-	-	-	-	-	-	-	-	-	3.2	1.7	-	0.8

Well I.I.D. 2
Selected Bulk Shales

[illegible]

Well Elmore 1
Selected Bulk Shales

[illegible]

Well Sinclair 4 Selected Bulk Shales

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	MICA	ILLI	IMIX	2MIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	TALC	PYRI	MEMA	PHRR	COPY	SPHA	AMPH	EPID	ANNY	GYPs	ZEOL
MCSH13 13	2750.0	24.3	3.0	2.4	-	13.9	18.7	9.9	-	-	11.6	6.5	3.1	3.7	-	-	-	-	-	-	-	-	-	-	-
MCSH13 14	2792.0	22.7	2.6	2.9	-	13.2	15.1	14.2	-	-	10.6	6.5	2.1	5.2	-	0.7	-	-	-	-	-	-	-	-	-
MCSH13 15	2886.0	33.9	5.2	4.0	-	16.0	10.7	-	-	-	10.2	15.6	0.9	1.0	-	1.8	-	-	-	-	-	-	0.8	-	-
MCSH13 16	3014.0	27.2	4.7	2.5	-	19.2	15.8	-	-	-	9.4	11.2	2.5	5.7	-	1.7	-	-	-	-	-	-	-	-	-
MCSH13 17	3171.0	26.3	3.7	5.3	-	18.0	14.6	-	-	-	13.1	9.1	2.9	5.6	-	-	-	-	-	-	-	-	-	1.3	-
MCSH13 18	3359.0	30.4	4.5	4.0	-	18.1	13.6	-	-	-	13.7	10.4	1.8	3.4	-	-	-	-	-	-	-	-	-	-	-
MCSH13 19	3389.0	34.7	4.3	3.8	-	18.5	10.1	-	-	-	12.6	16.0	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH13 20	3434.0	31.4	3.6	4.5	-	19.4	12.0	-	-	-	12.9	11.5	-	2.4	-	0.9	-	-	-	-	-	-	1.5	-	-
MCSH13 21	3610.0	35.4	5.0	4.4	-	16.8	8.3	-	-	-	13.4	13.4	-	2.2	-	0.9	-	-	-	-	-	-	-	-	-
MCSH13 22	3758.0	31.9	4.4	5.7	-	22.1	12.2	-	-	-	13.0	12.9	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH13 23	4047.0	31.0	5.4	1.8	-	19.7	10.2	-	-	-	15.0	12.9	1.9	6.8	-	-	-	-	-	-	-	-	1.2	-	-
MCSH13 24	4354.0	29.2	5.5	2.3	-	23.1	14.1	-	-	-	12.6	10.4	1.6	-	-	1.1	-	-	-	-	-	-	-	-	-
MCSH13 25	4573.0	33.5	3.7	2.6	-	21.4	9.3	-	-	-	14.9	12.9	1.7	-	-	-	-	-	-	-	-	-	-	-	-
MCSH13 26	4865.0	32.7	5.3	2.8	-	23.4	8.7	-	-	-	15.5	9.8	0.9	-	-	0.9	-	-	-	-	-	-	-	-	-
MCSH13 27	4934.0	35.0	5.2	1.1	-	22.7	5.6	-	-	-	15.2	11.8	0.6	-	-	0.7	-	-	-	-	-	-	-	-	-
MCSH13 28	5011.0	35.6	5.0	1.1	-	16.9	10.7	-	-	-	11.2	12.6	1.4	-	-	-	-	-	-	-	-	-	-	-	-
MCSH13 29	5166.0	37.7	4.3	1.1	-	19.0	6.0	-	-	-	15.6	14.1	1.2	-	-	6.9	-	-	-	-	-	-	-	-	-

(McDowell, unpublished data)

Well Sinclair 3 Selected Bulk Shales

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	MICA	ILLI	IMIX	2MIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	TALC	PYRI	MEMA	PHRR	COPY	SPHA	AMPH	EPID	ANNY	GYPs	ZEOL
MCSH43 11	2550.0	24.9	4.0	4.0	-	3.3	4.1	-	-	3.6	2.3	6.6	-	46.6	-	-	-	-	-	-	-	-	0.6	-	-
MCSH43 12	2845.0	23.8	5.2	4.1	-	7.8	16.4	14.1	5.5	6.7	3.3	9.2	3.9	3.4	-	3.0	-	-	-	-	-	-	0.7	-	-
MCSH43 13	3095.0	25.2	4.0	4.8	-	11.4	13.9	11.2	-	3.1	1.6	7.7	6.0	9.6	-	1.4	-	-	-	-	-	-	0.5	-	-
MCSH43 14	3222.0	24.8	3.3	4.5	-	14.7	15.6	8.6	-	2.6	2.3	7.9	6.0	3.3	-	0.8	-	-	-	-	-	-	0.6	-	-
MCSH43 15	3512.0	24.5	2.6	5.3	-	20.5	20.2	8.2	-	-	2.0	6.5	5.0	3.5	-	1.0	-	-	-	-	-	-	0.6	-	-
MCSH43 16	3755.0	24.1	3.6	4.4	-	16.2	17.8	10.4	-	-	4.7	7.3	6.4	3.5	-	0.7	-	-	-	-	-	-	0.9	-	-
MCSH43 17	4110.0	25.5	5.7	3.5	-	10.6	14.5	12.4	-	-	7.9	6.0	5.5	7.8	-	-	-	-	-	-	-	-	-	-	-
MCSH43 18	4314.0	23.0	3.5	3.5	-	15.4	15.7	9.0	-	-	5.7	8.4	5.5	4.4	-	1.0	-	-	-	-	-	-	-	-	-
MCSH43 19	4670.0	22.4	4.1	3.6	-	13.0	20.9	14.5	-	-	8.1	6.1	4.2	3.1	-	-	-	-	-	-	-	-	-	-	-
MCSH43 20	4870.0	27.1	4.2	4.0	-	13.4	18.1	9.1	-	-	7.2	8.1	5.5	3.3	-	0.6	-	-	-	-	-	-	-	-	-
MCSH43 21	5090.0	26.9	4.3	4.1	-	13.4	16.4	10.8	-	-	8.4	8.1	4.8	3.3	-	-	-	-	-	-	-	-	-	-	-
MCSH43 22	5326.0	27.7	3.5	3.7	-	14.4	17.7	8.5	-	-	7.7	7.2	5.6	3.3	-	1.8	-	-	-	-	-	-	-	-	-
MCSH43 23	5727.0	31.0	4.3	3.2	-	19.6	18.4	-	-	-	10.3	12.1	5.0	3.3	-	0.7	-	-	-	-	-	-	-	-	-
MCSH43 24	6093.0	35.0	4.7	2.6	-	20.6	9.4	-	-	-	11.6	16.0	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH43 25	6345.0	34.0	5.0	4.3	-	18.3	11.0	-	-	-	12.7	11.2	3.4	-	-	-	-	-	-	-	-	-	-	-	-
MCSH43 26	6563.0	35.3	4.6	3.6	-	14.2	10.8	-	-	-	12.9	17.5	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH43 27	6821.0	36.6	5.8	4.1	-	18.2	7.1	-	-	-	11.7	15.4	-	-	-	-	-	-	-	-	-	-	1.0	-	-

(McDowell, unpublished data)

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	MICA	ILLI	IMIX	SMIX	MONT	KAOL	CMLO	CALC	DOLO	AKER	SIDE	TALC	PYRI	HEMA	PHRR	COPY	SPHA	AMPH	EPID	ANNY	GYP	ZEOL
BRITISH 01	1000.0	17.2	3.6	5.1	-	10.3	16.1	18.7	4.1	3.7	-	6.2	6.7	7.1	0.7	-	-	-	-	-	-	-	-	0.6	-	-
BRITISH 02	1250.0	15.8	3.0	4.2	-	6.5	8.0	9.5	2.8	-	-	5.5	8.6	33.4	-	-	-	-	-	-	-	-	0.5	-	-	
BRITISH 03	1500.0	19.2	3.5	5.1	-	7.7	10.5	9.6	2.1	2.5	-	5.0	8.0	26.0	0.4	-	-	-	-	-	-	-	0.4	-	-	
BRITISH 04	1750.0	26.2	3.5	4.7	-	9.3	15.8	16.3	-	3.8	-	10.0	2.3	6.7	0.4	-	-	-	-	-	-	-	1.0	-	-	
BRITISH 05	2000.0	20.1	3.1	4.7	-	10.5	16.7	14.4	-	4.3	-	5.5	8.0	12.2	-	-	-	-	-	-	-	-	0.6	-	-	
BRITISH 06	2250.0	18.8	3.3	3.9	-	11.2	16.4	11.2	-	5.2	-	4.7	5.0	18.9	0.7	-	-	-	-	-	-	-	0.7	-	-	
BRITISH 07	2500.0	20.3	3.3	4.3	-	13.3	12.2	10.6	-	7.4	-	3.2	4.4	18.6	-	-	-	-	-	-	-	-	2.5	-	-	
BRITISH 08	2750.0	17.6	3.4	4.1	-	16.3	23.7	15.9	-	6.1	-	6.2	2.7	2.5	0.9	-	-	-	-	-	-	-	0.7	-	-	
BRITISH 09	3000.0	17.2	4.2	3.7	-	9.3	24.5	18.6	-	4.4	1.7	5.7	2.9	6.8	1.2	-	-	-	-	-	-	-	-	-	-	
BRITISH 10	3250.0	15.2	3.4	3.6	-	14.8	25.5	15.9	-	4.6	2.6	3.5	5.4	4.7	-	-	-	-	-	-	-	-	0.7	-	-	
BRITISH 11	3500.0	18.6	4.4	3.8	-	13.4	25.0	13.5	-	4.6	2.1	5.4	3.6	3.9	1.0	-	-	-	-	-	-	-	0.6	-	-	
BRITISH 12	3750.0	17.6	4.2	3.3	-	13.7	23.3	14.7	-	3.9	2.7	4.0	5.0	5.9	0.9	-	-	-	-	-	-	-	0.6	-	-	
BRITISH 13	4000.0	15.8	3.4	4.1	-	15.0	24.3	15.6	-	4.9	2.1	3.9	4.0	5.9	1.0	-	-	-	-	-	-	-	0.8	-	-	
BRITISH 14	4250.0	17.0	4.0	3.9	-	13.5	24.0	16.7	-	3.8	2.3	4.8	3.8	4.0	1.1	-	-	-	-	-	-	-	1.2	-	-	
BRITISH 15	4500.0	17.5	2.7	3.5	-	15.7	28.1	11.5	-	2.7	2.6	4.2	3.8	5.6	0.9	-	-	-	-	-	-	-	1.2	-	-	
BRITISH 16	4750.0	16.6	3.2	3.1	-	14.3	26.4	14.8	-	3.1	2.0	3.3	4.6	6.4	0.9	-	-	-	-	-	-	-	1.1	-	-	
BRITISH 17	5000.0	15.9	3.1	3.3	-	14.7	26.6	15.5	-	3.3	2.1	2.5	4.4	5.5	0.8	-	-	-	-	-	-	-	2.4	-	-	
BRITISH 18	5250.0	17.3	3.6	2.9	-	14.7	23.9	11.2	-	2.8	2.1	4.0	8.3	7.3	0.9	-	-	-	-	-	-	-	0.8	-	-	
BRITISH 19	5500.0	17.9	3.8	3.1	-	14.9	29.3	12.9	-	1.9	2.2	2.0	4.1	5.8	1.0	-	-	-	-	-	-	-	1.2	-	-	
BRITISH 20	5750.0	18.0	3.3	3.3	-	15.8	27.9	10.3	-	1.3	2.0	2.0	5.0	6.9	1.0	-	-	-	-	-	-	-	1.3	-	-	
BRITISH 21	6000.0	20.5	4.2	3.3	-	15.6	24.1	8.0	-	0.9	4.3	2.0	8.0	6.5	0.6	-	-	-	-	-	-	-	0.5	-	-	
BRITISH 22	6250.0	18.9	4.4	3.4	-	16.0	25.0	8.0	-	-	7.7	3.4	5.6	7.3	-	-	-	-	-	-	-	-	-	-	-	
BRITISH 23	6500.0	19.7	5.4	3.7	-	15.1	24.8	9.3	-	-	6.8	3.1	5.0	6.6	0.6	-	-	-	-	-	-	-	-	-	-	
BRITISH 24	6750.0	22.4	4.9	3.9	-	15.5	24.3	-	-	0.8	6.2	3.1	7.7	10.3	0.8	-	-	-	-	-	-	-	0.5	-	-	
BRITISH 25	7000.0	20.0	5.0	3.4	-	19.1	22.0	5.0	-	-	6.0	2.2	7.7	9.8	-	-	-	-	-	-	-	-	-	-	-	
BRITISH 26	7250.0	14.8	23.0	9.5	-	14.8	5.1	-	-	-	8.1	-	10.5	9.7	1.9	-	-	-	-	-	-	-	2.6	-	-	
BRITISH 27	7500.0	24.9	8.0	4.3	-	18.1	16.0	-	-	-	9.1	4.2	6.6	8.3	-	-	-	-	-	-	-	-	0.8	-	-	
BRITISH 28	8000.0	24.1	8.0	3.6	-	19.1	14.9	-	-	-	11.5	4.2	6.6	7.9	-	-	-	-	-	-	-	-	-	-	-	
BRITISH 29	8250.0	24.9	4.5	3.3	-	18.5	18.8	-	-	-	13.5	7.7	3.8	5.0	-	-	-	-	-	-	-	-	-	-	-	
BRITISH 30	8500.0	19.4	11.9	10.4	-	17.4	11.8	-	-	-	9.5	7.1	5.0	6.2	1.1	-	-	-	-	-	-	-	1.3	-	-	
BRITISH 31	8750.0	24.9	5.8	3.9	-	19.6	15.4	-	-	-	13.5	8.2	4.2	4.5	-	-	-	-	-	-	-	-	-	-	-	
BRITISH 32	9000.0	22.1	5.4	3.8	-	21.6	22.0	-	-	-	11.2	6.3	3.6	3.9	-	-	-	-	-	-	-	-	-	-	-	
BRITISH 33	9250.0	35.1	8.2	3.0	-	16.5	6.9	-	-	-	16.5	11.1	7.7	-	-	-	-	-	-	-	-	-	-	-	-	
BRITISH 34	9500.0	31.9	6.6	3.8	-	19.7	8.6	-	-	-	14.8	9.3	3.9	2.3	-	-	-	-	-	-	-	-	-	-	-	
BRITISH 35	9750.0	30.8	6.4	3.8	-	20.9	7.7	-	-	-	16.1	8.6	3.8	1.9	-	-	-	-	-	-	-	-	-	-	-	
BRITISH 36	1000.0	29.6	8.1	1.5	-	18.0	7.9	-	-	-	19.0	11.4	2.4	-	-	-	-	-	-	-	-	-	2.0	-	-	
BRITISH 37	1025.0	27.9	6.7	3.8	-	23.5	8.8	-	-	-	14.7	8.7	3.2	1.5	-	-	-	-	-	-	-	-	1.1	-	-	

Well Landers 1 Selected Bulk Shales

SAMPLE NO.	DEPT	GUAR	PLAG	ALKA	MICA	ILLI	IMIX	SMIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	SIDE	TALC	PYRI	HEMA	PHRR	COPY	SPHA	AMPH	EPID	ANNY	GYP	ZEOL
LAND 01	3910.0	32.8	5.8	7.9	-	7.8	7.4	5.9	-	3.1	1.4	10.3	5.3	2.7	9.5	-	-	-	-	-	-	-	-	-	-	-
LAND 02	3250.0	17.3	3.3	4.0	-	10.4	19.5	16.7	-	4.3	2.8	12.5	4.0	2.8	1.3	-	1.1	-	-	-	-	-	-	-	-	-
LAND 03	3520.0	17.9	3.3	4.1	-	12.4	20.9	17.0	-	4.7	2.5	6.8	4.9	4.0	-	-	0.5	0.8	-	-	-	-	-	-	-	-
LAND 04	3760.0	18.6	3.4	4.8	-	14.2	22.6	13.2	-	4.9	2.3	6.6	4.4	2.5	1.3	-	0.6	-	-	-	-	-	-	0.6	-	-
LAND 05	4000.0	19.9	3.9	4.9	-	11.2	18.8	15.5	-	4.8	2.8	8.5	4.5	2.7	0.9	-	0.5	0.6	-	-	-	-	-	0.5	-	-
LAND 06	4240.0	14.4	2.5	3.8	-	12.8	27.5	19.0	-	6.0	2.6	6.4	2.5	0.0	0.4	-	0.6	-	-	-	-	-	-	0.4	-	-
LAND 07	4510.0	17.1	3.1	3.7	-	11.7	25.2	20.6	-	4.7	2.3	5.9	2.6	1.2	1.1	-	-	-	-	-	-	-	-	0.8	-	-
LAND 08	4750.0	19.4	3.6	3.9	-	13.1	23.1	14.9	-	4.6	2.6	6.1	0.1	2.2	1.1	-	0.3	0.6	-	-	-	-	-	0.6	-	-
LAND 09	5020.0	18.8	3.4	3.6	-	13.3	23.3	16.4	-	3.8	1.9	5.7	4.0	2.2	0.9	-	0.3	0.8	-	-	-	-	-	0.4	-	-
LAND 10	5260.0	16.7	3.5	4.1	-	13.1	22.7	18.4	-	3.9	2.1	4.9	2.8	1.1	0.9	-	0.5	0.5	-	-	-	-	-	0.3	-	-
LAND 11	5550.0	18.0	3.5	3.8	-	15.2	29.6	15.3	-	3.1	-	5.4	3.3	1.4	1.0	-	-	-	-	-	-	-	-	0.5	-	-
LAND 12	5740.0	15.9	3.6	3.6	-	18.6	34.6	13.3	-	0.5	-	3.6	3.6	2.0	0.8	-	-	-	-	-	-	-	-	0.6	-	-
LAND 13	6010.0	19.1	3.1	3.1	-	18.1	29.2	10.8	-	2.0	-	4.9	4.5	2.8	0.9	-	0.9	-	-	-	-	-	-	0.6	-	-
LAND 14	6250.0	21.6	3.9	3.5	-	17.3	24.9	6.5	-	0.5	-	7.7	6.3	3.1	1.1	-	-	-	-	-	-	-	-	0.3	-	-
LAND 15	6490.0	22.0	3.6	3.6	-	17.3	24.9	6.5	-	0.9	-	5.2	7.7	4.0	0.9	-	-	-	-	-	-	-	-	0.9	-	-
LAND 16	6760.0	24.0	3.1	3.1	-	21.1	25.7	-	-	0.8	3.3	4.4	9.3	3.8	0.8	-	-	-	-	-	-	-	-	0.7	-	-
LAND 17	7000.0	25.5	3.5	3.5	-	20.0	25.7	-	-	0.8	3.3	4.4	7.1	3.8	0.8	-	-	-	-	-	-	-	-	0.6	-	-
LAND 18	7240.0	22.0	3.9	3.9	-	22.3	28.0	-	-	0.9	3.9	7.7	7.7	3.9	1.1	-	-	0.9	-	-	-	-	-	0.4	-	-
LAND 19	7510.0	23.3	3.3	3.3	-	21.9	29.3	-	-	1.1	4.2	6.9	6.9	2.7	1.0	-	-	-	-	-	-	-	-	0.5	-	-
LAND 20	7690.0	25.4	3.5	2.3	-	24.3	16.8	-	-	2.5	5.2	7.8	8.1	3.3	-	-	-	-	-	-	-	-	-	-	-	-

Well Kalin Farms 1 Selected Bulk Shales

SAMPLE NO.	DEPT	GUAR	PLAG	ALKA	MICA	ILLI	IMIX	SMIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	SIDE	TALC	PYRI	HEMA	PHRR	COPY	SPHA	AMPH	EPID	ANNY	GYP	ZEOL
KALFRM 01	1180.0	22.0	4.6	6.0	-	8.3	12.6	15.9	6.0	4.8	2.0	8.5	4.3	2.4	1.8	-	0.8	-	-	-	-	-	-	-	-	-
KALFRM 02	1420.0	24.2	5.3	6.8	-	8.2	11.7	10.7	4.5	4.5	3.2	11.7	5.4	2.7	-	-	1.2	-	-	-	-	-	-	-	-	-
KALFRM 03	1990.0	18.5	4.6	5.6	-	8.5	14.6	20.7	6.4	4.9	3.3	6.4	3.6	2.2	-	-	0.9	-	-	-	-	-	-	-	-	-
KALFRM 04	2530.0	25.5	5.7	7.2	-	7.7	8.9	11.7	2.5	3.4	1.6	10.7	5.6	3.8	5.0	-	0.8	-	-	-	-	-	-	-	-	-
KALFRM 05	3010.0	17.4	3.4	4.6	-	9.5	18.4	21.0	3.7	6.2	3.7	6.8	6.8	3.9	-	-	0.6	-	-	-	-	-	-	-	-	-
KALFRM 06	3490.0	18.7	4.7	5.5	-	9.5	18.4	17.8	4.3	4.8	3.6	6.3	6.8	3.9	-	-	0.6	-	-	-	-	-	-	-	-	-
KALFRM 07	3730.0	16.3	3.8	5.1	-	11.4	20.7	18.7	4.3	4.8	2.6	6.5	6.8	3.9	-	-	0.6	-	-	-	-	-	-	-	-	-
KALFRM 08	3940.0	20.3	4.0	5.5	-	10.2	19.1	18.7	-	4.7	2.6	6.5	6.8	3.9	-	-	0.6	-	-	-	-	-	-	-	-	-
KALFRM 09	4230.0	20.9	4.9	5.6	-	11.0	19.4	17.6	-	4.9	2.5	7.6	4.3	1.2	-	-	0.9	0.6	-	-	-	-	-	-	-	-
KALFRM 10	4180.0	20.1	4.2	6.1	-	10.8	19.6	17.4	-	5.0	2.0	6.9	4.3	2.2	-	-	0.7	-	-	-	-	-	-	-	-	-
KALFRM 11	4300.0	15.7	3.2	4.6	-	11.4	22.6	18.8	-	4.4	3.2	5.5	3.4	2.0	-	-	1.3	-	-	-	-	-	-	-	-	-
KALFRM 12	4510.0	21.0	3.2	4.9	-	14.3	20.3	14.4	-	7.0	2.7	5.4	3.9	-	-	-	1.3	-	-	-	-	-	-	-	-	-
KALFRM 13	4690.0	17.4	2.0	4.4	-	14.5	25.8	17.5	-	7.2	1.9	3.8	3.1	1.7	-	-	1.1	-	-	-	-	-	-	-	-	-
KALFRM 14	4990.0	18.3	1.6	3.6	-	16.3	30.0	15.1	-	3.4	3.3	3.3	3.3	1.7	-	-	0.8	-	-	-	-	-	-	-	-	-
KALFRM 15	5230.0	18.1	1.6	3.6	-	17.7	27.3	11.6	-	2.0	-	3.3	3.3	1.7	-	-	0.6	-	-	-	-	-	-	-	-	-
KALFRM 16	5500.0	26.6	4.3	4.3	-	27.5	21.6	-	-	-	3.7	3.3	3.3	1.7	-	-	1.2	-	-	-	-	-	-	-	-	-
KALFRM 17	5580.0	25.5	4.3	4.3	-	24.8	23.1	-	-	-	12.0	9.9	7.7	-	-	-	1.2	-	-	-	-	-	-	-	-	-
KALFRM 18	6490.0	25.4	3.4	3.4	-	22.3	20.7	-	-	-	-	10.9	7.2	-	-	-	-	-	-	-	-	-	-	-	-	-
KALFRM 19	7000.0	25.5	3.3	3.3	-	23.3	20.7	-	-	-	-	14.6	8.1	-	-	-	-	-	-	-	-	-	-	-	-	-
KALFRM 20	7510.0	23.3	3.3	3.3	-	23.1	21.1	-	-	-	-	14.8	8.3	-	-	-	-	-	-	-	-	-	-	-	-	-
KALFRM 21	7990.0	23.3	3.3	3.3	-	24.9	9.1	-	-	-	-	18.5	9.0	-	-	-	-	-	-	-	-	-	-	-	-	-
KALFRM 22	8470.0	28.6	4.3	3.2	-	22.2	15.7	-	-	-	-	17.5	8.4	-	-	-	-	-	-	-	-	-	-	-	-	-

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	NICA	ILLI	INIX	ZNIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	SIDE	TALC	PYRI	HEMA	PHRR	COPY	SPHA	AMPH	EPID	ANNY	GYP	ZEOL
DEAR 01	2000.0	18.2								3.5		33.6	4.8	8.0	2.2		29.7									
DEAR 02	2210.0	26.3	3.0	3.7		5.2	3.9			3.0	1.4	3.4	7.4	41.7	1.0											
DEAR 03	2300.0	28.8	3.9	5.4		5.6	3.6			3.5		5.9	5.0	37.2	1.2											
DEAR 04	2390.0	29.0	4.5	5.3		10.6	8.5			4.0	1.7	9.1	4.2	24.0	1.2											
DEAR 05	2510.0	22.0	3.3	4.8		12.9	19.7	11.0		6.7	2.2	8.8	5.3	26.6	1.5											
DEAR 06	3020.0	22.5	3.2	3.9		13.1	3.3	18.9		5.9		5.1	4.8	33.5	0.9											
DEAR 07	3500.0	20.4	4.4	4.9		11.7	22.0	16.3		3.7	1.5	6.1	4.0	30.0	1.1		2.2									
DEAR 08	4010.0	17.9	4.1	4.6		13.4	26.3	15.5			1.3	4.5	4.8	22.9	0.5			1.1								
DEAR 09	4310.0	16.7	3.5	4.2		14.0	28.0	15.5			1.7	4.2	4.4	22.8	0.5			0.8								
DEAR 10	4410.0	19.8	3.4	4.1		14.0	27.3	14.5			1.2	3.9	4.2	33.1	0.8			0.7								
DEAR 11	4520.0	17.4	2.9	3.4		13.2	26.7	17.0		4.1	2.2	4.2	4.4	33.3	0.6			0.6								
DEAR 12	4640.0	11.8	2.4	3.8		12.9	30.0	22.0		4.5	2.3	4.1	2.7	11.9	0.3			0.7								
DEAR 13	4730.0	16.6	2.9	3.9		12.8	26.7	17.2		4.5	2.2	4.4	3.7	23.9	0.5			0.7								
DEAR 14	5000.0	21.7	1.9	3.3		16.2	29.0	13.4		1.7	1.0	3.4	4.2	27.7	1.4			0.7								
DEAR 15	5510.0	18.8	2.4	3.8		18.1	31.6	14.1		1.0	0.6	2.0	4.1	22.6	0.9											
DEAR 16	6220.0	20.7	2.6	3.6		15.8	30.0	12.8		1.1	2.5	4.0	4.1	22.8												
DEAR 17	6500.0	18.0	2.5	4.2		17.0	29.3	11.4		1.1	4.1	4.1	4.1	22.0												
DEAR 18	7010.0	19.9	3.4	3.7		17.2	28.8	12.0			4.3	4.2	4.1	1.7				0.8								
DEAR 19	7520.0	20.8	3.2	3.5		17.4	28.1	9.1			6.0	5.0	4.1	2.0				0.9								
DEAR 20	7610.0	21.3	3.0	3.6		18.4	27.1	8.7			5.2	5.0	3.0	4.0				0.9								
DEAR 21	7820.0	19.2	2.9	3.6		19.0	26.3	11.7			7.3	4.4	3.4	2.3												
DEAR 22	7970.0	18.5	2.9	3.6		19.8	28.4	10.0			6.5	4.1	3.2	2.3				0.6								

Well Landers 2 Selected Bulk Shales

SAMPLE NO	DEPT	QUAR	PLAG	ALKA	NICA	ILLI	IMIX	BMIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	SIDE	TALC	PYRI	HEMA	PHRR	COPY	SPHA	AMPH	EPID	AMY	GYP	ZEOL
LAN23 01	10200	20 2	5 1	5 7	-	8 0	11 2	15 0	8 9	4 3	-	9 9	4 2	2 6	-	-	-	1 3	-	-	-	-	-	0 6	2 9	-
LAN23 02	22500	18 8	1 8	3 3	-	13 5	18 4	11 5	-	5 4	-	4 7	3 8	14 8	0 7	-	1 0	1 7	-	-	-	-	-	0 4	-	-
LAN23 03	24900	17 5	2 2	3 1	-	13 0	4 6	-	-	1 8	-	6 6	8 8	49 3	0 7	-	-	-	-	-	-	-	-	0 3	-	-
LAN23 04	27600	16 9	2 3	3 0	-	13 0	3 1	-	-	2 0	-	9 0	10 0	42 9	0 6	-	-	-	-	-	-	-	-	-	-	-
LAN23 05	30000	20 8	2 2	3 2	-	9 2	12 5	7 8	-	3 7	-	13 3	3 2	21 3	0 7	-	-	-	-	-	-	-	-	0 4	-	-
LAN23 06	32400	23 4	4 4	2 2	-	14 4	17 0	9 7	-	1 1	-	6 3	3 7	11 0	1 5	-	-	-	-	-	-	-	-	0 4	-	-
LAN23 07	35100	22 3	3 1	4 1	-	16 2	19 8	13 0	-	5 7	2 4	5 5	3 1	3 3	1 4	-	-	-	-	-	-	-	-	-	-	-
LAN23 08	37500	19 7	3 3	5 5	-	12 4	19 4	18 3	-	4 9	1 4	5 6	3 7	3 1	1 3	-	0 8	-	-	-	-	-	-	-	-	-
LAN23 09	40200	19 0	3 2	4 0	-	14 0	23 4	15 6	-	5 0	-	5 8	3 1	4 7	1 3	-	0 9	-	-	-	-	-	-	-	-	-
LAN23 10	42600	19 1	7 7	3 4	-	13 7	21 1	12 0	-	4 7	1 0	5 4	7 5	8 1	1 2	-	-	-	-	-	-	-	-	-	-	-
LAN23 11	45000	17 2	3 7	-	-	14 4	28 4	16 9	-	4 1	1 3	4 2	2 2	2 1	0 9	-	0 5	0 5	-	-	-	-	-	-	-	-
LAN23 12	47400	17 3	3 0	-	-	13 2	25 5	19 1	-	4 8	2 6	5 7	3 2	1 1	0 9	-	-	-	-	-	-	-	-	-	-	-
LAN23 13	50200	17 7	2 8	-	-	19 3	31 8	10 2	-	0 8	2 6	3 1	2 0	5 5	1 2	-	-	-	-	-	-	-	-	-	-	-
LAN23 14	52500	15 9	3 3	-	-	12 1	24 6	21 5	-	3 6	1 4	4 7	3 0	5 2	0 8	-	-	1 0	-	-	-	-	-	-	-	-
LAN23 15	55200	19 2	3 5	-	-	16 0	26 6	13 0	-	2 2	1 0	5 5	3 6	3 0	1 1	-	-	-	-	-	-	-	-	-	-	-
LAN23 16	57600	18 7	3 5	-	-	16 5	27 7	13 4	-	1 8	-	4 6	5 0	2 4	1 0	-	-	-	-	-	-	-	-	-	-	-
LAN23 17	60000	17 2	3 3	-	-	14 4	30 7	15 7	-	2 8	1 4	4 1	7 7	2 4	1 0	-	-	-	-	-	-	-	-	-	-	-
LAN23 18	62400	17 8	3 1	6	-	14 2	31 3	12 2	-	0 9	1 8	2 9	7 0	4 4	0 7	-	-	-	-	-	-	-	-	-	-	-
LAN23 19	65100	19 7	3 0	-	-	17 1	33 4	10 5	-	-	-	2 8	2 0	2 4	1 7	-	-	1 1	-	-	-	-	-	-	-	-
LAN23 20	66900	20 8	3 3	-	-	17 3	32 7	9 2	-	-	-	3 6	6 2	2 2	1 0	-	-	-	-	-	-	-	-	-	-	-
LAN23 21	69300	21 3	3 3	-	-	19 3	32 7	9 3	-	-	-	3 6	6 2	2 2	0 9	-	-	-	-	-	-	-	-	-	-	-
LAN23 22	72300	19 9	2 9	3 6	-	19 5	30 9	10 6	-	-	-	3 1	6 0	2 2	1 3	-	-	-	-	-	-	-	-	-	-	-
LAN23 23	74700	26 7	4 1	2 9	-	16 4	24 1	8 3	-	-	-	4 8	2 6	2 2	1 5	-	-	-	-	-	-	-	-	-	-	-

Well River Ranch 1
Selected Bulk Shales

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	MICA	ILLI	IMIX	EMIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	SIDE	TALC	PYRI	HEMA	PHRR	COPY	SPHA	AMPH	EPID	ANNY	GYPG	ZEOL
RR1SH.01	2333.0	24.4	3.8	20.4	-	20.0	-	-	-	-	19.3	10.5	-	-	-	-	1.7	-	-	-	-	-	-	-	-	-
RR1SH.02	2573.0	28.1	7.6	5.4	-	27.7	-	-	-	-	18.2	13.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RR1SH.03	2843.0	24.4	13.1	21.7	-	12.5	-	-	-	-	19.2	9.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RR1SH.04	3133.0	11.5	4.9	40.6	-	-	-	-	-	-	41.8	-	-	-	-	-	1.2	-	-	-	-	-	-	-	-	-
RR1SH.05	3313.0	18.0	5.3	36.1	-	-	-	-	-	-	35.7	-	-	-	-	-	4.9	-	-	-	-	-	-	-	-	-
RR1SH.06	3680.0	20.1	3.6	24.0	-	-	-	-	-	-	41.2	-	-	-	-	-	11.0	-	-	-	-	-	-	-	-	-
RR1SH.07	3888.0	43.9	8.4	22.5	-	-	-	-	-	-	15.1	-	-	-	-	-	4.1	-	-	-	-	-	-	-	-	-
RR1SH.08	4150.0	23.0	10.3	6.2	-	19.4	-	-	-	-	14.3	19.5	-	-	-	-	1.4	-	-	-	-	-	-	-	-	-
RR1SH.09	4422.0	27.5	11.6	12.0	-	16.9	-	-	-	-	18.9	12.0	-	-	-	-	1.0	-	-	-	-	-	-	-	-	-
RR1SH.10	4600.0	27.7	10.1	8.8	-	17.9	-	-	-	-	14.5	19.8	-	-	-	-	1.3	-	-	-	-	-	-	-	-	-
RR1SH.11	4782.0	28.5	16.3	11.2	-	15.1	-	-	-	-	18.2	10.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RR1SH.12	5110.0	29.6	11.2	10.7	-	21.0	-	-	-	-	18.0	9.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RR1SH.13	5500.0	29.1	10.8	6.5	-	20.3	-	-	-	-	19.0	14.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RR1SH.14	6100.0	27.0	9.7	9.7	-	15.6	-	-	-	-	29.6	8.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Well Woolsey 1
Selected Bulk Shales

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	MICA	ILLI	IMIX	EMIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	TALC	PYRI	HEMA	PHRR	COPY	SPHA	AMPH	EPID	ANNY	GYPG	ZEOL
MCSH4B.01	1575.0	30.2	3.5	6.8	-	28.0	-	-	-	-	13.4	17.3	-	-	-	0.8	-	-	-	-	-	-	-	-	-
MCSH4B.02	1820.0	34.5	6.2	3.8	-	25.1	-	-	-	-	19.9	10.5	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH4B.03	2000.0	33.9	4.6	3.0	-	28.6	-	-	-	-	18.0	11.9	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH4B.04	2135.0	32.4	3.1	2.5	-	29.0	-	-	-	-	19.7	13.4	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH4B.05	2400.0	27.2	7.1	7.6	-	22.6	-	-	-	-	23.3	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH4B.06	2748.0	34.9	10.4	4.3	-	14.3	-	-	-	-	24.8	11.5	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH4B.07	2788.0	30.5	6.5	5.5	-	26.6	-	-	-	-	20.2	9.7	-	-	-	1.0	-	-	-	-	-	-	-	-	-
MCSH4B.08	3068.0	24.5	13.9	13.1	-	21.0	-	-	-	-	17.1	9.0	-	-	-	1.4	-	-	-	-	-	-	-	-	-
MCSH4B.09	3148.0	11.0	19.7	22.0	-	1.9	-	-	-	-	39.6	2.8	-	-	-	3.0	-	-	-	-	-	-	-	-	-
MCSH4B.10	3468.0	22.9	18.2	19.9	-	5.7	-	-	-	-	17.3	7.4	-	-	-	1.3	-	-	-	-	-	-	7.3	-	-

(McDowell, unpublished data)

Well Elmore 3
Selected Bulk Shales

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	MICA	ILLI	IMIX	EMIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	TALC	PYRI	HEMA	PHRR	COPY	SPHA	AMPH	EPID	ANNY	GYPG	ZEOL
MCSH1B.01	1210.0	21.0	3.2	3.6	-	13.4	17.9	13.8	-	1.8	3.8	16.3	2.8	-	-	1.6	-	-	-	-	-	-	0.7	-	-
MCSH1B.02	1409.0	20.3	3.8	3.2	-	13.6	21.3	17.7	-	2.2	5.3	9.1	2.5	-	-	-	-	-	-	-	-	-	0.9	-	-
MCSH1B.03	1415.0	16.2	3.9	2.6	-	13.5	20.8	16.8	-	1.1	3.9	18.5	1.9	-	-	1.3	-	-	-	-	-	-	0.6	-	-
MCSH1B.04	1600.0	31.0	3.9	3.1	-	18.8	14.0	-	-	-	14.3	10.9	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH1B.05	1810.0	33.5	2.3	2.7	-	19.2	12.1	-	-	-	13.4	16.8	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH1B.06	1960.0	33.0	3.1	2.0	-	20.4	14.7	-	-	-	13.2	13.6	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH1B.07	2160.0	36.7	3.7	3.9	-	21.8	8.3	-	-	-	14.3	11.4	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH1B.08	2280.0	33.0	3.0	3.3	-	22.0	10.5	-	-	-	15.5	12.5	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH1B.09	2300.0	28.2	3.6	1.4	-	16.4	7.9	-	-	-	10.2	30.0	-	-	-	1.1	-	-	-	-	-	-	2.2	-	-
MCSH1B.10	2403.0	32.3	3.7	2.9	-	25.9	6.7	-	-	-	16.1	12.4	-	-	-	-	-	-	-	-	-	-	-	-	-
MCSH1B.11	2490.0	31.1	3.7	3.6	-	25.5	9.1	-	-	-	16.8	9.0	-	-	-	1.0	-	-	-	-	-	-	-	-	-

(McDowell, unpublished data)

APPENDIX 3

SANDSTONE X-RAY DIFFRACTION DATA

Well Magmamax 2
Selected Bulk Sandstones

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	MICA	ILLI	INIX	EMIX	MONT	KAOL	CHLO	CALC	DOLO	AXER	TALC	PYRI	HEMA	PIRR	COPY	SPHA	ATPH	EPID	ANHY	GYP	ZEOL
MC001B	1240	29.5	7.8	13.6	-	7.2	6.6	-	-	-	4.6	19.4	4.5	6.7	-	-	-	-	-	-	-	-	-	-	-
MC002B	1430	45.2	5.4	11.4	-	7.4	-	-	-	-	2.1	24.3	-	3.2	-	-	-	-	-	-	-	-	-	-	-
MC003B	1520	57.4	5.4	8.2	-	7.1	6.7	-	-	-	7.0	8.3	-	-	-	-	-	-	-	-	-	-	-	-	-
MC004B	1540	58.1	5.4	3.6	-	5.6	5.1	-	-	-	6.4	27.2	-	-	-	-	-	-	-	-	-	-	-	-	-
MC005B	1700	58.1	5.4	5.4	-	7.9	5.1	-	-	-	6.4	19.7	-	-	-	-	-	-	-	-	-	-	-	-	-
MC006B	1820	56.4	5.7	15.0	-	11.7	-	-	2.8	-	6.0	13.3	-	-	-	-	-	-	-	-	-	-	-	-	-
MC007B	1830	56.2	8.0	12.5	-	2.9	-	-	-	-	6.0	13.5	-	-	-	-	-	-	-	-	-	-	-	-	-
MC008B	1940	55.9	9.2	11.6	-	1.9	-	-	3.3	-	5.9	12.1	-	-	-	-	-	-	-	-	-	-	-	-	-
MC009B	2000	56.5	8.5	11.7	-	3.2	-	-	-	-	7.9	12.2	-	-	-	-	-	-	-	-	-	-	-	-	-
MC010B	2050	56.1	12.9	8.3	-	1.7	-	-	1.8	-	10.8	8.4	-	-	-	-	-	-	-	-	-	-	-	-	-
MC011B	2120	58.5	10.0	11.0	-	3.7	-	-	-	-	11.9	10.8	-	-	-	-	-	-	-	-	-	-	-	-	2.2
MC012B	2180	55.5	4.6	7.1	6.4	-	-	-	-	-	12.9	8.5	-	-	-	1.0	-	-	-	-	-	-	-	-	4.1
MC013B	2240	59.8	4.3	7.2	2.6	-	-	-	-	-	9.7	8.4	-	-	-	-	-	-	-	-	-	-	-	-	4.1
MC014B	2360	59.3	9.2	8.8	2.3	-	-	-	3.3	-	8.9	7.1	-	-	-	-	-	-	-	-	-	-	-	-	0.9
MC015B	2420	54.7	10.2	6.8	1.1	-	-	-	3.3	-	10.4	6.6	-	-	-	-	-	-	-	-	-	-	-	-	-
MC016B	2480	54.1	11.0	7.9	1.1	-	-	-	3.3	-	10.9	6.9	-	-	-	-	-	-	-	-	-	-	-	-	-
MC017B	2570	64.1	10.5	8.9	-	-	-	-	3.5	-	5.4	5.0	-	-	-	-	-	-	-	-	-	-	-	-	-
MC018B	2690	43.3	13.0	14.3	2.1	-	-	-	5.5	-	4.6	5.0	-	-	-	1.1	-	-	-	-	-	-	-	-	-
MC019B	2780	51.9	14.9	9.7	-	-	-	-	2.5	-	7.7	5.0	-	-	-	-	-	-	-	-	-	-	-	-	-
MC020B	2930	58.3	18.6	5.6	-	-	-	-	4.8	-	5.5	4.4	-	-	-	1.1	-	-	-	-	-	-	-	-	-
MC021B	2930	57.8	19.4	5.1	-	-	-	-	4.8	-	4.7	5.4	-	-	-	1.2	-	-	-	-	-	-	-	-	-
MC022B	3080	57.1	19.3	4.8	1.9	-	-	-	5.7	-	10.7	2.1	-	-	-	1.0	-	-	-	-	-	-	-	-	-
MC023B	3140	55.2	10.6	8.6	2.3	-	-	-	5.8	-	7.4	10.1	-	-	-	-	-	-	-	-	-	-	-	-	-
MC024B	3240	51.4	13.5	11.9	-	-	-	-	5.5	-	6.6	4.4	-	-	-	-	-	-	-	-	-	-	-	-	-
MC025B	3290	42.5	20.1	8.8	1.0	-	-	-	5.5	-	6.6	4.4	-	-	-	2.0	-	-	-	-	-	-	-	-	-
MC026B	3320	50.0	20.0	7.7	-	-	-	-	5.5	-	5.5	5.5	-	-	-	0.9	-	-	-	-	-	-	-	-	-
MC027B	3358	52.1	23.2	7.4	-	-	-	-	5.5	-	6.4	5.5	-	-	-	0.9	-	-	-	-	-	-	-	-	-
MC028B	3410	35.1	21.1	7.4	-	7.1	-	-	5.5	-	18.1	9.7	-	-	-	1.4	-	-	-	-	-	-	-	-	-
MC029B	3440	34.0	24.0	12.9	3.4	-	-	-	5.5	-	13.3	9.3	-	-	-	1.4	-	-	-	-	-	-	-	-	-
MC030B	3503	47.9	18.3	6.1	2.8	-	-	-	2.1	-	4.8	1.1	-	-	-	1.8	-	-	-	-	-	-	-	-	-
MC031B	3550	39.2	18.0	8.7	2.0	-	-	-	5.5	-	5.1	0.5	-	-	-	1.0	-	-	-	-	-	-	-	-	-
MC032B	3720	36.6	21.0	6.9	4.4	-	-	-	5.5	-	8.8	8.8	-	-	-	1.5	-	-	-	-	-	-	-	-	-
MC033B	3780	49.0	22.4	6.5	-	-	-	-	5.5	-	6.5	8.8	-	-	-	5.6	-	-	-	-	-	-	-	-	-
MC034B	3840	29.8	17.1	4.1	-	-	-	-	5.5	-	5.5	8.8	-	-	-	-	-	-	-	-	-	-	-	-	-
MC035B	3930	43.2	18.5	8.2	0.9	-	-	-	5.5	-	5.2	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-
MC036B	3950	44.3	22.4	6.4	8.2	-	-	-	5.5	-	5.1	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-
MC037B	4020	40.9	19.3	6.6	3.5	-	-	-	5.5	-	16.7	1.6	-	-	-	-	-	-	-	-	-	-	-	-	-
MC038B	4032	45.9	16.3	8.0	-	-	-	-	5.5	-	1.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MC039B	4140	51.8	14.4	8.7	-	-	-	-	5.5	-	3.7	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-
MC040B	4200	52.1	14.2	9.6	8.5	-	-	-	5.5	-	3.7	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-
MC041B	4250	46.4	21.0	10.0	-	-	-	-	5.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MC042B	4310	41.4	17.3	13.1	2.5	-	-	-	5.5	-	7.8	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-

(McDowell, unpublished data)

Well Magmamax 3
Selected Bulk Sandstones

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	MICA	ILLI	INIX	ZNIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	TALC	PYRI	HEMA	PHOR	COPY	SPHA	AMPH	EPID	ANNY	GYP	ZEOL
MD001B	1210	44.4	3.1	9.5	-	-	-	-	-	-	3.6	31.9	-	-	-	-	-	-	-	-	-	-	-	-	-
MD002B	1270	51.6	3.6	12.4	-	-	-	-	-	-	1.4	23.8	-	-	-	-	-	-	-	-	-	-	-	-	-
MD003B	1300	45.6	3.6	10.4	-	-	-	-	-	-	1.8	33.8	-	-	-	-	-	-	-	-	-	-	-	-	-
MD004B	1330	44.1	3.9	8.4	-	-	-	-	-	-	2.3	35.6	-	-	-	-	-	-	-	-	-	-	-	-	-
MD005B	1360	43.3	4.0	9.7	-	-	-	-	-	-	1.9	32.2	-	-	-	-	-	-	-	-	-	-	-	-	-
MD006B	1430	39.8	6.4	6.6	-	-	-	-	-	-	2.7	12.4	2.7	-	-	-	-	-	-	-	-	-	-	-	-
MD007B	1465	46.3	5.8	4.7	-	-	-	-	-	-	1.1	33.2	1.7	-	-	-	-	-	-	-	-	-	-	-	-
MD008B	1525	45.3	4.6	6.2	-	-	-	-	-	-	3.4	29.9	2.3	-	-	-	-	-	-	-	-	-	-	-	-
MD009B	1590	48.3	7.9	9.0	-	-	-	-	-	-	2.8	12.3	-	-	-	-	-	-	-	-	-	-	-	-	-
MD010B	1270	43.5	3.8	9.3	-	-	-	-	-	-	3.0	34.4	-	-	-	-	-	-	-	-	-	-	-	-	-
MD011B	1930	55.7	6.6	5.5	-	-	-	-	-	-	7.2	13.5	0.6	-	-	-	-	-	-	-	-	-	-	-	-
MD012B	1950	57.1	6.6	5.5	-	-	-	-	-	-	6.4	16.4	-	-	-	-	-	-	-	-	-	-	-	-	-
MD013B	2080	58.6	8.8	5.5	-	-	-	-	-	-	8.8	6.8	-	-	-	-	-	-	-	-	-	-	-	-	-
MD014B	2200	57.1	5.5	5.5	-	-	-	-	-	-	6.9	18.2	-	-	-	-	-	-	-	-	-	-	-	-	-
MD015B	2370	56.4	6.6	3.8	-	-	-	-	-	-	6.8	14.2	-	-	-	-	-	-	-	-	-	-	-	-	-
MD016B	2400	58.1	6.6	3.8	5.2	-	-	-	-	-	10.4	11.1	-	-	-	-	-	-	-	-	-	-	-	-	-
MD017B	2500	61.9	8.2	4.2	-	-	-	-	-	-	7.1	12.6	-	-	-	-	-	-	-	-	-	-	-	-	-
MD018B	2560	43.3	2.6	6.6	-	-	-	-	-	-	7.9	29.0	-	-	-	-	-	-	-	-	-	-	-	-	-
MD019B	2620	66.4	2.2	2.0	9.5	-	-	-	-	-	7.6	8.8	-	-	-	-	-	-	-	-	-	-	-	-	-
MD020B	2650	68.2	1.3	1.8	11.9	-	-	-	-	-	8.0	8.8	-	-	-	-	-	-	-	-	-	-	-	-	-
MD021B	2740	68.2	6.6	5.4	11.1	-	-	-	-	-	9.2	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-
MD022B	2530	55.8	10.9	7.7	-	-	-	-	-	-	14.7	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-
MD023B	2980	52.4	15.6	7.2	-	-	-	-	-	-	20.0	2.4	-	-	-	-	-	-	-	-	-	-	-	-	-
MD024B	3070	56.7	14.7	6.4	-	-	-	-	-	-	16.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MD025B	3130	46.6	19.3	11.0	-	-	-	-	-	-	9.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MD026B	3360	44.6	19.6	12.0	-	-	-	-	-	-	7.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MD027B	3420	49.9	15.1	8.6	-	-	-	-	-	-	11.2	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-
MD028B	3480	32.2	24.3	9.5	-	-	-	-	-	-	15.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MD029B	3570	28.0	12.5	8.6	7.0	-	-	-	-	-	8.9	4.7	-	-	-	-	-	-	-	-	-	-	-	-	-
MD030B	3680	52.8	22.4	5.5	2.8	-	-	-	-	-	2.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MD031B	4000	55.2	24.0	7.0	-	-	-	-	-	-	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(McDowell, unpublished data)

Well Sinclair 4
Selected Bulk Sandstones

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	MICA	ILLI	INIX	ZNIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	TALC	PYRI	HEMA	PHOR	COPY	SPHA	AMPH	EPID	ANNY	GYP
MS14001B	2855	34.9	6.1	4.4	-	-	3.2	-	-	-	7.2	13.5	-	-	-	-	-	-	-	-	-	-	-	-
MS14002B	3170	48.3	4.7	17.4	-	-	-	-	-	-	11.1	8.4	-	-	-	-	-	-	-	-	-	-	-	-
MS14003B	3233	56.9	1.9	16.8	-	-	-	-	-	-	8.4	8.2	-	-	-	-	-	-	-	-	-	-	-	-
MS14004B	3448	44.8	3.3	9.7	-	-	-	-	-	-	17.6	10.8	-	-	-	-	-	-	-	-	-	-	-	-
MS14005B	3733	61.3	5.7	7.7	-	-	-	-	-	-	8.1	10.0	-	-	-	-	-	-	-	-	-	-	-	-
MS14006B	3793	53.3	7.3	6.1	-	-	-	-	-	-	13.1	13.9	-	-	-	-	-	-	-	-	-	-	-	-
MS14007B	3828	50.4	6.5	5.7	-	-	-	-	-	-	12.2	15.2	-	-	-	-	-	-	-	-	-	-	-	-
MS14008B	4109	45.8	7.8	4.1	-	-	-	-	-	-	14.6	10.2	-	-	-	-	-	-	-	-	-	-	-	-
MS14009B	4202	51.9	6.7	5.7	-	-	-	-	-	-	10.3	15.0	-	-	-	-	-	-	-	-	-	-	-	-
MS14010B	4386	59.5	-	5.5	-	-	-	-	-	-	16.0	10.6	-	-	-	-	-	-	-	-	-	-	-	-
MS14011B	4543	60.3	0.4	11.6	-	-	-	-	-	-	8.5	12.6	-	-	-	-	-	-	-	-	-	-	-	-
MS14012B	4727	51.8	5.0	7.0	-	-	-	-	-	-	12.4	16.3	-	-	-	-	-	-	-	-	-	-	-	-
MS14013B	4865	59.5	7.2	8.1	-	-	-	-	-	-	9.5	10.3	-	-	-	-	-	-	-	-	-	-	-	-
MS14014B	4948	57.5	5.4	6.0	-	-	-	-	-	-	7.4	9.6	-	-	-	-	-	-	-	-	-	-	-	-
MS14015B	5011	52.7	7.8	6.6	-	-	-	-	-	-	11.9	13.9	-	-	-	-	-	-	-	-	-	-	-	-
MS14016B	5156	55.4	5.0	5.2	-	-	-	-	-	-	11.3	12.1	-	-	-	-	-	-	-	-	-	-	-	-

(McDowell, unpublished data)

Well I.I.D. 2
Selected Bulk Sandstones

SAMPLE NO.	DEPT	QWAR	PLAG	ALKA	HTCA	ILLI	SNIX	ENIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	TALC	PYRI	META	PHRR	COPY	SPIN	ASPH	EPID	ASHY	GYPS	ZEOL
FF2-6012	780	44.4	33.3	7.0	..	2.9	..	..	..	2.6	..	22.1	1.0	..	..	..	..	..	..	..	..	..	17.5	..	..
FF2-6025	840	46.2	33.3	8.0	..	..	..	..	..	..	..	22.1	1.0	..	..	..	..	..	..	..	..	..	32.9	..	..
FF2-6039	900	44.4	33.3	8.0	..	..	..	..	..	1.2	..	33.5	1.0	..	..	..	..	..	..	..	..	..	5.4	..	..
FF2-6043	1260	44.4	33.3	4.0	..	..	9.8	..	..	..	..	10.0	1.0	..	..	..	..	..	..	..	..	..	1.8	..	..
FF2-6058	1440	68.0	33.3	4.0	..	..	..	..	..	..	..	11.0	..	..	..	1.1	..	..	..	..	..	..	..	..	..
FF2-6068	1530	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	1.1	..	..	..	..	..	..	..	..	..
FF2-6078	1560	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	1.1	..	..	..	..
FF2-6088	1630	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6098	1680	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6108	1710	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6118	1770	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6128	2400	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6138	2550	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6148	2880	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6158	2940	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6168	3340	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6178	3220	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6188	3405	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6198	3480	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6208	3540	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6218	4130	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6228	4200	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6238	4320	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6248	4470	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6258	4750	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6268	4850	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6278	4970	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6288	4920	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6298	5340	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6308	5370	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6318	5470	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6328	5570	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6333	5710	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..
FF2-6333	5830	68.0	33.3	4.0	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	..	..

(McDowell, unpublished data)

Well Sinclair 3 Selected Bulk Sandstones

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	MICA	ILLI	INIX	EMIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	TALC	PYRI	HEHA	PIRR	COPY	SPHA	AMPH	EPID	ANHY	GYP	ZEOL
MSJ-001B	2149																						0.7		
MSJ-002B	2150																						0.6		
MSJ-003B	2151																						1.1		
MSJ-004B	2152																						1.3		
MSJ-005B	2153																						1.7		
MSJ-006B	2154																						1.3		
MSJ-007B	2155																						1.7		
MSJ-008B	2156																						1.3		
MSJ-009B	2157																						1.7		
MSJ-010B	2158																						1.3		
MSJ-011B	2159																						1.7		
MSJ-012B	2160																						1.3		
MSJ-013B	2161																						1.7		
MSJ-014B	2162																						1.3		
MSJ-015B	2163																						1.7		
MSJ-016B	2164																						1.3		
MSJ-017B	2165																						1.7		
MSJ-018B	2166																						1.3		
MSJ-019B	2167																						1.7		
MSJ-020B	2168																						1.3		
MSJ-021B	2169																						1.7		
MSJ-022B	2170																						1.3		
MSJ-023B	2171																						1.7		
MSJ-024B	2172																						1.3		
MSJ-025B	2173																						1.7		
MSJ-026B	2174																						1.3		
MSJ-027B	2175																						1.7		
MSJ-028B	2176																						1.3		
MSJ-029B	2177																						1.7		
MSJ-030B	2178																						1.3		
MSJ-031B	2179																						1.7		
MSJ-032B	2180																						1.3		
MSJ-033B	2181																						1.7		
MSJ-034B	2182																						1.3		
MSJ-035B	2183																						1.7		
MSJ-036B	2184																						1.3		
MSJ-037B	2185																						1.7		
MSJ-038B	2186																						1.3		
MSJ-039B	2187																						1.7		
MSJ-040B	2188																						1.3		
MSJ-041B	2189																						1.7		
MSJ-042B	2190																						1.3		
MSJ-043B	2191																						1.7		
MSJ-044B	2192																						1.3		
MSJ-045B	2193																						1.7		
MSJ-046B	2194																						1.3		
MSJ-047B	2195																						1.7		
MSJ-048B	2196																						1.3		
MSJ-049B	2197																						1.7		
MSJ-050B	2198																						1.3		
MSJ-051B	2199																						1.7		
MSJ-052B	2200																						1.3		
MSJ-053B	2201																						1.7		
MSJ-054B	2202																						1.3		
MSJ-055B	2203																						1.7		
MSJ-056B	2204																						1.3		
MSJ-057B	2205																						1.7		
MSJ-058B	2206																						1.3		
MSJ-059B	2207																						1.7		
MSJ-060B	2208																						1.3		
MSJ-061B	2209																						1.7		
MSJ-062B	2210																						1.3		
MSJ-063B	2211																						1.7		
MSJ-064B	2212																						1.3		
MSJ-065B	2213																						1.7		
MSJ-066B	2214																						1.3		
MSJ-067B	2215																						1.7		
MSJ-068B	2216																						1.3		
MSJ-069B	2217																						1.7		
MSJ-070B	2218																						1.3		
MSJ-071B	2219																						1.7		
MSJ-072B	2220																						1.3		
MSJ-073B	2221																						1.7		
MSJ-074B	2222																						1.3		
MSJ-075B	2223																						1.7		
MSJ-076B	2224																						1.3		
MSJ-077B	2225																						1.7		
MSJ-078B	2226																						1.3		
MSJ-079B	2227																						1.7		
MSJ-080B	2228																						1.3		
MSJ-081B	2229																						1.7		
MSJ-082B	2230																						1.3		
MSJ-083B	2231																						1.7		
MSJ-084B	2232																						1.3		
MSJ-085B	2233																						1.7		
MSJ-086B	2234																						1.3		
MSJ-087B	2235																						1.7		
MSJ-088B	2236																						1.3		
MSJ-089B	2237																						1.7		
MSJ-090B	2238																						1.3		

(McDowell, unpublished data)

SAMPLE NO.	DEPT	QUAR	PLAC	ALKA	NICA	ILLI	IMIX	2MIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	SIDE	TALC	PYRI	MENA	PHRR	COPY	SPHA	AMPH	EPID	ANHY	GYP	ZEOL
BRIT55 01	1250 0	63 2	8 3	10 9	-	2 5	1 5	-	-	1 1	-	2 5	3 8	6 1	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 02	1700 0	62 1	9 1	13 9	-	2 9	2 1	-	-	1 0	-	3 1	1 8	3 5	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 03	2100 0	37 5	5 0	8 7	-	2 2	2 0	-	-	1 8	-	1 9	8 8	30 3	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 04	2250 0	41 2	4 8	7 7	-	2 1	1 9	-	-	2 7	-	1 3	2 9	16 0	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 05	2500 0	38 3	9 3	8 1	-	4 1	3 2	-	-	1 6	-	1 1	3 3	11 1	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 06	2750 0	31 1	10 6	9 0	-	7 0	-	-	-	-	-	4 1	2 2	22 0	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 07	3250 0	42 1	10 3	8 8	-	3 9	0 4	-	-	2 4	-	3 1	9 9	7 0	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 08	3500 0	36 8	11 6	8 8	-	4 9	3 3	-	-	3 1	-	1 1	0 0	8 2	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 09	3750 0	38 8	10 4	8 1	-	3 9	3 0	-	-	3 1	-	0 0	5 5	10 4	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 10	4000 0	34 0	8 3	3 5	-	4 1	4 3	-	-	2 3	-	0 7	4 4	25 1	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 11	4250 0	49 0	1 6	3 7	-	4 4	3 8	-	-	-	-	1 1	7 7	21 5	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 12	4500 0	45 7	5 3	5 6	-	4 4	4 8	-	-	0 9	-	6 6	4 6	16 0	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 13	4750 0	44 2	6 4	4 4	-	3 8	5 0	-	-	1 6	-	3 0	5 0	18 7	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 14	5000 0	41 8	9 4	3 1	-	3 3	4 4	-	-	0 8	-	3 3	3 3	10 4	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 15	5250 0	40 4	11 4	3 3	-	3 3	5 5	-	-	2 0	-	3 3	3 3	12 1	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 16	5500 0	53 0	7 9	3 8	-	7 7	6 0	-	-	2 1	-	3 3	3 3	14 1	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 17	5750 0	41 0	10 1	4 1	-	4 4	4 4	-	-	0 2	-	3 3	3 3	13 5	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 18	6000 0	58 6	9 6	3 8	-	4 4	4 4	-	-	-	-	3 3	3 3	11 4	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 19	6250 0	40 6	17 0	0 0	-	4 4	4 4	-	-	-	-	3 3	3 3	10 3	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 20	6500 0	48 7	15 5	5 5	-	3 3	6 6	-	-	0 0	-	3 3	3 3	11 8	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 21	6750 0	50 3	11 6	6 6	-	3 3	6 6	-	-	-	-	0 9	3 3	17 6	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 22	7000 0	16 6	33 7	10 0	-	3 3	6 6	-	-	1 1	-	1 1	7 7	11 9	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 23	7300 0	23 7	25 1	1 0	-	5 5	6 6	-	-	2 4	-	3 3	3 3	16 0	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 24	7500 0	40 8	20 8	5 5	-	6 6	6 6	-	-	1 1	-	3 3	3 3	7 7	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 25	7750 0	51 6	9 4	3 3	-	4 4	9 9	-	-	1 1	-	3 3	3 3	8 4	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 26	8000 0	58 2	13 7	1 3	-	5 5	6 6	-	-	-	-	3 3	3 3	1 1	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 27	8500 0	62 3	22 0	1 3	-	5 5	6 6	-	-	-	-	1 1	3 3	1 1	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 28	8750 0	68 0	22 0	1 3	-	5 5	6 6	-	-	-	-	1 1	3 3	1 1	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 29	9000 0	51 1	24 9	2 4	-	5 5	6 6	-	-	-	-	1 1	3 3	4 6	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 30	9250 0	39 9	24 9	10 0	-	3 3	6 6	-	-	1 1	-	3 3	3 3	1 1	-	-	-	-	-	-	-	-	-	-	-	-
BRIT55 31	9750 0	56 3	16 3	6 3	-	3 3	6 6	-	-	-	-	3 3	3 3	1 1	-	-	-	-	-	-	-	-	-	-	-	-

Well Landers 1 Selected Bulk Sandstones

[illegible]

Well Kalin Farms 1
Selected Bulk Sandstones

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	MICA	ILLI	IRIX	EMIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	SIDE	TALC	PYRI	HEMA	PHRR	COPY	SPHA	AMPH	EPID	ANNV	GYPG	ZEOL
LAKA 21	4270.0	42.1	4.9	6.8	-	1.8	1.1	-	-	1.0	-	31.0	4.0	7.3	-	-	-	-	-	-	-	-	-	-	-	-
LAKA 22	4780.0	53.6	-	6.8	-	3.7	3.4	-	-	7.2	-	6.9	7.4	10.5	-	-	-	-	-	-	-	-	-	0.5	-	-
LAKA 23	5110.0	52.6	-	6.6	-	4.0	5.3	-	-	1.2	2.3	20.4	2.6	3.5	-	-	-	-	-	-	-	-	-	0.6	-	-
LAKA 24	5440.0	53.7	2.2	11.6	-	6.8	6.1	-	-	-	3.4	15.4	-	-	-	-	-	-	-	-	-	-	-	0.8	-	-
LAKA 25	5650.0	57.7	3.9	7.4	-	2.7	2.3	-	-	-	3.0	22.2	-	-	-	-	-	-	-	-	-	-	-	0.7	-	-
LAKA 26	5890.0	56.8	9.6	8.0	-	3.3	2.6	-	-	-	2.0	13.2	1.2	2.1	-	-	-	-	-	-	-	-	-	0.9	-	-
LAKA 27	7000.0	65.2	6.3	6.8	-	2.3	-	-	-	-	1.9	13.7	0.8	2.4	-	-	-	-	-	-	-	-	-	0.6	-	-
LAKA 28	7240.0	59.7	7.8	8.3	-	4.1	-	-	-	-	3.0	13.0	0.9	2.3	-	-	-	-	-	-	-	-	-	0.9	-	-
LAKA 29	7510.0	73.0	5.4	6.2	-	3.4	-	-	-	-	3.1	8.2	-	-	-	-	-	-	-	-	-	-	-	0.7	-	-
LAKA 30	7840.0	72.9	4.5	6.1	-	4.5	-	-	-	-	3.2	8.0	-	-	-	-	-	-	-	-	-	-	-	0.8	-	-
LAKA 31	8140.0	66.9	6.3	7.4	-	4.8	-	-	-	-	3.1	8.6	0.6	1.6	-	-	-	-	-	-	-	-	-	0.8	-	-
LAKA 32	8340.0	58.1	9.1	8.0	-	5.5	-	-	-	-	4.1	11.5	0.8	2.0	-	-	-	-	-	-	-	-	-	0.9	-	-

Well River Ranch 1
Selected Bulk Sandstones

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	MICA	ILLI	IRIX	EMIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	TALC	PYRI	HEMA	PHRR	COPY	SPHA	AMPH	EPID	ANNV	GYPG
MT0018	3660	54.9	5.9	17.7	-	-	-	-	-	-	13.7	-	-	-	-	7.9	-	-	-	-	-	-	-	-
MT0020	3600	62.6	4.9	19.2	-	-	-	-	-	-	10.0	-	-	-	-	2.3	-	-	-	-	-	-	-	-
MT0030	3860	75.6	3.4	13.8	-	-	-	-	-	-	4.3	0.6	-	-	-	2.3	-	-	-	-	-	-	-	-
MT0040	4280	56.3	5.5	23.3	-	-	-	-	-	-	3.3	8.6	-	-	-	-	-	-	-	-	-	-	-	-
MT0050	4447	46.0	10.0	23.2	-	-	-	-	-	-	15.4	11.4	-	-	-	2.7	-	-	-	-	-	2.8	-	-
MT0060	4520	33.6	17.0	18.0	2.2	-	-	-	-	-	15.0	11.4	-	-	-	-	-	-	-	-	-	9.1	-	-
MT0070	4600	46.7	9.5	23.3	2.7	-	-	-	-	-	15.0	12.2	-	-	-	1.1	-	-	-	-	-	-	-	-
MT0080	4680	38.8	13.3	9.3	2.7	-	-	-	-	-	14.3	17.8	-	-	-	-	-	-	-	-	-	3.7	-	-
MT0090	4800	51.9	9.9	18.8	2.2	-	-	-	-	-	7.3	9.5	-	-	-	0.9	-	-	-	-	-	-	-	-
MT0100	4910	35.5	7.6	20.5	-	-	-	-	-	-	32.3	3.6	-	-	-	0.5	-	-	-	-	-	-	-	-
MT0110	4990	40.6	6.2	9.9	-	-	-	-	-	-	25.7	2.3	-	-	-	-	-	-	-	0.7	-	13.6	-	-
MT0120	5020	62.8	0.7	12.6	-	-	-	-	-	-	20.3	1.0	-	-	-	2.6	-	-	-	-	-	-	-	-
MT0130	5080	52.6	1.3	16.8	-	-	-	-	-	-	22.5	1.1	-	-	-	1.9	-	-	-	-	-	3.6	-	-
MT0140	5160	48.5	7.3	15.2	-	-	-	-	-	-	16.7	3.0	-	-	-	1.6	-	-	-	-	-	6.3	-	-
MT0150	5310	45.6	4.8	28.6	-	-	-	-	-	-	11.2	6.6	-	-	-	1.0	-	-	-	1.4	-	2.2	-	-
MT0160	5390	40.7	16.0	7.6	3.1	3.1	-	-	-	-	15.0	13.5	-	-	-	-	-	-	-	-	-	-	-	-
MT0170	5490	36.4	15.0	5.4	3.4	3.4	-	-	-	-	13.3	16.1	-	-	-	-	-	-	-	-	-	6.1	-	-
MT0180	5600	36.1	13.2	7.8	-	-	-	-	-	-	9.2	15.1	-	-	-	-	-	-	-	-	-	11.1	7.5	-
MT0190	5710	43.8	15.5	18.0	-	-	-	-	-	-	8.7	3.1	-	-	-	0.9	-	-	-	-	-	6.4	3.5	-
MT0200	5810	43.6	18.8	18.1	-	-	-	-	-	-	15.0	3.2	-	-	-	1.2	-	-	-	-	-	-	-	-
MT0210	5850	36.3	18.7	18.9	-	-	-	-	-	-	12.9	13.2	-	-	-	-	-	-	-	-	-	-	-	-
MT0220	6010	50.9	12.1	11.8	-	-	-	-	-	-	13.2	8.5	-	-	-	0.6	-	-	-	-	-	2.8	-	-
MT0230	6120	42.3	22.5	11.7	-	-	-	-	-	-	9.7	11.8	-	-	-	1.1	-	-	-	-	-	-	-	-
MT0240	6280	44.2	13.3	7.7	-	-	-	-	-	-	13.6	19.6	-	-	-	1.5	-	-	-	-	-	-	-	-
MT0250	6410	43.1	16.0	16.2	-	-	-	-	-	-	13.0	11.7	-	-	-	-	-	-	-	-	-	-	-	-
MT0260	6480	51.5	12.4	3.6	4.2	-	-	-	-	-	14.1	13.4	-	-	-	0.9	-	-	-	-	-	-	-	-
MT0270	6590	44.1	11.4	13.3	-	-	-	-	-	-	11.7	19.5	-	-	-	-	-	-	-	-	-	-	-	-
MT0280	6670	52.2	2.0	3.0	-	-	-	-	-	-	28.9	-	-	-	-	1.3	-	-	-	-	-	9.6	-	-
MT0290	6750	36.3	9.2	4.5	2.1	-	-	-	-	-	25.6	21.4	-	-	-	-	-	-	-	2.2	-	-	-	-
MT0300	7810	49.2	3.9	6.5	-	-	-	-	-	-	3.1	0.6	-	-	-	1.2	3.2	-	-	-	3.6	23.1	5.6	-
MT0310	7900	59.3	3.2	2.7	-	-	-	-	-	-	6.0	-	-	-	-	-	-	-	-	-	27.2	27.2	6.5	-
MT0320	8030	59.4	2.1	-	-	-	-	-	-	-	-	-	-	-	-	1.1	2.0	-	-	-	2.0	26.8	-	-

(McDowell, unpublished data)

SAMPLE NO.	DEPT	QUAR	PLAG	ALKA	NICA	ILLI	INIX	2NIX	MONT	KAOL	CHLO	CALC	DOLO	AKER	TALC	PYRI	HEMA	PHRR	COPY	SPHA	AMPH	EPID	ANTH	GYP	ZEOL
ME1-0018	1575	56.8	3.6	11.3							21.3	21.3									1.2		2.9		
ME1-0028	1640	56.8	3.6	11.3							21.3	21.3								0.8					
ME1-0038	1769	56.8	3.6	11.3							21.3	21.3				1.4				4.6			1.1		
ME1-0048	1820	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0058	1850	56.8	3.6	11.3							21.3	21.3				1.1							1.1		
ME1-0068	1889	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0078	1940	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0088	2000	56.8	3.6	11.3							21.3	21.3				1.1				1.1			3.3		
ME1-0098	2070	56.8	3.6	11.3							21.3	21.3				1.1							1.1		
ME1-0108	2135	56.8	3.6	11.3							21.3	21.3				1.1							1.1		
ME1-0118	2200	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0128	2260	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0138	2320	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0148	2380	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0158	2400	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0168	2450	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0178	2510	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0188	2570	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0198	2630	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0208	2680	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0218	2740	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0228	2800	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0238	2860	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0248	2920	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0258	2980	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0268	3040	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0278	3268	56.8	3.6	11.3							21.3	21.3											1.1		
ME1-0288	3348	56.8	3.6	11.3							21.3	21.3											1.1		

Well Elmore 3
Selected Bulk Sandstones

[illegible]

(McDowell, unpublished data)

APPENDIX 4

RECONNAISSANCE PETROGRAPHIC DESCRIPTION OF WELL BRITZ #3 - SALTON SEA GEOTHERMAL SYSTEM

(Sampled Interval 4250 - 10,250 ft)

The sandstones of Britz #3, classified as subarkose to sublitharenites, are medium-to fine-grained with largely subangular to subrounded detrital clasts. Varying from moderately to poorly sorted, these sandstones are composed of detrital quartz, plagioclase, K-feldspar, biotite, chlorite, muscovite, and the clay minerals (montmorillonite, illite, and kaolinite, Appendix 3). Also present are detrital clasts of volcanic origin, siltstones, and chert. Quartz constitutes approximately 50-75% of the detrital clasts by volume. These grains are dominantly monocrystalline with occasional undulose and polycrystalline individuals. Intergrowths of anhydrite within quartz clasts sporadically occur throughout the well. The feldspars constitute between 10-20% of the detrital mineralogy, approximately 50-60% are microcline and perthitic microcline, with the remainder being plagioclase. The detrital micas, biotite, chlorite, and muscovite, are commonly bent and broken.

The alteration mineralogy includes quartz, calcite, anhydrite, chlorite, pyrite, and microcline (adularia?). Authigenic quartz, although not abundant but found in all of the thin sections examined, usually occurs as optically continuous syntaxial rims on detrital quartz. Epitaxial quartz overgrowths on detrital feldspar and lithic clasts are also sporadically found. The major cementing mineral in this well is calcite. This authigenic mineral occurs as micritic to interlocking sparry cement that encloses sand remnants. Grain size and porosity appear to control the type of cementation; the more coarse-grained sandstones contain the larger crystals; whereas the finer grained, more poorly sorted sandstones contain the micritic cement. Often associated with calcite are euhedral colorless sperulites (mostly occurring in veins) to pore-filling material of anhydrite. Anhydrite is identified by its high, second order birefringence and cubic cleavage. Occasionally, anhydrite appears to be replacing detrital clasts. The sheet silicate, chlorite, pleochroic in deep-green to green colors, is predominantly present below 7000 ft (2133 m). The chlorite is likely an alteration of detrital kaolinite (Muffler and White, 1969). Euhedral to subhedral pyrite is found in all intervals sampled. Microcline (adularia?) is probably the alteration product of plagioclase caused by K-metasomatism. This K-feldspar is present below 7000 ft (2133 m).

APPENDIX 5

COMPUTATION OF R_t AND R_{xo} FROM THE DUAL INDUCTION-LATEROLOG (from Bateman and Konen, 1977b)

$$R_t = (R_{ild})(RatioA)$$

$$\text{where RatioA} = R_{ilm}((GID - GIM)/(GID \cdot R_{ild} - GIM \cdot R_{ilm}))$$

$$GID = 0.096DI - 0.34 + ALPHA - BETA$$

$$ALPHA = 10[.001(156 - 53DI)]$$

$$BETA = 10[.001(25DI - 3780)]$$

$$GIM = 0.0123DI - 0.212 - 0.0037e^{0.04DI}$$

$$G_{LL8} = (DI - 20)/(1.21DI + 20) + 0.343$$

$$DI = (-B + \sqrt{B^2 - 4.0AC})/2A$$

$$A = Y - 0.52X - 0.46$$

$$B = -33Y + 23X + 90$$

$$C = 269Y + 530X + 1589$$

$$Y = (R_{LL8} - R_{ild})/(R_{ilm} - R_{ild})$$

$$X = (R_{LL8} - R_{ild})/R_{ild}$$

$$R_{xo} = R_t \cdot RatioA$$

APPENDIX 6

WELL LANDERS 1 SALINITY FROM ARCHIE'S EQUATION

AT FORMATION TEMPERATURE

depth	ppm	rwc	rt	temp	ppm	rw
4657.	15868.	0.368	0.697	312.	14379.	0.094
4726.	9935.	0.568	1.079	316.	10243.	0.144
4791.	17777.	0.526	1.128	319.	11111.	0.132
4823.	13520.	0.426	1.183	323.	13951.	0.106
4889.	14623.	0.396	0.998	324.	15092.	0.098
4952.	10991.	0.517	1.237	329.	11324.	0.126
4989.	13179.	0.439	0.995	331.	13524.	0.106
5073.	12201.	0.469	1.191	338.	12587.	0.111
5123.	12682.	0.452	0.953	343.	13084.	0.106
5221.	11436.	0.498	1.086	347.	11796.	0.115
5301.	10940.	0.519	1.193	353.	11283.	0.118
5361.	13441.	0.429	0.998	356.	13867.	0.097
5429.	19453.	0.305	0.692	360.	20092.	0.068
5501.	16401.	0.356	0.750	365.	16933.	0.078
5604.	2241.	2.315	4.487	373.	2302.	0.499
5661.	4167.	1.286	2.690	375.	4287.	0.275
5698.	13170.	0.437	0.992	376.	13590.	0.093
5780.	5661.	0.963	1.832	380.	5829.	0.204
5847.	6370.	0.862	1.998	385.	6561.	0.180
5890.	11615.	0.491	0.991	386.	11981.	0.102
5978.	11235.	0.506	0.993	392.	11589.	0.104
6053.	9326.	0.602	1.088	398.	9615.	0.122
6096.	7929.	0.701	1.590	400.	8171.	0.141
6161.	11693.	0.488	1.494	402.	12063.	0.078
6228.	9834.	0.573	1.817	406.	10140.	0.114
6289.	22851.	0.263	0.896	410.	23614.	0.052
6346.	18277.	0.323	0.886	412.	18876.	0.063
6377.	44468.	0.145	0.793	413.	46023.	0.028
6461.	27381.	0.223	0.603	419.	28307.	0.043
6495.	19563.	0.303	0.696	420.	20208.	0.058
6547.	19225.	0.308	0.699	425.	19858.	0.058
6582.	17726.	0.332	0.795	425.	18306.	0.063
6622.	16179.	0.361	0.887	428.	16705.	0.068
6675.	18952.	0.312	0.810	429.	19576.	0.059
6774.	28961.	0.212	0.811	431.	29944.	0.040
6859.	25327.	0.240	0.896	436.	26179.	0.044
6901.	27214.	0.225	0.792	440.	28135.	0.041
6984.	43109.	0.149	0.500	441.	44615.	0.027
7014.	26641.	0.229	0.796	442.	27541.	0.042
7070.	38442.	0.165	0.603	446.	39775.	0.030
7184.	9335.	0.602	1.998	450.	9625.	0.108
7243.	23910.	0.252	0.999	452.	24712.	0.045
7282.	38608.	0.164	0.589	455.	39947.	0.029
7328.	42989.	0.152	0.493	457.	43557.	0.027
7361.	36181.	0.174	0.561	459.	37431.	0.031

WELL LANDERS 1 SALINITY CALCULATION FROM SP CURVE

CORRECTED TO 75° F						AT FORMATION TEMPERATURE	
depth	ppm	ssp	rwc	rmf	temp	ppm	rw
99.	6261.	10.00	0.876	0.630	75.	6433.	0.876
157.	6282.	10.00	0.873	0.594	80.	6456.	0.823
203.	6290.	10.00	0.872	0.580	82.	6464.	0.803
255.	5405.	14.00	0.990	0.561	85.	5646.	0.882
334.	5330.	15.00	1.019	0.538	89.	5477.	0.870
387.	6111.	11.00	0.896	0.532	90.	6281.	0.757
584.	6804.	8.00	0.810	0.478	101.	6997.	0.614
634.	5778.	13.00	0.944	0.461	105.	5940.	0.691
709.	5949.	12.00	0.913	0.445	109.	6158.	0.645
785.	4931.	18.00	1.097	0.437	111.	5067.	0.762
832.	4956.	18.00	1.092	0.420	116.	5094.	0.727
876.	5134.	17.00	1.056	0.410	119.	5278.	0.686
950.	4688.	20.00	1.150	0.394	124.	4818.	0.719
1013.	5649.	14.00	0.957	0.379	129.	5860.	0.576
1038.	5707.	14.00	0.956	0.374	131.	5970.	0.567
1170.	2209.	12.00	2.347	0.938	137.	2266.	1.335
1222.	1273.	30.00	3.964	0.912	141.	1305.	2.193
1268.	1167.	33.00	4.306	0.894	144.	1196.	2.335
1302.	1208.	32.00	4.169	0.882	146.	1237.	2.232
1370.	1327.	29.00	3.811	0.871	148.	1360.	2.014
1396.	1413.	27.00	3.589	0.861	150.	1449.	1.874
1440.	1183.	33.00	4.251	0.849	152.	1712.	2.190
1481.	1863.	18.00	2.759	0.839	154.	1911.	1.403
1614.	1167.	34.00	4.306	0.799	162.	1196.	2.086
1732.	1404.	28.00	3.612	0.776	167.	1439.	1.700
1805.	1455.	27.00	3.491	0.754	172.	1492.	1.597
1897.	1339.	30.00	3.779	0.742	175.	1372.	1.700
1968.	1346.	30.00	3.759	0.724	179.	1380.	1.655
2049.	1109.	37.00	4.520	0.707	184.	1136.	1.937
2077.	1176.	35.00	4.277	0.705	185.	1204.	1.829
2115.	1074.	40.00	4.880	0.696	187.	1048.	2.059
2180.	1059.	39.00	4.726	0.685	190.	1084.	1.964
2240.	853.	47.00	5.809	0.668	195.	873.	2.354
2311.	1045.	40.00	4.784	0.655	199.	1071.	1.901
2342.	990.	42.00	5.037	0.652	200.	1014.	1.992
2468.	821.	49.00	6.019	0.640	204.	961.	2.335
2511.	1395.	30.00	3.634	0.634	206.	1430.	1.397
2563.	1065.	40.00	4.699	0.627	210.	1091.	1.773
2643.	1448.	29.00	3.507	0.611	214.	1485.	1.299
2704.	824.	50.00	6.000	0.597	219.	844.	2.173
2774.	784.	52.00	6.293	0.592	221.	802.	2.259
2860.	858.	49.00	5.771	0.579	226.	879.	2.027
3015.	762.	54.00	6.466	0.562	233.	780.	2.205
3097.	1654.	25.00	3.090	0.551	238.	1697.	1.032
3136.	815.	52.00	6.065	0.546	240.	834.	2.010
3182.	1091.	41.00	4.591	0.542	242.	1118.	1.509
3225.	865.	50.00	5.727	0.538	244.	886.	1.868
3284.	704.	58.00	6.976	0.535	245.	720.	2.266
3335.	727.	57.00	6.763	0.529	248.	744.	2.171
3381.	710.	58.00	6.919	0.527	249.	726.	2.212
3435.	749.	56.00	6.572	0.525	250.	767.	2.093
3468.	693.	59.00	7.073	0.524	250.	710.	2.250
3508.	854.	51.00	5.798	0.523	251.	875.	1.839
3564.	773.	55.00	6.374	0.519	253.	792.	2.007
3617.	1004.	45.00	4.969	0.515	255.	1029.	1.552
3685.	864.	51.00	5.737	0.511	257.	885.	1.778
3779.	1014.	45.00	4.923	0.503	261.	1039.	1.503
3820.	1128.	41.00	4.448	0.498	264.	1156.	1.343
3835.	1190.	42.00	4.556	0.498	264.	1127.	1.375
3961.	995.	46.00	5.013	0.496	265.	1019.	1.508

WELL LANDERS 1
SALINITY CALCULATION FROM SP CURVE

CORRECTED TO 75° F						AT FORMATION TEMPERATURE	
depth	ppm	ssp	rwc	rmf	temp	ppm	rw
4019.	1024.	45.00	4.879	0.492	267.	1049.	1.457
4063.	954.	48.00	5.219	0.487	270.	977.	1.542
4120.	1510.	30.00	3.371	0.478	275.	1548.	0.978
4160.	1590.	28.00	3.208	0.475	277.	1631.	0.924
4281.	954.	49.00	5.219	0.462	285.	977.	1.463
4380.	1172.	41.00	4.291	0.453	291.	1201.	1.178
4488.	1370.	35.00	3.698	0.441	299.	1405.	0.989
4555.	1882.	22.00	2.734	0.437	302.	1931.	0.724
4657.	1294.	38.00	3.904	0.423	312.	1327.	1.002
4726.	1457.	33.20	3.488	0.418	316.	1494.	0.884
4791.	1132.	44.00	4.433	0.414	319.	1160.	1.113
4823.	1250.	40.00	4.033	0.409	323.	1282.	1.000
4889.	1252.	40.00	4.029	0.408	324.	1284.	0.996
4952.	1483.	33.00	3.429	0.402	329.	1521.	0.835
4989.	1262.	40.00	3.996	0.399	331.	1294.	0.967
5073.	1604.	29.96	3.181	0.391	338.	1646.	0.755
5123.	1402.	36.00	3.616	0.386	343.	1438.	0.847
5221.	1286.	40.00	3.926	0.381	347.	1319.	0.907
5301.	1386.	37.00	3.657	0.375	353.	1421.	0.831
5361.	1242.	42.00	4.059	0.372	356.	1274.	0.915
5429.	1043.	50.00	4.793	0.368	360.	1069.	1.069
5501.	1148.	46.00	4.375	0.363	365.	1177.	0.962
5607.	1267.	42.00	3.984	0.355	373.	1299.	0.858
5661.	1374.	38.42	3.688	0.353	375.	1409.	0.790
5698.	1559.	32.70	3.269	0.352	376.	1600.	0.698
5698.	1741.	28.00	2.944	0.344	385.	1787.	0.614
5890.	1313.	41.00	3.849	0.343	386.	1357.	0.801
6053.	1607.	46.00	3.177	0.251	398.	1649.	0.642
6096.	2367.	28.00	2.198	0.250	400.	2432.	0.442
6161.	1874.	39.00	2.744	0.249	402.	1924.	0.549
6228.	2075.	34.40	2.491	0.246	406.	2131.	0.494
6346.	2078.	34.56	2.487	0.243	412.	2134.	0.486
6377.	2119.	33.66	2.442	0.243	413.	2176.	0.476
6461.	2041.	35.70	2.530	0.239	419.	2096.	0.486
6495.	1867.	40.00	2.754	0.238	420.	1917.	0.528
6547.	1462.	52.00	3.475	0.236	425.	1500.	0.658
6582.	1525.	50.00	3.339	0.235	425.	1564.	0.632
6622.	1351.	56.00	3.746	0.234	428.	1386.	0.705
6675.	1532.	50.00	3.325	0.233	429.	1571.	0.624
6774.	1356.	56.00	3.732	0.232	431.	1391.	0.697
6901.	1489.	52.00	3.415	0.228	440.	1528.	0.625
6984.	1612.	48.16	3.166	0.227	441.	1655.	0.578
7014.	993.	72.00	5.021	0.227	442.	1018.	0.913
7070.	1580.	49.44	3.229	0.225	446.	1621.	0.583
7184.	2022.	37.45	2.554	0.223	450.	2076.	0.457
7243.	1660.	47.30	3.079	0.222	452.	1704.	0.549
7282.	1210.	63.22	4.162	0.220	455.	1241.	0.737
7328.	1204.	63.60	4.181	0.219	457.	1235.	0.737
7361.	1021.	71.98	4.890	0.218	459.	1047.	0.858

WELL LANDERS 1
SALINITY CALCULATION FROM FLUSHED ZONE DATA

AT 75° F						AT FORMATION TEMPERATURE		
depth	ppm	rwc	rt	rxo	rmf	temp	ppm	rw
99.	13199.	0.436	1.169	1.690	0.630	75.00	13598.	0.436
157.	14681.	0.395	0.789	1.259	0.594	80.00	15119.	0.372
203.	15969.	0.365	0.665	1.147	0.580	82.00	16450.	0.337
255.	14772.	0.393	0.658	1.056	0.561	85.00	15216.	0.350
334.	22400.	0.268	0.365	0.859	0.538	89.00	23099.	0.229
387.	29351.	0.210	0.221	0.664	0.532	90.00	30287.	0.177
544.	39909.	0.160	0.191	0.755	0.478	101.00	41116.	0.121
634.	28882.	0.213	0.255	0.755	0.461	105.00	29812.	0.156
709.	21256.	0.281	0.395	0.886	0.445	109.00	21926.	0.198
785.	22626.	0.265	0.378	0.897	0.437	111.00	23344.	0.184
832.	20792.	0.287	0.397	0.873	0.420	116.00	21450.	0.191
875.	30952.	0.200	0.253	0.797	0.410	119.00	31962.	0.130
950.	13513.	0.426	0.392	0.580	0.394	124.00	13927.	0.267
1013.	325045.	0.032	0.041	0.806	0.379	129.00	336427.	0.019
1038.	20409.	0.292	0.498	0.882	0.374	131.00	21058.	0.173
1170.	4962.	1.000	1.588	2.401	0.938	137.00	5101.	0.620
1222.	6306.	0.870	1.242	2.354	0.912	141.00	6488.	0.481
1268.	6395.	0.858	1.168	2.243	0.894	144.00	6580.	0.466
1302.	7083.	0.790	1.209	2.556	0.882	146.00	7290.	0.417
1370.	6562.	0.838	1.048	2.043	0.871	148.00	6752.	0.443
1396.	10361.	0.546	1.392	4.203	0.865	149.00	10675.	0.287
1440.	8583.	0.651	0.980	2.229	0.849	152.00	8838.	0.335
1481.	6300.	0.871	1.200	2.272	0.839	154.00	6482.	0.443
1614.	5635.	0.584	0.814	2.297	0.799	162.00	9926.	0.283
1732.	9273.	0.606	0.961	2.344	0.776	167.00	9553.	0.285
1805.	10106.	0.559	0.859	2.535	0.754	172.00	10413.	0.256
1897.	12308.	0.465	0.764	2.707	0.742	175.00	12689.	0.209
1968.	13667.	0.422	0.611	2.386	0.726	179.00	14094.	0.186
2049.	10928.	0.520	0.911	2.892	0.707	184.00	11263.	0.223
2077.	13228.	0.435	0.705	2.674	0.705	184.50	13640.	0.186
2115.	14527.	0.399	0.592	2.446	0.696	187.00	14984.	0.168
2180.	14216.	0.407	0.576	2.335	0.685	190.00	14663.	0.169
2240.	17533.	0.335	0.545	2.680	0.668	195.00	18095.	0.136
2311.	16456.	0.355	0.605	2.809	0.655	199.00	16981.	0.141
2342.	16656.	0.351	0.518	2.432	0.652	200.00	17188.	0.139
2468.	18351.	0.321	0.509	2.609	0.640	204.00	18942.	0.125
2511.	65140.	0.105	0.137	2.157	0.634	206.00	67427.	0.040
2563.	14042.	0.412	0.655	2.625	0.622	210.00	14484.	0.155
2643.	22236.	0.270	0.310	1.892	0.611	214.00	22963.	0.100
2704.	11591.	0.492	0.696	2.334	0.597	219.00	11951.	0.178
2774.	16074.	0.363	0.542	2.459	0.592	221.00	16587.	0.130
2815.	10385.	0.545	0.796	2.408	0.582	225.00	10795.	0.192
2860.	18501.	0.319	0.450	2.325	0.579	226.00	19099.	0.112
2928.	19053.	0.311	0.398	2.111	0.567	231.00	19671.	0.107
3015.	17944.	0.328	0.436	2.189	0.562	233.00	18523.	0.112
3136.	15872.	0.367	0.514	2.307	0.546	240.00	16379.	0.122
3182.	19821.	0.390	0.459	2.528	0.542	242.00	20467.	0.098
3225.	22626.	0.265	0.365	2.269	0.538	244.00	23370.	0.087
3284.	17449.	0.337	0.519	2.540	0.535	245.00	18012.	0.109
3335.	19445.	0.305	0.469	2.535	0.529	249.00	20078.	0.098
3381.	16933.	0.346	0.497	2.368	0.527	249.00	17478.	0.111
3435.	17507.	0.336	0.456	2.239	0.525	250.00	18072.	0.107
3468.	15265.	0.381	0.521	2.255	0.524	250.30	15753.	0.121
3508.	13630.	0.423	0.619	2.412	0.523	251.00	14061.	0.134
3564.	21462.	0.279	0.397	2.349	0.519	253.00	22166.	0.088
3617.	15282.	0.381	0.608	2.633	0.515	255.00	15770.	0.119
3685.	15599.	0.373	0.532	2.350	0.511	257.00	16099.	0.116
3779.	12658.	0.453	0.563	2.047	0.503	261.00	13057.	0.138
3820.	12833.	0.447	0.615	2.267	0.498	264.00	13237.	0.135
3835.	16860.	0.348	0.524	2.488	0.498	264.20	17494.	0.105
3961.	29066.	0.296	0.324	1.805	0.496	265.00	20722.	0.089

WELL LANDERS 1
SALINITY CALCULATION FROM FLUSHED ZONE DATA

depth	AT 75° F					AT FORMATION TEMPERATURE		
	ppm	rwc	rt	rxo	rmf	temp	ppm	rw
4019.	14873.	0.390	0.593	2.508	0.492	267.00	15348.	0.117
4063.	14644.	0.396	0.600	2.500	0.487	270.00	15111.	0.117
4120.	12780.	0.449	0.548	2.012	0.478	275.00	13183.	0.130
4160.	11599.	0.491	0.592	1.985	0.475	277.00	11962.	0.142
4281.	15828.	0.368	0.596	2.668	0.462	285.00	16336.	0.103
4380.	16951.	0.346	0.572	2.728	0.453	291.00	17500.	0.095
4488.	12893.	0.445	0.649	2.403	0.441	299.00	13301.	0.119
4555.	11818.	0.483	0.615	2.099	0.437	302.00	12189.	0.128
4657.	14055.	0.411	0.557	2.232	0.423	312.00	14503.	0.105
4726.	11067.	0.513	0.799	2.566	0.418	316.00	11413.	0.130
4791.	10443.	0.542	0.946	2.878	0.414	319.00	10768.	0.136
4823.	12968.	0.443	0.898	3.341	0.409	323.00	13379.	0.110
4889.	47666.	0.137	0.245	2.964	0.408	324.00	49331.	0.034
4952.	10829.	0.524	1.099	3.459	0.402	329.00	11167.	0.128
4989.	10363.	0.546	0.921	2.783	0.399	331.00	10685.	0.132
5073.	11863.	0.481	0.797	2.730	0.391	338.00	12237.	0.114
5123.	9771.	0.577	0.814	2.328	0.386	342.50	10074.	0.135
5221.	9708.	0.580	0.880	2.501	0.381	347.00	10009.	0.134
5301.	8206.	0.679	1.177	2.858	0.375	353.00	8457.	0.154
5361.	11033.	0.515	0.795	2.546	0.372	356.00	11379.	0.116
5429.	13456.	0.428	0.565	2.176	0.368	360.00	13885.	0.095
5501.	9905.	0.569	0.698	2.020	0.363	365.00	10213.	0.125
5607.	5089.	1.065	3.372	5.222	0.355	373.00	5238.	0.229
5661.	4503.	1.195	2.238	3.088	0.353	375.00	4633.	0.256
5698.	10578.	0.536	0.704	2.168	0.352	376.00	10909.	0.114
5847.	4207.	1.274	1.926	2.491	0.344	385.00	4328.	0.266
5890.	13387.	0.430	0.594	2.278	0.343	386.00	13814.	0.090
6053.	11602.	0.491	0.917	2.321	0.251	398.00	11968.	0.099
6096.	4838.	1.117	1.430	1.593	0.250	400.00	4979.	0.224
6161.	9783.	0.576	1.154	2.491	0.249	402.00	10087.	0.115
6228.	7142.	0.774	1.791	2.879	0.246	406.00	7359.	0.153
6346.	15307.	0.380	0.641	2.097	0.243	412.00	15801.	0.074
6377.	13777.	0.419	0.763	2.264	0.243	412.50	14219.	0.082
6461.	30990.	0.200	0.325	2.025	0.239	419.00	32047.	0.038
6495.	19154.	0.309	0.611	2.457	0.238	420.00	19784.	0.059
6547.	18968.	0.312	0.590	2.352	0.236	425.00	19592.	0.059
6582.	16323.	0.358	0.785	2.728	0.235	425.20	16854.	0.068
6622.	16163.	0.361	0.893	3.075	0.234	428.00	16688.	0.068
6675.	22937.	0.262	0.519	2.463	0.233	429.00	23703.	0.049
6774.	27007.	0.226	0.557	3.064	0.232	431.00	27920.	0.042
6859.	16535.	0.354	0.645	2.267	0.230	436.00	17073.	0.065
6901.	30466.	0.203	0.750	4.598	0.228	440.00	31505.	0.037
6984.	46028.	0.141	0.374	3.303	0.227	441.00	47642.	0.026
7014.	24820.	0.244	0.807	4.110	0.227	442.00	25654.	0.044
7070.	45404.	0.142	0.217	1.894	0.225	446.00	46995.	0.026
7184.	6773.	0.813	1.883	2.879	0.223	450.00	6977.	0.146
7243.	17759.	0.331	0.566	2.124	0.222	452.00	18340.	0.059
7282.	26001.	0.234	0.449	2.388	0.220	455.00	26878.	0.041
7328.	29138.	0.211	0.354	2.083	0.219	457.00	30130.	0.037
7361.	25782.	0.236	0.506	2.671	0.218	459.00	26652.	0.041

WELL LANDERS 2 SALINITY FROM ARCHIE'S EQUATION

DEPTH	PPM	RWC	RT	TEMP	PPM(TF)	R _w (TF)
3017	16109.	0.362	0.428	245.	16625.	0.118
3116	9756.	0.578	0.644	248.	10056.	0.185
3196	18668.	0.316	0.445	254.	19274.	0.099
3248	11984.	0.477	0.645	258.	12359.	0.147
3320	16428.	0.356	0.501	260.	16956.	0.109
3363	14912.	0.389	0.549	262.	15387.	0.118
3385	11605.	0.491	0.750	263.	11968.	0.149
3497	22315.	0.269	0.556	267.	23050.	0.080
3546	22057.	0.272	0.597	270.	22783.	0.080
3582	21740.	0.275	0.551	271.	22477.	0.081
3652	11904.	0.480	0.650	273.	12277.	0.140
3697	11711.	0.487	0.646	275.	12077.	0.141
3740	9435.	0.596	0.693	277.	9725.	0.172
3779	8052.	0.691	0.794	278.	8296.	0.198
3803	12348.	0.464	0.610	280.	12736.	0.132
3892	12787.	0.449	0.652	284.	13191.	0.126
3952	8771.	0.638	0.604	287.	9040.	0.178
4002	13303.	0.433	0.683	290.	13725.	0.119
4097	18308.	0.322	0.525	295.	18404.	0.087
4151	17416.	0.337	0.545	298.	17981.	0.090
4262	18230.	0.373	0.594	299.	18823.	0.086
4315	16229.	0.360	0.698	305.	16753.	0.094
4369	22288.	0.269	0.595	309.	23025.	0.070
4424	22333.	0.269	0.704	311.	23074.	0.069
4485	14476.	0.400	0.645	312.	14939.	0.103
4567	19172.	0.309	0.600	314.	19799.	0.079
4607	16967.	0.346	0.601	315.	17517.	0.088
4666	13596.	0.424	0.602	318.	14029.	0.107
4762	21684.	0.276	0.608	325.	22401.	0.068
4811	13043.	0.434	0.805	327.	13509.	0.108
4857	19534.	0.304	0.617	328.	20174.	0.074
4935	12325.	0.464	0.655	329.	12715.	0.114
4963	12835.	0.447	0.710	330.	13242.	0.109
5027	11841.	0.488	0.806	334.	12058.	0.117
5107	15614.	0.373	0.797	340.	16117.	0.088
5143	12599.	0.455	0.866	344.	12998.	0.106
5194	19661.	0.302	0.794	349.	20307.	0.069
5257	15282.	0.381	0.786	350.	15775.	0.087
5322	22541.	0.266	0.667	350.	23341.	0.061
5350	23203.	0.254	0.705	351.	23476.	0.059
5382	20076.	0.296	0.607	357.	20737.	0.067
5480	21865.	0.274	0.602	359.	22590.	0.061
5562	21337.	0.280	0.407	361.	22044.	0.062
5606	24741.	0.244	0.407	365.	25621.	0.054
5681	24173.	0.250	0.407	369.	24981.	0.054
5712	28437.	0.216	0.356	371.	29399.	0.047
5764	31346.	0.197	0.305	373.	32466.	0.043
5801	45365.	0.143	0.273	375.	46949.	0.031
5967	19585.	0.303	0.566	387.	20240.	0.063
6008	22286.	0.264	0.557	390.	23027.	0.055
6050	19245.	0.307	0.805	392.	19429.	0.063
6109	23871.	0.254	0.499	395.	24669.	0.051
6148	25708.	0.236	0.504	397.	26572.	0.048
6226	23016.	0.261	0.507	402.	23783.	0.052
6278	20436.	0.291	0.549	407.	21111.	0.058
6342	29557.	0.208	0.451	410.	30562.	0.041
6443	18814.	0.314	0.705	420.	19432.	0.060
6480	20900.	0.285	0.702	424.	21593.	0.054
6523	15967.	0.365	0.401	430.	16485.	0.068
6606	13741.	0.418	0.916	434.	14234.	0.078
6647	24592.	0.246	0.553	436.	25417.	0.045
6746	17505.	0.336	0.563	438.	18077.	0.062
6787	24406.	0.248	0.661	439.	25225.	0.045
6831	25707.	0.236	0.602	441.	26573.	0.043
6894	27148.	0.225	0.709	443.	28119.	0.041
6949	28857.	0.213	0.614	447.	29838.	0.038
6991	27717.	0.221	0.616	450.	28656.	0.040
7079	24417.	0.248	0.894	454.	25237.	0.044
7127	19247.	0.308	0.806	459.	19882.	0.054
7175	29915.	0.206	0.893	460.	30935.	0.036
7175	29915.	0.206	0.893	460.	30935.	0.036
7251	26703.	0.228	1.005	463.	27606.	0.040
7298	30226.	0.204	0.995	475.	31258.	0.035
7385	28470.	0.216	0.894	478.	29438.	0.036
7444	18905.	0.313	1.003	480.	19528.	0.053
7491	39550.	0.161	0.610	482.	40926.	0.027
7532	36344.	0.173	0.610	483.	37601.	0.029
7605	54402.	0.122	0.562	490.	56333.	0.020

WELL LANDERS 2 SALINITY CALCULATION FROM SP CURVE

CORRECTED TO 75° F						AT FORMATION TEMPERATURE	
depth	ppm	ssp	rwc	rmf	temp	ppm	rw
200	13086.	-10.00	0.439	0.553	83.	13475.	0.400
304	13036.	-10.00	0.441	0.519	89.	13425.	0.376
362	12944.	-10.00	0.442	0.493	94.	13384.	0.359
362	15916.	-16.00	0.366	0.479	97.	16403.	0.289
400	14826.	-14.00	0.391	0.465	100.	15277.	0.300
428	12907.	-10.00	0.445	0.444	105.	13297.	0.326
554	11270.	-6.00	0.505	0.425	110.	11607.	0.354
602	10846.	-5.00	0.521	0.418	112.	11222.	0.359
661	13705.	-12.00	0.421	0.408	115.	14123.	0.283
699	14617.	-14.00	0.397	0.401	117.	15066.	0.262
770	18851.	-22.00	0.314	0.377	125.	19445.	0.195
801	18222.	-21.00	0.324	0.374	126.	18795.	0.199
892	24406.	-30.00	0.248	0.369	128.	25192.	0.150
934	15935.	-17.00	0.366	0.363	130.	16432.	0.214
976	19913.	-24.00	0.298	0.355	133.	20545.	0.174
1022	13959.	-13.00	0.414	0.350	135.	14390.	0.239
1053	25648.	-32.00	0.236	0.348	136.	26532.	0.135
1099	23961.	-30.00	0.252	0.341	139.	24735.	0.141
1170	26215.	-33.00	0.232	0.332	143.	27069.	0.127
1191	13443.	-12.00	0.428	0.329	144.	13858.	0.242
1305	12462.	-11.00	0.443	0.311	153.	13362.	0.227
1351	12561.	-10.00	0.456	0.309	154.	12948.	0.242
1377	12555.	-10.00	0.457	0.307	155.	12942.	0.231
1447	14590.	-15.00	0.397	0.298	160.	15046.	0.195
1503	14101.	-14.00	0.410	0.289	165.	14541.	0.195
1574	13248.	-12.00	0.434	0.284	168.	13660.	0.203
1614	14482.	-15.00	0.400	0.281	170.	14936.	0.185
1695	15731.	-18.00	0.370	0.267	179.	16228.	0.163
1742	13528.	-13.00	0.426	0.262	183.	13951.	0.184
1804	13487.	-13.00	0.427	0.255	188.	13909.	0.179
1848	13870.	-14.00	0.416	0.252	190.	14305.	0.173
1901	13464.	-13.00	0.428	0.251	191.	13885.	0.177
1975	12324.	-10.00	0.465	0.247	194.	12707.	0.189
2052	7080.	-20.00	0.782	0.535	197.	7269.	0.514
2098	8833.	-28.00	0.634	0.528	200.	9100.	0.251
2201	9337.	-30.00	0.602	0.525	201.	9621.	0.237
2257	10714.	-35.00	0.529	0.518	204.	11044.	0.205
2313	7837.	-24.00	0.709	0.513	206.	8072.	0.273
2346	10354.	-34.00	0.546	0.508	208.	10672.	0.208
2402	10420.	-36.00	0.520	0.504	210.	11258.	0.196
2447	12138.	-40.00	0.471	0.494	214.	12516.	0.174
2486	11460.	-38.00	0.497	0.492	215.	11815.	0.184
2535	11387.	-38.00	0.500	0.483	219.	11741.	0.181
2582	10757.	-36.00	0.527	0.481	220.	11089.	0.190
2634	10164.	-34.00	0.556	0.479	221.	10477.	0.200
2700	10434.	-35.00	0.542	0.477	222.	10755.	0.194
2773	14777.	-48.00	0.393	0.465	228.	15246.	0.137
2822	9757.	-33.00	0.577	0.459	231.	10056.	0.199
2867	14240.	-47.00	0.406	0.455	233.	14691.	0.139
2906	14574.	-48.00	0.397	0.451	235.	15042.	0.134
2981	11994.	-41.00	0.476	0.446	238.	12368.	0.159
3017	12182.	-42.00	0.470	0.433	245.	12564.	0.152
3116	11495.	-40.00	0.496	0.428	248.	11854.	0.159
3196	16072.	-53.00	0.363	0.418	254.	16588.	0.114
2248	13718.	-47.30	0.421	0.412	258.	14153.	0.130
3320	11540.	-41.00	0.442	0.409	260.	11952.	0.151
3363	13875.	-48.00	0.416	0.406	262.	14315.	0.127
3385	11538.	-41.00	0.444	0.404	264.	11898.	0.150
3447	15264.	-52.00	0.381	0.394	267.	15752.	0.114
3548	14789.	-51.00	0.392	0.394	270.	15261.	0.116
3582	14762.	-51.00	0.393	0.393	271.	15233.	0.116
3652	13968.	-44.00	0.414	0.390	273.	14412.	0.121
3697	15038.	-52.00	0.386	0.387	275.	15518.	0.112
3740	14232.	-50.00	0.406	0.385	277.	14685.	0.117
3779	11003.	-40.00	0.516	0.383	278.	11346.	0.148
3803	14524.	-51.00	0.394	0.380	280.	14987.	0.114
3892	14421.	-51.00	0.401	0.375	284.	14881.	0.113
3952	12641.	-46.00	0.454	0.371	287.	13040.	0.126
4002	10041.	-37.00	0.562	0.368	290.	10351.	0.155
4097	13798.	-50.00	0.418	0.362	295.	14237.	0.113
4151	15555.	-55.00	0.374	0.358	298.	16055.	0.100
4262	10962.	-41.00	0.518	0.357	299.	11304.	0.139
4315	17388.	-60.00	0.338	0.350	305.	17952.	0.089
4369	17252.	-60.00	0.340	0.346	309.	17812.	0.088
4424	13774.	-51.00	0.414	0.343	311.	14212.	0.108

WELL LANDERS 2
SALINITY CALCULATION FROM SP CURVE

CORRECTED TO 75° F						AT FORMATION TEMPERATURE	
depth	ppm	ssp	rwc	rmf	temp	ppm	rw
4485	16328.	-58.00	0.354	0.342	312.	16855.	0.092
4567	15489.	-58.00	0.376	0.340	314.	15987.	0.094
4607	13684.	-51.00	0.421	0.339	315.	14120.	0.107
4666	16147.	-58.00	0.362	0.336	318.	16668.	0.091
4762	15942.	-58.00	0.366	0.329	325.	16457.	0.090
4811	15770.	-57.70	0.370	0.327	327.	16279.	0.091
4857	10810.	-42.00	0.525	0.326	328.	11148.	0.128
4935	7003.	-23.75	0.788	0.325	329.	7214.	0.142
4963	12203.	-47.20	0.464	0.324	330.	12588.	0.114
5027	8028.	-29.70	0.693	0.320	334.	8273.	0.166
5107	15046.	-56.68	0.386	0.315	340.	15540.	0.091
5143	11417.	-45.20	0.499	0.311	344.	11776.	0.116
5194	12682.	-50.00	0.452	0.307	349.	13084.	0.104
5257	15635.	-59.00	0.373	0.306	350.	16139.	0.086
5322	12372.	-49.00	0.463	0.306	350.	12764.	0.106
5350	14883.	-57.00	0.390	0.305	351.	15361.	0.089
5382	19423.	-68.87	0.305	0.300	357.	20061.	0.069
5480	15744.	-60.00	0.370	0.298	359.	16252.	0.083
5562	17778.	-65.40	0.331	0.297	361.	18358.	0.074
5606	16647.	-63.00	0.351	0.294	365.	17239.	0.077
5681	15733.	-70.00	0.370	0.353	369.	16242.	0.081
5712	19488.	-79.52	0.304	0.351	371.	20128.	0.066
5764	15611.	-70.00	0.373	0.350	373.	16116.	0.080
5801	18236.	-77.00	0.323	0.348	375.	18833.	0.069
5856	12911.	-62.00	0.445	0.345	378.	13322.	0.095
5895	16021.	-72.00	0.364	0.341	383.	16540.	0.076
5967	12412.	-60.90	0.461	0.337	387.	12806.	0.096
6008	10383.	-53.04	0.545	0.335	390.	10707.	0.112
6050	6545.	-32.10	0.840	0.333	392.	6742.	0.172
6104	8907.	-46.35	0.629	0.330	395.	9182.	0.128
6148	10387.	-53.50	0.545	0.329	397.	10712.	0.110
6226	15453.	-72.00	0.377	0.325	402.	15953.	0.075
6278	14658.	-70.00	0.395	0.321	407.	15140.	0.078
6342	15563.	-73.00	0.374	0.319	410.	16067.	0.073
6443	12072.	-62.00	0.474	0.311	420.	12455.	0.091
6480	8410.	-45.22	0.664	0.308	424.	8669.	0.126
6523	8352.	-45.20	0.668	0.304	430.	8609.	0.125
6606	8299.	-45.10	0.672	0.301	434.	8544.	0.125
6647	9365.	-51.00	0.600	0.300	436.	9656.	0.111
6746	12153.	-63.60	0.471	0.298	438.	12539.	0.087
6787	11756.	-60.00	0.505	0.298	439.	11611.	0.093
6831	13842.	-70.04	0.417	0.296	441.	14286.	0.076
6894	10867.	-58.54	0.522	0.295	443.	11209.	0.095
6944	11747.	-60.50	0.506	0.293	447.	11601.	0.091
6991	12290.	-65.00	0.466	0.291	450.	12681.	0.083
7074	9951.	-55.00	0.567	0.288	454.	10261.	0.101
7127	11222.	-61.20	0.507	0.285	459.	11576.	0.089
7175	16204.	-79.20	0.360	0.284	460.	16731.	0.063
7257	13351.	-70.00	0.431	0.283	463.	13779.	0.075
7298	14497.	-75.00	0.400	0.276	475.	14964.	0.068
7385	23698.	-99.45	0.254	0.274	478.	24492.	0.043
7444	9058.	-51.85	0.619	0.273	480.	9338.	0.104
7491	12968.	-70.00	0.443	0.272	482.	13383.	0.074
7532	12449.	-70.00	0.444	0.271	483.	13363.	0.074
7605	14123.	-74.40	0.404	0.267	490.	14578.	0.067
7652	12265.	-68.00	0.467	0.266	493.	12656.	0.076

WELL LANDERS 2 SALINITY CALCULATION FROM FLUSHED ZONE DATA

AT 75° F							AT FORMATION TEMPERATURE	
depth	ppm	rwc	rt	rxo	rmf	temp	ppm	rw
200	16284.	0.354	0.713	1.206	0.541	85.00	16780.	0.320
232	24594.	0.246	0.490	0.463	0.519	89.00	25367.	0.210
304	18576.	0.318	0.465	0.488	0.493	94.00	19150.	0.254
362	24990.	0.206	0.260	0.767	0.479	97.00	30953.	0.162
400	29842.	0.206	0.268	0.784	0.465	100.00	30843.	0.154
428	42603.	0.151	0.160	0.643	0.444	105.00	44012.	0.110
554	54735.	0.121	0.102	0.512	0.425	110.00	56579.	0.085
602	39384.	0.161	0.201	0.757	0.418	112.00	40684.	0.111
661	56054.	0.119	0.129	0.660	0.408	115.00	57955.	0.080
699	46994.	0.138	0.135	0.591	0.401	117.00	48569.	0.091
770	16790.	0.344	0.295	0.513	0.377	125.00	17315.	0.216
801	18505.	0.319	0.242	0.556	0.374	126.00	19088.	0.196
934	16584.	0.353	0.338	0.582	0.363	130.00	17107.	0.211
976	66536.	0.103	0.111	0.659	0.355	133.00	68828.	0.060
1022	42342.	0.151	0.194	0.744	0.350	135.00	43763.	0.087
1053	55851.	0.119	0.163	0.832	0.348	136.00	57759.	0.068
1099	61783.	0.109	0.143	0.746	0.341	139.00	63908.	0.061
1170	67268.	0.102	0.114	0.713	0.332	143.00	69596.	0.056
1191	36032.	0.175	0.222	0.772	0.329	144.00	37233.	0.095
1305	25115.	0.241	0.608	1.530	0.311	153.00	25933.	0.124
1351	13475.	0.428	1.125	1.544	0.309	154.00	13893.	0.217
1377	16470.	0.455	0.931	1.544	0.307	155.00	16994.	0.174
1447	22464.	0.267	0.682	1.551	0.298	160.00	23196.	0.131
1503	16024.	0.364	1.043	1.824	0.284	165.00	16535.	0.173
1574	25205.	0.241	0.522	1.318	0.284	168.00	26030.	0.113
1615	15674.	0.372	0.794	1.307	0.281	170.00	16169.	0.172
1695	17186.	0.341	0.832	1.481	0.267	174.00	17733.	0.150
1742	23182.	0.260	0.572	1.438	0.262	183.00	23434.	0.112
1804	26444.	0.230	0.500	1.318	0.255	188.00	27317.	0.097
1848	18995.	0.311	0.633	1.234	0.252	190.00	19607.	0.129
1901	21533.	0.278	0.521	1.140	0.251	191.00	22233.	0.115
1975	15707.	0.371	0.881	1.442	0.247	194.00	16205.	0.151
2052	10904.	0.520	0.769	1.971	0.235	197.00	11244.	0.209
2099	13360.	0.431	0.611	1.842	0.224	200.00	13779.	0.170
2201	18414.	0.320	0.479	1.995	0.225	201.00	19011.	0.126
2257	11381.	0.500	0.721	1.923	0.218	204.00	11733.	0.194
2313	18683.	0.316	0.486	2.052	0.213	206.00	19246.	0.122
2346	18021.	0.327	0.483	1.971	0.208	208.00	18601.	0.124
2402	16155.	0.361	0.463	1.708	0.203	210.00	16670.	0.136
2447	15446.	0.377	0.454	1.607	0.194	214.00	15437.	0.140
2486	18283.	0.323	0.477	1.974	0.192	215.00	18872.	0.119
2535	21535.	0.278	0.388	1.862	0.183	219.00	22238.	0.101
2582	22687.	0.265	0.479	1.908	0.181	220.00	23432.	0.095
2634	17563.	0.335	0.472	1.883	0.179	221.00	18128.	0.120
2700	20103.	0.246	0.486	2.194	0.177	222.00	20756.	0.106
2773	20271.	0.243	0.388	1.766	0.165	228.00	20431.	0.102
2827	15554.	0.374	0.365	2.013	0.154	231.00	16054.	0.129
2867	19072.	0.310	0.362	1.558	0.155	234.00	19490.	0.106
2906	20582.	0.284	0.244	1.474	0.151	235.00	21253.	0.098
2981	24442.	0.247	0.407	1.657	0.146	238.00	25250.	0.083
3017	23587.	0.256	0.318	1.654	0.143	245.00	24365.	0.083
3116	24364.	0.248	0.443	2.379	0.128	248.00	25155.	0.080
3196	31068.	0.144	0.259	1.737	0.118	254.00	32115.	0.062
3248	15849.	0.368	0.654	2.371	0.112	258.00	16357.	0.114
3320	32194.	0.143	0.248	1.717	0.109	260.00	34283.	0.054
3363	14537.	0.304	0.429	1.886	0.106	262.00	20174.	0.092
3385	18454.	0.420	0.704	2.444	0.104	263.00	19058.	0.097
3497	24080.	0.251	0.388	2.066	0.099	267.00	24878.	0.075
3548	20692.	0.288	0.471	2.181	0.094	270.00	21370.	0.085
3582	22323.	0.269	0.447	2.221	0.093	271.00	24059.	0.079
3652	18743.	0.315	0.508	2.150	0.090	273.00	19353.	0.092
3697	20515.	0.240	0.486	2.234	0.087	275.00	21188.	0.084
3740	16405.	0.356	0.592	2.215	0.085	277.00	16433.	0.103
3779	15517.	0.375	0.558	1.984	0.083	278.00	16015.	0.108
3803	18028.	0.327	0.523	2.136	0.080	280.00	18611.	0.093
3892	20466.	0.241	0.514	2.354	0.075	284.00	21137.	0.082
3952	18268.	0.323	0.504	2.103	0.071	287.00	18842.	0.090
4002	12830.	0.447	0.644	1.435	0.068	290.00	13246.	0.123
4097	14572.	0.303	0.403	1.776	0.062	295.00	20213.	0.082
4151	20307.	0.243	0.471	2.146	0.058	298.00	20471.	0.074
4262	18161.	0.325	0.584	2.422	0.057	299.00	18752.	0.087
4315	23697.	0.254	0.507	2.656	0.050	305.00	24444.	0.067
4369	21551.	0.277	0.477	2.246	0.046	309.00	22262.	0.072
4424	17245.	0.444	0.603	2.371	0.043	311.00	17856.	0.087

WELL LANDERS 2 SALINITY CALCULATION FROM FLUSHED ZONE DATA

AT 75° F						AT FORMATION TEMPERATURE		
depth	ppm	rwc	rt	rxo	rmf	temp	ppm	rw
4485	18014.	0.327	0.597	2.438	0.342	312.00	18400.	0.084
4567	20721.	0.244	0.513	2.380	0.340	314.00	21404.	0.074
4607	20571.	0.240	0.467	2.151	0.339	315.00	21248.	0.074
4666	19606.	0.303	0.471	2.078	0.346	318.00	20249.	0.076
4762	24204.	0.211	0.333	2.108	0.329	325.00	30191.	0.052
4811	17012.	0.345	0.540	2.283	0.327	327.00	17564.	0.084
4857	20958.	0.245	0.431	2.023	0.326	328.00	21649.	0.070
4935	11784.	0.484	0.533	1.470	0.325	329.00	12155.	0.118
4963	16145.	0.361	0.593	2.193	0.324	330.00	16718.	0.084
5027	13764.	0.419	0.625	1.989	0.320	334.00	14708.	0.101
5107	18491.	0.319	0.570	2.381	0.315	340.00	19095.	0.075
5143	17742.	0.332	0.567	2.281	0.311	344.00	18320.	0.077
5194	15601.	0.373	0.697	2.440	0.307	344.00	16104.	0.086
5237	15935.	0.366	0.665	2.426	0.306	344.50	16450.	0.084
5272	15762.	0.370	0.572	2.063	0.306	350.00	16271.	0.085
5350	15013.	0.347	0.546	2.056	0.305	351.00	15495.	0.084
5382	23127.	0.260	0.465	2.386	0.300	357.00	23847.	0.058
5480	14544.	0.303	0.444	2.194	0.298	359.00	20192.	0.088
5562	23314.	0.258	0.266	1.476	0.297	361.00	23091.	0.057
5606	23832.	0.253	0.272	1.433	0.294	365.00	24628.	0.058
5683	15852.	0.368	0.335	1.477	0.293	364.00	16444.	0.080
5764	21412.	0.279	0.194	1.124	0.290	374.00	22122.	0.060
5801	90814.	0.074	0.071	1.454	0.288	375.00	94110.	0.017
5856	15351.	0.379	0.516	2.209	0.285	378.00	15847.	0.081
5895	15473.	0.376	0.347	1.499	0.281	383.00	15473.	0.079
5967	18772.	0.315	0.395	2.038	0.287	387.00	19388.	0.065
6008	30126.	0.205	0.269	2.135	0.285	390.00	31155.	0.042
6050	45468.	0.142	0.800	4.133	0.283	392.00	47057.	0.029
6104	24086.	0.211	0.284	2.177	0.280	395.00	30073.	0.043
6148	32533.	0.191	0.322	2.737	0.279	397.00	33645.	0.039
6226	30077.	0.205	0.358	2.836	0.275	402.00	31100.	0.041
6278	23740.	0.254	0.507	3.247	0.271	407.00	24586.	0.050
6342	34177.	0.183	0.299	2.650	0.279	418.00	36298.	0.036
6443	29348.	0.210	0.483	3.742	0.271	420.00	30346.	0.040
6480	14654.	0.302	0.454	2.467	0.268	424.00	20302.	0.057
6523	14684.	0.345	0.682	2.807	0.264	430.00	15163.	0.074
6606	16802.	0.349	0.779	3.627	0.261	434.00	17350.	0.065
6647	22476.	0.262	0.406	2.576	0.260	436.00	23743.	0.048
6746	21755.	0.275	0.432	2.552	0.248	438.00	22474.	0.051
6787	27616.	0.222	0.462	3.383	0.248	439.00	28551.	0.041
6831	34343.	0.162	0.359	3.603	0.246	441.00	40709.	0.030
6894	24581.	0.246	0.570	3.754	0.245	443.00	25407.	0.045
6944	23866.	0.253	0.421	2.705	0.243	447.00	24666.	0.046
6991	32045.	0.194	0.424	3.555	0.241	450.00	34142.	0.035
7174	12447.	0.460	0.837	2.454	0.238	454.00	12843.	0.082
7177	20419.	0.291	0.771	4.293	0.235	459.00	21095.	0.051
7175	25777.	0.236	0.808	5.566	0.234	460.00	28646.	0.041
7257	29677.	0.208	0.820	6.409	0.233	463.00	30688.	0.036
7298	44718.	0.144	0.644	7.293	0.276	475.00	46286.	0.025
7385	22713.	0.265	0.890	5.465	0.274	478.00	23472.	0.045
7444	8223.	0.678	0.995	2.384	0.273	480.00	8476.	0.114
7491	27754.	0.221	0.543	3.998	0.272	482.00	28699.	0.047
7532	28544.	0.215	0.557	4.206	0.271	483.00	29519.	0.036
7605	26574.	0.229	0.444	3.142	0.267	490.00	27475.	0.038
7652	27484.	0.219	0.674	4.997	0.266	493.00	28935.	0.036

WELL DEARBORN FARMS 1
SALINITY FROM ARCHIE'S EQUATION

AT FORMATION TEMPERATURE

depth	ppm	rwc	rt	temp	ppm	rw
3024.	17112.	0.343	0.911	214.	17661.	0.127
3096.	19270.	0.307	0.951	216.	19893.	0.113
3142.	17561.	0.335	0.812	220.	18125.	0.121
3249.	18016.	0.327	0.854	225.	18547.	0.115
3349.	14800.	0.352	1.018	226.	15270.	0.138
3447.	15061.	0.386	1.009	230.	15540.	0.133
3446.	15326.	0.380	1.009	235.	15814.	0.124
3542.	16402.	0.356	0.904	236.	16927.	0.120
3571.	22130.	0.271	0.905	237.	22457.	0.091
3623.	17384.	0.338	1.005	239.	17945.	0.112
3673.	15443.	0.371	0.906	244.	16195.	0.121
3754.	15106.	0.385	0.972	246.	15588.	0.124
3787.	17106.	0.343	1.000	249.	17657.	0.110
3849.	17527.	0.335	0.960	250.	18093.	0.107
3932.	20125.	0.295	0.811	256.	20782.	0.092
4062.	17441.	0.337	0.905	260.	18004.	0.103
4081.	19345.	0.306	0.830	263.	19975.	0.093
4122.	12369.	0.463	1.003	264.	12758.	0.140
4224.	14774.	0.393	1.007	269.	15246.	0.116
4284.	14850.	0.391	1.063	273.	15324.	0.114
4324.	18373.	0.321	0.847	276.	18970.	0.093
4373.	20002.	0.297	0.907	278.	20656.	0.085
4452.	14716.	0.394	0.981	283.	15186.	0.111
4521.	18461.	0.320	0.981	285.	19061.	0.090
4562.	8065.	0.669	1.484	286.	8331.	0.192
4617.	10009.	0.564	1.310	288.	10319.	0.156
4668.	20115.	0.296	1.611	291.	20774.	0.081
4734.	8876.	0.631	1.418	296.	9148.	0.170
4780.	10757.	0.527	1.200	298.	11092.	0.141
4819.	13249.	0.434	1.008	300.	13669.	0.116
4871.	12748.	0.450	1.008	301.	13151.	0.120
5059.	10567.	0.536	2.214	310.	10896.	0.138
5165.	9664.	0.563	1.666	311.	9963.	0.150
5199.	8857.	0.632	1.802	312.	9128.	0.162
5220.	7898.	0.704	2.000	313.	8138.	0.180
5266.	6662.	0.826	2.200	315.	6861.	0.210
5314.	7109.	0.777	2.007	318.	7323.	0.196
5340.	7519.	0.737	2.010	324.	7746.	0.182
5458.	7559.	0.734	2.299	326.	7788.	0.180
5542.	8020.	0.694	1.906	334.	8264.	0.166
5628.	7134.	0.775	2.014	335.	7349.	0.185
5686.	8108.	0.687	2.304	336.	8355.	0.164
5805.	6904.	0.799	2.818	342.	7112.	0.187
5844.	6601.	0.833	3.494	348.	6798.	0.192
5920.	7449.	0.744	2.017	349.	7674.	0.171
5997.	6974.	0.791	2.508	350.	7184.	0.181
6048.	7550.	0.734	3.008	353.	7779.	0.167
6218.	6522.	0.843	2.671	356.	6717.	0.190
6270.	6450.	0.744	2.754	351.	7159.	0.181
6322.	7086.	0.779	2.813	354.	7299.	0.174
6380.	7424.	0.746	3.018	361.	7649.	0.166
6457.	7209.	0.767	3.115	363.	7427.	0.170
6468.	10141.	0.557	3.021	366.	10457.	0.122
6535.	10204.	0.554	3.021	368.	10522.	0.121
6646.	12242.	0.466	2.001	375.	12671.	0.100
6781.	9985.	0.565	2.985	376.	10296.	0.121
6822.	7173.	0.771	2.992	380.	7390.	0.163
6850.	9193.	0.611	3.114	381.	9478.	0.129
7023.	9129.	0.615	2.974	384.	9411.	0.129
7083.	8454.	0.660	3.515	386.	8713.	0.137
7186.	9804.	0.575	3.603	391.	10109.	0.118
7295.	13636.	0.423	3.106	394.	14072.	0.086
7461.	6884.	0.801	3.875	402.	7092.	0.160
7454.	6913.	0.798	3.874	405.	7121.	0.158
7466.	9578.	0.588	4.018	407.	9875.	0.116
7558.	15863.	0.368	2.311	410.	16377.	0.072
7679.	14816.	0.392	2.814	414.	15294.	0.076
7703.	14170.	0.324	1.805	415.	18766.	0.063
7772.	33445.	0.186	0.996	417.	34644.	0.036
7812.	20554.	0.290	2.008	418.	21234.	0.056
7874.	28330.	0.217	1.602	419.	29291.	0.042
7918.	28121.	0.218	1.500	421.	29073.	0.042

WELL DEARBORN FARMS 1 SALINITY CALCULATION FROM SP CURVE

CORRECTED TO 75° F						AT FORMATION TEMPERATURE	
depth	ppm	ssp	rwc	rmf	temp	ppm	rw
367.	278.	29.00	16.911	4.663	116.	284.	11.309
412.	365.	20.50	13.036	4.644	116.	373.	8.682
445.	327.	24.00	14.468	4.569	118.	334.	9.482
521.	247.	33.00	18.958	4.497	120.	251.	12.228
615.	375.	20.00	12.703	4.294	126.	383.	7.824
670.	400.	18.00	11.941	4.230	128.	409.	7.245
708.	427.	16.00	11.220	4.138	141.	446.	6.660
759.	415.	17.00	11.524	4.050	134.	424.	6.697
863.	431.	16.00	11.122	3.832	142.	441.	6.113
878.	432.	16.00	11.118	3.819	143.	441.	6.090
980.	446.	15.00	10.778	3.756	145.	455.	5.807
1020.	447.	15.00	10.754	3.695	148.	446.	5.703
1096.	341.	24.00	13.917	3.637	150.	348.	7.259
1246.	354.	23.00	13.419	3.481	157.	362.	6.700
1294.	335.	25.00	14.156	3.418	160.	342.	6.941
1341.	378.	21.00	12.615	3.378	162.	386.	6.112
1438.	466.	14.00	10.334	3.338	164.	476.	4.951
1509.	337.	25.00	14.054	3.300	166.	345.	6.654
1577.	348.	24.00	13.640	3.262	168.	356.	6.382
1577.	346.	20.50	12.357	3.243	169.	395.	5.749
1634.	339.	25.00	13.995	3.225	170.	346.	6.474
1717.	321.	27.00	14.727	3.154	174.	378.	6.661
1768.	322.	27.00	14.718	3.145	175.	324.	6.639
1827.	313.	28.00	15.121	3.136	175.	319.	6.802
1950.	1195.	33.00	4.211	0.755	177.	1224.	1.874
2078.	1273.	31.00	3.964	0.738	181.	1305.	1.726
2124.	1703.	21.00	3.006	0.727	184.	1747.	1.288
2148.	1019.	34.00	4.901	0.723	185.	1044.	2.090
2214.	1968.	16.00	2.619	0.719	186.	2020.	1.111
2245.	946.	40.00	5.011	0.712	188.	1020.	2.104
2350.	1406.	28.00	3.608	0.701	191.	1441.	1.492
2423.	1536.	25.00	3.317	0.691	194.	1575.	1.351
2501.	1012.	40.00	4.933	0.679	197.	1037.	1.976
2572.	1634.	22.00	3.126	0.671	200.	1676.	1.236
2602.	1076.	38.00	4.654	0.669	201.	1102.	1.836
2623.	1273.	32.00	3.966	0.667	201.	1304.	1.561
2689.	1142.	36.00	4.397	0.661	203.	1170.	1.714
2718.	1209.	34.00	4.165	0.658	204.	1239.	1.616
2797.	945.	43.00	5.264	0.652	206.	968.	2.023
2853.	1032.	40.00	4.841	0.643	209.	1057.	1.835
2947.	1157.	35.97	4.343	0.637	211.	1145.	1.631
3024.	1226.	34.00	4.104	0.628	214.	1257.	1.522
3096.	1016.	41.00	4.914	0.622	216.	1041.	1.804
3142.	1080.	34.00	4.637	0.611	220.	1106.	1.672
3249.	1104.	40.00	4.521	0.573	225.	1136.	1.595
3447.	1312.	34.00	3.853	0.561	230.	1345.	1.331
3496.	1097.	41.00	4.568	0.549	235.	1124.	1.545
3542.	1015.	44.00	4.920	0.547	236.	1040.	1.657
3571.	1057.	40.80	4.733	0.569	237.	1083.	1.588
3623.	1001.	43.00	4.987	0.564	239.	1025.	1.659
3673.	1091.	40.00	4.592	0.553	244.	1118.	1.497
3754.	1039.	42.00	4.812	0.549	246.	1064.	1.557
3787.	1071.	41.00	4.671	0.542	249.	1097.	1.494
3849.	1160.	38.00	4.332	0.539	250.	1189.	1.378
3932.	952.	46.00	5.230	0.528	256.	975.	1.627
4062.	1117.	40.00	4.490	0.520	260.	1145.	1.376
4081.	1013.	44.00	4.927	0.514	263.	1038.	1.494
4122.	1645.	25.00	3.106	0.512	264.	1688.	0.938
4224.	1420.	31.00	3.573	0.503	269.	1456.	1.059
4244.	1390.	32.03	3.647	0.496	273.	1425.	1.066
4324.	1295.	35.00	3.902	0.490	276.	1327.	1.128
4373.	1204.	38.00	4.180	0.487	278.	1234.	1.200
4452.	1389.	32.50	3.649	0.479	283.	1424.	1.030
4521.	1556.	28.00	3.276	0.475	285.	1596.	0.918
4562.	1943.	18.00	2.588	0.474	286.	2046.	0.723
4617.	1722.	24.00	2.975	0.470	288.	1766.	0.825
4648.	1857.	21.00	2.768	0.466	291.	1906.	0.760
4780.	1246.	36.00	3.896	0.455	298.	1329.	1.045
4819.	1467.	31.00	3.465	0.452	300.	1504.	0.924
4871.	1333.	35.00	3.795	0.451	301.	1367.	1.008
5059.	1951.	20.40	2.642	0.429	310.	2002.	0.682
5145.	1924.	21.00	2.676	0.427	311.	1975.	0.684
5199.	1744.	25.14	2.938	0.426	312.	1790.	0.754
5220.	1500.	31.50	3.391	0.425	313.	1539.	0.867

WELL DEARBORN FARMS 1
SALINITY CALCULATION FROM SP CURVE

CORRECTED TO 75° F						AT FORMATION TEMPERATURE	
depth	ppm	ssp	rwc	rmf	temp	ppm	rw
5266.	1495.	31.72	3.401	0.422	315.	1534.	0.864
5314.	1343.	36.38	3.767	0.418	318.	1378.	0.948
5390.	1725.	26.00	2.964	0.411	324.	1771.	0.734
5458.	1619.	28.78	3.154	0.408	326.	1661.	0.775
5628.	1842.	22.40	2.720	0.397	335.	1942.	0.651
5686.	1784.	24.46	2.876	0.396	336.	1831.	0.686
5805.	1762.	25.68	2.909	0.389	342.	1809.	0.682
5844.	1747.	26.25	2.933	0.383	348.	1793.	0.676
5920.	2016.	20.00	2.560	0.382	349.	2070.	0.588
5967.	2077.	18.70	2.485	0.381	350.	2133.	0.571
5997.	1842.	24.00	2.740	0.381	350.	1890.	0.639
6048.	2081.	18.70	2.484	0.378	353.	2137.	0.565
6218.	1988.	20.40	2.595	0.374	356.	2041.	0.585
6270.	1739.	26.78	2.946	0.372	358.	1785.	0.660
6322.	1566.	31.50	3.256	0.371	359.	1606.	0.728
6457.	1807.	25.25	2.842	0.367	363.	1854.	0.628
6498.	1940.	21.00	2.592	0.364	366.	2043.	0.569
6535.	1438.	22.24	2.654	0.362	368.	1989.	0.580
6696.	2120.	18.36	2.440	0.356	375.	2177.	0.523
6781.	1993.	21.20	2.589	0.355	376.	2046.	0.553
6822.	1730.	27.75	2.961	0.351	380.	1776.	0.626
6850.	1749.	26.00	2.853	0.350	381.	1847.	0.602
7023.	1965.	22.05	2.624	0.348	384.	2017.	0.549
7083.	1715.	28.35	2.985	0.346	386.	1760.	0.622
7186.	2030.	20.74	2.544	0.341	391.	2084.	0.523
7401.	2285.	15.45	2.273	0.332	402.	2347.	0.455
7558.	1081.	51.00	4.631	0.326	410.	1109.	0.909
7679.	1571.	33.48	3.246	0.323	414.	1612.	0.631
7703.	1404.	38.85	3.611	0.322	415.	1441.	0.700
7772.	1009.	54.74	4.948	0.320	417.	1034.	0.955

WELL DEARBORN FARMS 1
SALINITY CALCULATION FROM FLUSHED ZONE DATA

AT 75° F						AT FORMATION TEMPERATURE		
depth	ppm	rwc	rt	rxo	rmf	temp	ppm	rw
367.	2555.	2.044	0.777	2.649	4.663	115.50	2621.	1.367
412.	2616.	1.999	0.797	2.779	4.644	116.00	2684.	1.332
445.	2435.	2.140	0.709	2.309	4.569	118.00	2498.	1.402
521.	2958.	1.779	0.712	2.792	4.497	120.00	3036.	1.148
1624.	2257.	2.300	0.773	2.343	3.225	170.00	2316.	1.064
1717.	2775.	1.890	0.820	3.024	3.154	174.00	2850.	0.855
1768.	1964.	2.625	0.719	1.909	3.145	174.50	2015.	1.184
1827.	2248.	2.308	0.848	2.561	3.136	175.00	2307.	1.038
1950.	2450.	2.127	0.663	2.172	3.102	177.00	2516.	0.946
5059.	9288.	0.605	1.695	4.657	0.429	310.00	9574.	0.156
5165.	12384.	0.462	1.002	3.599	0.427	311.00	12775.	0.119
5199.	10616.	0.534	1.615	5.027	0.426	312.00	10947.	0.137
5230.	14419.	0.402	1.331	5.504	0.425	313.00	14880.	0.103
5266.	12349.	0.464	1.549	5.551	0.422	315.00	12739.	0.118
5314.	15555.	0.374	1.248	5.537	0.418	318.00	16055.	0.094
5390.	12874.	0.446	1.221	4.547	0.411	324.00	13283.	0.110
5458.	10140.	0.557	1.687	5.030	0.408	326.00	10455.	0.137
5542.	7054.	0.783	1.919	4.073	0.399	334.00	7267.	0.188
5628.	9145.	0.614	1.634	4.423	0.397	335.00	9426.	0.147
5686.	9956.	0.567	2.091	6.128	0.396	336.00	10265.	0.135
5805.	7920.	0.702	2.522	5.966	0.389	342.00	8161.	0.165
5844.	8087.	0.688	2.801	6.759	0.383	348.00	8334.	0.159
5920.	8031.	0.693	2.009	4.815	0.382	349.00	8276.	0.159
5967.	8954.	0.626	1.669	4.429	0.381	349.50	9229.	0.144
5997.	7979.	0.697	2.186	5.208	0.381	350.00	8723.	0.160
6098.	7219.	0.766	2.694	5.842	0.378	353.00	7437.	0.174
6156.	5753.	0.948	2.283	3.999	0.376	354.00	5924.	0.215
6218.	6439.	0.853	2.526	4.919	0.374	356.00	6632.	0.192
6270.	8487.	0.658	2.753	6.949	0.372	358.00	8747.	0.148
6322.	8281.	0.673	2.788	6.877	0.371	359.00	8535.	0.151
6380.	10577.	0.536	2.110	6.543	0.369	361.00	10908.	0.119
6457.	9425.	0.597	2.379	6.625	0.367	363.00	9717.	0.132
6458.	9887.	0.570	2.036	5.929	0.364	366.00	10194.	0.125
6535.	10217.	0.553	1.927	5.787	0.362	368.00	10535.	0.121
6646.	5998.	0.912	1.946	3.545	0.356	375.00	6177.	0.195
6781.	9605.	0.586	1.900	5.384	0.355	376.00	9903.	0.125
6822.	8485.	0.624	2.802	7.461	0.351	380.00	9262.	0.132
6850.	9827.	0.574	2.396	6.937	0.350	381.00	10133.	0.121
7023.	9396.	0.598	2.111	5.860	0.348	384.00	9687.	0.125
7083.	9468.	0.594	2.854	7.982	0.346	386.00	9761.	0.124
7186.	6164.	0.889	3.425	6.402	0.341	391.00	6348.	0.183
7401.	5699.	0.957	3.767	6.539	0.332	402.00	5868.	0.191
7558.	14252.	0.406	1.974	8.078	0.326	410.00	14710.	0.080
7679.	8671.	0.645	2.669	6.874	0.323	414.00	8938.	0.125
7703.	10983.	0.517	1.810	5.815	0.322	415.00	11328.	0.100
7772.	10814.	0.524	0.420	2.914	0.320	417.00	11159.	0.101
7812.	13645.	0.423	2.036	8.003	0.320	418.00	14082.	0.081
7874.	9357.	0.601	1.620	4.481	0.319	419.00	9648.	0.115
7918.	11870.	0.481	1.522	5.257	0.318	421.00	12246.	0.092

Temperature profile, Landers 2 (Republic Geothermal Inc., 1981).

Temperature profile, Dearborn Farms 1 (Republic Geothermal Inc., 1981).