(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 May 2009 (07.05.2009)

PCT

(10) International Publication Number
WO 2009/059132 A1

(51) International Patent Classification:
E21B 49/08 (2006.01)

(21) International Application Number:
PCT/US2008/081989

(22) International Filing Date: 31 October 2008 (31.10.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/931,207 31 October 2007 (31.10.2007) US

(71) Applicant and
(72) Inventor: **ELLIS, Leroy** [AU/US]; 206 Hyde Park Drive, Richardson, TX 75080 (US).

(74) Agent: **DIAZ, Michael**; 555 Republic Drive, Suite 200, Plano, TX 75074 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

(54) Title: PROCESSING GAS ISOTOPE MEASUREMENTS IN ASSOCIATION WITH LOGS FROM OIL AND GAS DRILLING OPERATIONS

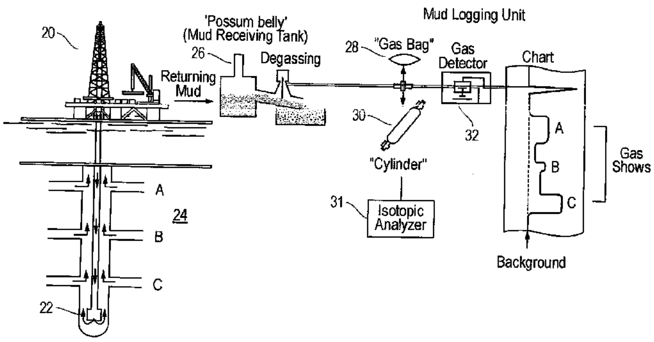


FIG. 1

(57) Abstract: A system and method of interpreting well log isotopic information in a drilling operation of a target area. The method begins by inputting a template for indicating a trend from analyzed mudgas samplings into a computing system. Next, a plurality of mud gas samplings are profiled through a well bore at a plurality of incremental depths of the well bore. The plurality of gas samplings are analyzed to obtain a plurality of isotopic data points associated with hydrocarbon isotopic composition of the plurality of gas samplings. The plurality of isotopic data points includes data associated with a composition of ethane and methane or other gaseous components within each of the mud gas samplings A trend associated with the template in determined by the computing system from the plurality of isotopic data points. The plurality of isotopic data points is analyzed to geochemically interpret the geological information.

WO 2009/059132 A1

PROCESSING GAS ISOTOPE MEASUREMENTS IN ASSOCIATION WITH LOGS FROM OIL AND GAS DRILLING OPERATIONS

TECHNICAL FIELD

This invention relates to the interpretation of mudlog and geophysical log data with isotopic measurements associated with oil and gas drilling operations. Specifically, the present invention relates to the interpretation and display of data derived from mud gas isotopic measurements to assess hydrocarbon charge, source identification, maturity, reservoir compartmentalization, mis-pay, and hydrocarbon communication concomitant with identification of lithological seals, baffles and barriers with conventional oil and gas exploration and production geophysical logs.

BACKGROUND ART

Analysis of gas samples obtained during a drilling operation may be employed to determine geochemical information associated with strikes of oil or gas deposits. The analysis may include the acquisition of compositional and isotopic data of sampled subsurface gases. This data is applied to traditional geochemical plots and templates. The interpretation of this data is used to provide geochemical information on the oil and gas provenance, how thermally mature the hydrocarbons are, whether subsurface post-generation effects were encountered during migration of the gaseous hydrocarbons from the source rock to a reservoir, and any problems or effects the hydrocarbons in the reservoir subsequently experienced.

Existing well sampling techniques use physical gas samples for compositional and isotopic analyses, obtained via wellheads, separators, down-hole logging tools (e.g., modular dynamic tester/repeat formation tester, etc.), canned cuttings, together with sampled gases entrained in the mud system during drilling.

As discussed in U.S. Patent No. 7,124,030 and U.S. Patent No. 7,174,254, there are several problems and issues not adequately addressed using standard mud gas chromatographic compositional analyses and interpretations. None of the existing techniques effectively detail or correlate geological information such as lithological hydrocarbon seals, baffles and barriers, good communication compartments, or gas diffusion and/or leakage into their interpretation. Compositional data can result in false positives and negatives where changes in operational conditions related to drilling variables such as increased rate of penetration or mud weight increases occur. U.S. Patent Nos. 7,124,030 and 7,174,254 provide far more advanced methods which apply new interpretative techniques involving mud gas chromatographic compositional and isotopic analyses together with detailed drilling, geological and engineering information integration.

Within the improved interpretative techniques disclosed in U.S. Patent Nos. 7,124,030 and 7,174,254 is the newly developed use of hydrocarbon mixing processes to determine or suggest good hydrocarbon communication compartments and zones. Subsurface gas mixing processes as defined by mixing lines are identified on plots where hydrocarbon gas compositional and isotopic data are plotted. The gas mixing lines may be employed and are defined by data points falling along an identified trend line, suggesting a depth section in the well that is in good gas communication, and therefore representative of a compartment. Breaks in any of the representative trends may identify approximate depth locations at which lithological seals, baffles or other barriers to hydrocarbon communication may in fact be present. The depth range of each trend may be considered to reflect or suggest an interval of good hydrocarbon communication. Furthermore, a number of seals baffles and barriers are suggested defining these intervals, supporting the interpretation that these intervals may be likely to show localized hydrocarbon communication zones concomitant with potentially serious compartmentalization issues.

A system and method is needed which enables a user to interpret the acquired data based on mathematical integration of the data and not directly dependent on the use of plots or logs. Furthermore, it would be advantageous to incorporate the interpretative techniques disclosed in U.S. Patent No. 7,124,030 and U.S. Patent No. 7,174,254 with current mudlog and other geophysical logs.

It would also be a distinct advantage to incorporate the interpretative techniques disclosed in U.S. Patent No. 7,124,030 and U.S. Patent No. 7,174,254 with a system and method which interprets the data based on mathematical integration of the data and not directly dependent on the use of plots or logs. It is an object of the present invention to provide such a system and method.

DISCLOSURE OF INVENTION

In one aspect, the present invention is a method of interpreting well log isotopic information in a drilling operation of a target area. The method begins by inputting a mathematical algorithm or other function (defined as a template) for indicating a trend from analyzed mudgas samplings into a computing system. Next, a plurality of mud gas samplings are profiled through a well bore at a plurality of incremental depths of the well bore. The plurality of gas samplings are analyzed to obtain a plurality of isotopic data points associated with isotopic composition of the plurality of gas samplings. The plurality of isotopic data points includes data associated with a composition of ethane and methane or other gaseous components within each of the mud gas samplings. A trend associated with the template is determined by the computing system from the plurality of isotopic measurements and data. The plurality of isotopic data points is analyzed to geologically interpret the geochemical information.

In another aspect, the present invention is a system for interpreting well log isotopic information in a drilling operation of a target area. The system includes a computing system for storing a template for defining and calculating a trend from analyzed mud gas samplings to a computing system. A user input (or other digital pipeline responsible for data transfer) is utilized for inputting a plurality of analyzed mud gas samplings into the computing system. The plurality of mud gas samplings are obtained from a target area. The computing system interprets the plurality of analyzed mud gas samplings to obtain compositional and isotopic data points from the plurality of gas samplings. The data points include information on composition of ethane and methane or other gaseous components within each of the mud gas samplings. The computing system analyzes, calculates, or determines trends identified with the template from the data points. An interpretation of the obtained mud gas samplings is then determined to provide an indication of hydrocarbon communication processes.

In still another aspect, the present invention is a method of displaying well log information in a drilling operation of a target area. Information from a gas isotope log is added to a formation evaluation log to analyze the targeted area in drilling operations. The method begins by profiling a plurality of mud gas samples through a well bore at a plurality of incremental depths of the well bore. The plurality of gas samples are analyzed to obtain a plurality of isotopic data points associated with hydrocarbon isotopic composition of the plurality of gas samples. The plurality of isotopic data points includes data associated with a composition of ethane and methane within each of the mud gas samples. The plurality of isotopic data points are plotted to determine geological information from the target area derived from the plotted plurality of isotopic data points. The plurality of isotopic data points is analyzed to geochemically interpret the geological information. The interpretation is then displayed in association with data from a mudlog and/or geophysical log.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a block diagram illustrating principles of mud circulation during drilling operations and sampling of mud gases in the preferred embodiment of the present invention;

FIG. 2 is an exemplary table illustrating tabulated data of a typical mud gas composition and gas isotope sampling data for a drilling well;

FIG. 3 is a chart illustrating a percentage C1 versus isotopic data chart in the preferred embodiment of the present invention;

FIG. 4 is an example lithology illustrating the principles of lithology mixing of drilling cuttings in mud-stream at sand/shale boundaries;

FIGs. 5A-5C illustrate the principles of the mixing processes in mud gas samplings;

FIGs. 6A-6C illustrates the prediction of reservoir compartments and discontinuous reservoirs separated by seals, baffles or barriers via a thin shale lithology example;

FIG. 7 illustrates an example drilling well log formed by a percentage summed C1 to C6 hydrocarbons, gas units, and isotopic data at various depths;

FIG. 8 illustrates a first exemplary gas mixing plot showing C1/Cn versus $\delta^{13}C_1$;

FIG. 9 illustrates a second exemplary gas mixing plot showing C2/Cn versus $\delta^{13}C_2$;

FIG. 10 illustrates a third exemplary gas mixing plot showing C1/Cn versus isotopic data;

FIG. 11 illustrates an example well log formed by percentage C1-C6, gas units, and 13C methane;

FIG. 12 is a simplified block diagram of a computer system for interpreting sampled mud gas compositional and isotopic data in a drilling operation of a target area;

FIG. 13 is a flow chart outlining the steps for interpreting engineering and geological interpretations from data determined from mud gas isotope logging according to the teachings of the present invention;

FIG. 14 (prior art) is an exemplary existing formation evaluation log utilized to providing information on a well;

FIG. 15 is an informational block diagram of the log information utilized in current mudlog and geophysical logs with new information derived from a gas isotope log in the preferred embodiment of the present invention; and

FIG. 16 is an exemplary log of the present invention.

MODES FOR CARRYING OUT THE INVENTION

The present invention is a system and method of utilizing acquired compositional and isotopic data for an interpretive method of mud gas isotope logging to determine hydrocarbon charge, source identification, maturity, reservoir hydrocarbon isotopic signature, good hydrocarbon communication, seals, baffles or other barriers to hydrocarbon communication in oil and gas drilling prospects.

FIG. 1 is a block diagram illustrating principles of mud circulation during drilling operations and sampling of mud gases in the preferred embodiment of the present invention. A well 20 having a drill 22 drills down into the ground 24. Levels A, B, and C provide exemplary gas shows related to subsurface reservoirs. Mud is circulated around the drill 22 to provide lubrication for the drill and removing debris (cuttings) as it drills. The mud is circulated to the surface. The returning mud is collected on the surface within a mud receiving tank 26, also known as a possum belly. The gas is mechanically or otherwise degassed/exsolved form the mud and may be collected within a gas sampling device 28, a cylinder 30, or delivered to a mobile/onsite/in-situ isotopic analyzer 31. Typically, at a remote laboratory, mud logging unit, or an isotopic analyzer 31, a gas detector 32 (such as a gas chromatograph or mass spectrometer) is also utilized to measure compositional ratios of different hydrocarbon species.

In the preferred embodiment of the present invention, for a new drilling well, the samplings are taken at regular and/or continuous depths, throughout the entire well in order to establish a background trend, and recognize oil and gas charges in reservoirs and other shows. Gases entrained in the circulating mud streams typically see more restricted gas diffusion relative to other techniques such as canned-cuttings that may smear, distribute or be collected over a wide composite depth interval in the mud system due to inherent density and fractal characteristic differences. Therefore, the sample depth recorded for the gas samplings is considered to more closely approximate the actual depth, whereas canned-cuttings by nature may not accurately indicate the actual depth as rock density and fractal variables come into play during passage in the mud system. It should be understood by one skilled in the art that samplings may be taken in a wide variety of ways and is not limited to obtaining samplings at specific regular depths. Any isotopic measurement of samplings, involving either continuous (e.g., laser measurement techniques) or discrete samplings, may be utilized in the present invention.

FIG. 2 is an exemplary table illustrating tabulated data of a typical mud gas composition and gas isotope sampling data for a drilling well. As discussed above, samplings are taken at regular intervals and/or continuously throughout the well. Alternatively, the samplings may be obtained in any fashion and may represent discrete or continuous measurements. The gas compositional data and isotopic data may be arranged in any fashion or combination of ratios. As illustrated in FIG. 2, matching rows are characterized by depth of the samplings. In the present invention, the data does not need to be presented in tabular form.

FIG. 3 is a chart illustrating a percentage C1 versus corresponding and related isotopic data (e.g., $\delta^{13}C$, ^{2}H) chart in the preferred embodiment of the present invention. Percentage C1 may be illustrated on the one axis (e.g., Y-axis) and isotopic data displayed on the other axis (e.g., x-axis). Straight lines (which usually are defined by at least three sequential depth data points) or other identified trends within the data are then identified and referred to as "mixing lines." These mixing lines equate to subsurface zones (compartments) in hydrocarbon gas communication. The points where the mixing lines start and end typically reveal "breaks" which may equate to lithological hydrocarbon communication seals, baffles or barriers. Baffles and barriers typically occur where a simple break in a mixing line occurs. Seals typically occur where the break is significant and the next depth data point deviates substantially. Either the next mixing line reverses direction or the next data point is far removed from the previous depth data point or mixing line. If the next (adjacent) mixing line reverses direction from one mixing line to another mixing line, this may represent one compartment where the point of reversal between the mixing lines may be representative of the actual reservoir hydrocarbon isotopic signature. If the next (adjacent) mixing line is substantially deviated, then a lithological seal, baffle or barrier may be indicated. FIG. 3 may include depth range labeling for any mixing line. Additionally, straight line-of-best-fit may also be drawn for data approximating a mixing line. Data groups that are tightly clustered are similarly interpreted to indicate good communication zones, analogous to mixing lines. From these data groups, a mathematical algorithm, formula, equation or function, known as a template, is applied to identify trends of the data.

FIGs. 4-11, discussed below, provide an explanation and illustrate examples of the principles involved in interpreting the data. FIG. 4 is a lithology illustrating the mixing of cuttings in a mud stream at sand/shale boundaries. Mud flows from a drill bore 50 (associated with drill 22) and moves upward as illustrated. As shown in FIG. 4, an upper shale area 52 overlays an upper mixing zone 54, a sand region 56, a lower mixing zone 58, and a lower shale area 60. The shale cuttings may mix with the sand region from above due to the higher density of the shale cuttings. The shale cuttings from the lower shale area may also invade the sand region due to higher frictional and fractal characteristics.

FIGs. 5A-5C illustrate the principles of related gas mixing processes entrained in drilling muds. FIG. 5A illustrates the lithology by showing the upper shale area 52, the sand region 56, and the lower shale area 60. The shales from the upper shale area 52 tend to cave. Specifically, shales may sink into the sand region due to lower buoyancy and higher density (more solids per volume) characteristics. Shale in the lower shale area 60 may upwell into the sand region due to higher frictional and/or fractal characteristics (more drag upwards; more particles/volume mud). FIG. 5B illustrates a chart showing depth versus isotopic data (e.g., $\delta^{13}C_1$). FIG. 5C is a gas mixing plot showing C1/Cn versus $\delta^{13}C_1$ or other compositional and isotopic data. The intersection of the top and bottom of the mixing line determines reservoir composition of one continuous reservoir where the point of reversal between the mixing lines may be representative of the actual reservoir hydrocarbon isotopic signature. The mixing of lithologies results in the mixing of associated gases. Mixing plots allow differentiation between hanging and footwall mixing.

FIGs. 6A-6C illustrates the prediction of reservoir compartments and discontinuous reservoirs separated by a thin shale, other lithology or geological phenomena. FIG. 6A illustrates the lithology showing an upper shale region 80, a sand region 82, a shale break 84, a sand region 86, and a lower shale region 88. Within the sand region 82 is a reservoir R1. Within the sand region 86 is a second reservoir R2. In a similar manner as FIG. 5B, FIG. 6B illustrates the processes of gas mixing and expected isotopic mixing trends in a reservoir separated by a thin shale. FIG. 6C illustrates a gas mixing plot showing C1/Cn versus $\delta^{13}C_1$.

FIG. 7 illustrates an example drilling well log formed by percentage C1 to C6 hydrocarbons, gas units and isotopic data at various depths. FIG. 7 provides a real-world example of missed-pay (A), charge recognition (B), biodegradation (C), seal identification (D), compartmentalization (E), hydrocarbon diffusion or leakage (F) and background (G). An absence of gas shows also recognizes missed-pay potential due to operational drilling variables such as overbalanced mud weight. An absence of an isotopic show may be indicative of a non-economical background gas-charged sand or biodegraded gas/oil mixture. An isotopic peak profile may also recognize gas cap seal integrity in reservoirs. Gas shows correspond to isotopic shows in typical charged sands. Sand 6 illustrates thin shale in sand, which results in compartmentalization. Figs. 8 and 9 show associated mixing lines.

FIG. 8 illustrates a gas mixing plot showing C1/Cn versus $\delta^{13}C_1$. Sands 3 and 5 (see FIG. 7) form closely approximating mixing lines, which indicate a possible relationship between these reservoirs. Sand 6a forms a good mixing line down to approximately 13251 feet, which while still within the reservoir suggests that this reservoir is compartmentalized. Separation of the mixing lines 6a and 6b illustrates identification of a seal, baffle or barrier between 13238 feet and 13251 feet. The depth range of mixing lines reflects vertical continuity within each reservoir. The present invention may be utilized for determining and comparing compartmentalization and hydrocarbon communication between wells across a field or other stratigraphic zone.

FIG. 9 illustrates a gas mixing plot showing C2/Cn versus $\delta^{13}C_2$. This plot, similar to Fig. 8 employs ethane (C2) compositional and associated isotopic data to provide an early assessment of reservoir continuity and compartmentalization. Sand 6a represents a mixing line, whereas sand 6b is, at best, a different mixing line. Sand 6a mixing line terminates at a point between 13238 feet and 13251 feet (similar to fig. 8) suggesting that a seal, baffle or barrier to communication may be present. Sand 6a and 6b appear to be separate compartments with zero or limited gas communication. The identification of a seal, baffle or barrier between 13238 feet and 13251 feet using ethane data further supports and validates similar interpretations arrived at in Fig. 8 using methane compositional and isotopic data.

FIG. 10 illustrates another real-world example of a gas mixing plot showing C1/Cn versus isotopic data (e.g., $\delta^{13}C_1$) and shows an early assessment of reservoir continuity, compartmentalization and hydrocarbon communication. Mixing trends are easily recognized with the resulting depth range of lines reflecting separate compartments and continuity. The recognition of breaks (e.g. reference number 100) between related depth intervals (i.e., formation of separate mixing lines) suggests that a baffle or other lithological barrier to communication may exist. Mixing processes of sands and shales (e.g. reference number 200) in the circulating mud stream can also be observed.

FIG. 11 illustrates an example log displaying percentage C1-C6 and 13C methane isotopic data. There are sixteen distinct gas communication compartments interpreted and identified. Reference number 102 shows the mixing line depth ranges superimposed on the gas compositional and isotopic log depths. Reference number 104 shows where isotopic shows and the gas shows agree. Mixing lines located in the same region on a plot reflecting discrete compartments (e.g., M1-M6 at reference number 106) may also be consolidated into broader stratigraphic compartments encompassing a number of smaller discrete compartments that may be determined to be related via observation or integration with other well log data and information.

The interpretive methodology may be used for reservoir seal identification. Seal integrity measured as a function of its ability to restrict reservoir gas diffusion or other hydrocarbon leakage may be observed through mud gas isotope logging. Data from wells may indicate diffusion or leakage of reservoir gases into formations both above and below identified reservoirs. This data present and support potential identification of low- and high gas reservoir saturations. Low gas saturations are commonly ascribed to leaky seals. If there is a leaky seal, the gas in the overlying seal interval may develop an isotopic signal similar to that of the underlying reservoir gas, and in contrast to the background shale methane and ethane isotopic ratios. In contrast, an intact seal may have some mixing a short interval above the reservoir, but overall, the overlying lithology should have a lighter, more constant methane and ethane isotopic signal. Therefore, an intact seal as discussed above may indicate high gas saturation, combined with a distinctly different gas isotopic signature in the reservoir. Seals that are intact, and seals that leak, may be identifiable from a change in background isotopic signatures (See FIGs. 4, 5, and 7). This provides calibration between physical property measurements of the shales or other caprocks and their ability to seal. Seals, however, may only be identified/recognized using this technique over a depth interval in which appropriate detailed mud gas isotope logging data have been acquired. This hydrocarbon diffusion or leakage process is likely to occur over geologic time and terminates upon contact with an impermeable barrier such as a continuous/homogeneous dense and compacted lithology (e.g. shale, marl, chalk, or other geological phenomena with associated pore pressure changes) of low porosity/permeability. Seals such as these may be generally referred to as 'trapping' seals, or more specifically as, 'regional' or 'localized' seals depending on their stratigraphic extent between wells. These seals represent barriers to the potential migration of hydrocarbons within and between wells. Identification of seals is important in establishing potential migration pathways and reservoir compartmentalization in a field. Reservoir sands within identified particular regional seals are likely to contain gases of the same type and maturity.

Reservoir seals are not as well understood as either source or reservoir rocks, and evaluating and predicting reservoir seals remain problematic. Within this context, mud gas isotope logging is a promising technique for both complementing existing seal analysis methodology and empirically verifying the presence of any seal, regardless of origin.

Mud gas isotope logging is a noninvasive technique used to evaluate exploration and field production. Isotopic measurements made on mud gas samplings from either side of a potentially sealing interval can be used to determine the effectiveness of a seal as well as establish likely migration pathways and reservoir compartmentalization. For example, in a thermogenic gas reservoir associated with a leaky seal, gas in the overlying seal may develop an isotopic signature similar to that of the underlying reservoir gas. This leaky seal isotopic signature will be isotopically heavier and contrast with methane and ethane isotopic ratios in background shales. In contrast, an effective seal in this same thermogenic setting will have an isotopically lighter and more constant methane and ethane signal. By measuring changes in background isotopic signal of intact seals vs. seals that leak, calibration between physical property measurements of the seals and their ability to seal can be determined.

It should be understood that plotting data upon a plot as shown in the above referenced figures (i.e., FIGs. 2A, 2B, 3, 5B, 5C, 6B, 6C, and 7-11) is not necessary for implementing the present invention. FIG. 12 is a simplified block diagram of a computer system 500 for interpreting sampled mud gas compositional and isotopic data in a drilling operation of a target area. The computer system 500 includes a computer 502, a memory 504, and a user interface 506. In addition, the computer 502 includes a trend analyzer 508. The computer may be any computing device providing common computational functions. The computer is connected to the memory 504 which stores data inputted to the computer through the user interface 506. The user interface may be any device allowing input of data from a user 510 to the computer. Additionally, the user interface allows presentation of the results of the analysis of the data. The trend analyzer 508 is embedded within the computer and provides analysis of the inputted data to determine trends. The trend analyzer identifies and calculates trends and relationships based on a mathematical algorithm, function or equation. The computer receives well log data (e.g., geophysical, geological, engineering, geochemical, isotopic, and log data) through the user interface. The user interface may be a direct link from any type of digital data pipeline or any device interfacing with a user. The computer outputs the result as desired by the operator (e.g., data, logs or other graphical display

The present invention incorporates the novel interpretive methodologies disclosed in U.S. Patent No. 7,124,030 and U.S. Patent No. 7,174,254 without utilizing plots or logs to determine the trends utilized in interpreting the data. Thus, the acquired data does not require plotting or logging on a table to interpret the data. Data is first obtained from gas samplings (analysis or measurement) of mudgases taken at discrete depth intervals. In alternate embodiments of the present invention, the interval may be varied according to the subsurface lithologies encountered. However, in any sample logging using the mud gas isotope logging technique, samplings must be obtained at sufficiently frequent intervals to determine a background trend, which may vary as depth increases or geological environments determine. The samplings are analyzed to provide gas compositional data and isotopic data. Next, the data is inputted through the user interface 506 to the computer 502. Specific ratios may be determined or calculated from the inputted data. Since the computer is receiving the data, there is no need to tabulate the data for organization in order to facilitate the compositional and isotopic ratios required for the data interpretation. In addition, the analyzed data may be produced in any form as required by the user. The present invention may also be utilized in associated with any other selected well log data.

Rather than plot the data as disclosed in U.S. Patent No. 7,124,030 and U.S. Patent No. 7,174,254, the computer determined trends from the inputted data. A user provides specific templates (a mathematical, formula, equation, algorithm or other function) to determine when sequential points of data actually form a trend. The templates may be stored in the memory of the computing system. For example, specific data points may form a mixing line on a plot. However, to forego the use of plots, the data previously used to identify "mixing lines" represents points of data which fall within a specific range of points. Thus, the user may input specific ranges which signify a mixing line. The trend analyzer receives information from the user to provide identification of a trend. Additionally, the trend may be identified by a mathematical equation which enables the identification of trends from the data points. The trend analyzer then determines any trends from the inputted data. Next, the computer may utilize the identified trends to determine barriers, seals and zones of good hydrocarbon communications (compartments). Mixing trends may be indicative of good hydrocarbon communication zones (e.g., compartments, charge zones, missed-pay, biodegraded zones, etc.). The start and end of identified trends may reveal breaks which equate to seals or barriers. A barrier occurs where a simple break between identified trends occurs. A seal occurs where the break is significant and the next depth data point or trend deviates substantially. The next trend either reverses direction or the next data point is far removed from the previous point or trend. Thus, the computer calculates and identifies trends representative of hydrocarbon compartments and communication. In addition, zones, seals barriers, baffles, etc. may be identified.

Areas indicative of gas/oil charge may then be identified from the determined trends and barriers, seals and zones of good hydrocarbon communications. These noteworthy areas are determined by background contrasting isotopic values associated with good hydrocarbon communication zones. Thus, significant geological characteristics are applied to geochemical analysis to provide accurate analysis during drilling operations.

FIG. 13 is a flow chart outlining the steps for interpreting engineering and geological interpretations from data determined from mud gas isotope logging according to the teachings of the present invention. With reference to FIGs. 1-13, the steps of the method will now be explained. The method begins with step 600, where a user provides templates for determining trends. The templates may include ranges of values of various ratios and measurements which would constitute a trend. Additionally, the user may provide mathematical equations for determining when data points constitute a trend. Next, in step 602, data is obtained. Data is obtained from gas samplings of mud taken at discrete depth intervals. In alternate embodiments of the present invention, the interval may be varied according to the subsurface lithologies encountered or the analytical equipment involved. However, in any sample logging using the mud gas isotope logging technique, samplings must be obtained at sufficiently frequent intervals to determine a background trend, which may vary as depth increases or geological environments determine. The samplings are analyzed to provide gas compositional data and carbon isotopic data. Next, in step 604, the data is inputted into the computer 502 through the user interface 506. Specific ratios or other trend identification processes may be determined or calculated from the inputted data. Since the computer is receiving the data, there is no need to tabulate the data for organization in order to facilitate the compositional and isotopic ratios required for the data interpretation. In addition, computer mudgas templates (e.g., algorithms, functions, etc.) may be manipulated through the use of "optimization" parameters, such as fewer lines, cluster groups and minimum points, to better correlate with associated geophysical well logs.

Next, in step 606, the computer determines trends from the inputted data. The user provides specific ranges or optimization parameters to determine when sequential points of data actually form a trend as defined in the templates in step 600. The trend analyzer then determines when a trend occurs. Next, in step 608, the computer may utilize the identified trends to determine barriers, seals and zones of good hydrocarbon communications (compartments). Trends may be indicative of good hydrocarbon communication zones (e.g., compartments, charge zones, pissed-pay, biodegraded zones, etc.). The start and end of identified trends may reveal breaks which equate to seals, baffles, barriers, or other hydrocarbon communication zones. A barrier occurs where a simple break between identified trends occurs. A seal occurs where the break is significant and the next depth data point or trend deviates substantially. The next trend either reverses direction or the next data point is far removed from the previous point or trend. The computer outputs the data as desired by the user (e.g., data, log or other displayed result).

Areas indicative of gas/oil charge may then be identified from the determined trends and barriers, seals and zones of good hydrocarbon communications. In addition, the present invention may be utilized in association with other well logs as desired. These noteworthy areas are determined by background contrasting isotopic values associated with good hydrocarbon communication zones. Thus, significant geological characteristics are applied to geochemical analysis to provide accurate analysis during drilling operations.

The present invention determines trends without requiring the plotting of data on plots or upon logging tables. The present invention enables a user to interpret data automatically by use of the computing system 500. The determined trends may be used to interpret compartments and seals to define reservoirs containing hydrocarbons and seals that define migration pathways in the subsurface. Additionally, new interpretations may be added, such as a determination of percent thermogenic and percent microbial content to assist in characterizing hydrocarbons in the subsurface.

The present invention provides many advantages to existing interpretative methods and systems used in the oil and gas industry. The present invention determines trends from inputted data automatically and provides various interpretations of current well data points while providing additional information for effectively and accurately predicting or suggesting good hydrocarbon communication (compartments), barriers, and seals.

In an alternate embodiment of the present invention, the present invention incorporates the novel interpretive methodologies disclosed in U.S. Patent No. 7,124,030 and U.S. Patent No. 7,174,254 with current geophysical logs. FIG. 14 is an exemplary existing log 300 utilized to providing information on a well. As discussed above, logs are displayed on a wide variety of individual charts/graphs on a long 'strip' of paper that are keyed to depths in the well, and may provide information on depth and thickness of strata/formations penetrated by a well, lithologic characteristics and types of formations encountered (such as shale, sandstone, limestone, dolomite), fluid content including presence of oil or gas, porosity, permeability, dip, reservoir, pressure, etc. The development of new logs, as well as new uses for old logs, is continuously changing. For example, FIG. 12

provides a portion of the strip of the log 300. The log 300 includes a plurality of columns for displaying information, such as column 302 (ROP data), column 304 (total gas), columns 306 and 308 (carbon data), column 310 (remarks), and column 312 (lithology). The information is listed for a depth 312 which is depicted upon a vertical axis. The above information may be listed in other forms, but in the most common form, data is listed abeam each other for each particular depth to provide ease in analyzing well log information.

FIG. 15 is an informational block diagram 400 of the log information utilized in current geophysical logs with the information gathered in the interpretive methodologies disclosed in U.S. Patent No. 7,124,030 and U.S. Patent No. 7,174,254. One or more columns 402 of the log may include mudgas data. The column 402 may include gas logs, ROP, lithology, etc. and include information on total gas, C2/C1, C1, C2, C3, %shale/sand, etc. Adjacent the mudlog column(s) 402 is information on the geophysical log 404 (e.g., completion logs, electric, sonic, radioactive, NMR, etc.). Different types of logs may include information on resistivity, sonic, gamma ray, NMR, neutron and other data pertinent to a well. The present invention now provides column 406, which may include gas isotope log information such as 13Cn (carbon isotopes, n=1 to 5), 2H (hydrogen isotopes), gas maturity, % thermogenic, %microbial (biogenic), compartments (good hydrocarbon communication in strata derived from mixing lines), and seal, barriers and baffles (restricted hydrocarbon communication in strata derived from mixing lines).

FIG. 16 is an exemplary log 700 of the present invention. The log 700 includes a depth column 702, a gas isotope log column 704, a maturity column 706, a thermogenic data column 708 and a column 710 providing information on seals/barriers (compartments, etc.).

The present invention provides all this information adjacent to each other at specific depths along side current log information to provide assistance in analyzing a well. The gas isotope logs may be utilized to verify other logs and enhance interpretation of information gathered from a well log. In addition, new interpretations, such as compartments and seals may be utilized to help define reservoirs containing hydrocarbons and seals that define migration pathways in the subsurface. Additionally, new interpretations may be added, such as percent thermogenic and percent microbial data to assist in characterizing hydrocarbons in the subsurface.

The present invention may take an existing formation evaluation log having a plurality of columns depicting various types of information versus a depth and add one or more columns providing gas isotope log information as discussed above. The additional column matches data at various depths. As depth increases, the information is provided at the relevant depth which may include mudgas information, geophysical information and the newly added gas isotope log information.

It should be understood, that the log display of FIG. 16 is exemplary of the present invention. Columns and order may vary and still remain within the scope of the present invention. In addition, although depth is depicted on the Y-axis of the log and column information on the X-axis, in alternate embodiments of the present invention, the present invention may include depth depicted on the X-axis and column data on the Y-axis.

While the present invention is described herein with reference to illustrative embodiments for particular applications, it should be understood that the invention is not limited thereto. Those having ordinary skill in the art and access to the teachings provided herein will recognize additional modifications, applications, and embodiments within the scope thereof and additional fields in which the present invention would be of significant utility.

Thus, the present invention has been described herein with reference to a particular embodiment for a particular application. Those having ordinary skill in the art and access to the present teachings will recognize additional modifications, applications and embodiments within the scope thereof.

It is therefore intended by the appended claims to cover any and all such applications, modifications and embodiments within the scope of the present invention.

WHAT IS CLAIMED IS:

1. A method of interpreting sampled mud gas compositional and isotopic data in a drilling operation of a target area, the method comprising the steps of:

providing at least one template to a computing system for defining or identifying a trend from analyzed mud gas samplings;

obtaining a plurality of mud gas samplings from a target area;

inputting data from the plurality of mud gas samplings into the computing system;

analyzing the data from the plurality of mud gas samplings to obtain hydrocarbon compositional and isotopic data points associated with hydrocarbon isotopic composition of the plurality of gas samplings, the data points including information on composition of hydrocarbons within each of the mud gas samplings;

determining a trend of the data points associated with the template;

deriving from the trend an interpretation of the obtained mud gas samplings indicative of hydrocarbon communication or compartmentalization.

2. The method of interpreting sampled mud gas compositional and isotopic data of claim 1 wherein the derived interpretation of the log includes gas isotopic data.

3. The method of interpreting sampled mud gas compositional and isotopic data of claim 1 wherein the isotopic data is utilized to verify information from the mudgas and geophysical and well log information.

4. The method of interpreting sampled mud gas compositional and isotopic data of claim 1 wherein the step of analyzing the plurality of mud gas samplings includes determining a $\delta^{13}C$ and ^{2}H composition within the mud gas samplings.

5. The method of interpreting sampled mud gas compositional and isotopic data of claim 1 wherein a break in at least two determined trends indicates a hydrocarbon communication barrier, baffle or seal.

6. The method of interpreting sampled mud gas compositional and isotopic data of claim 5 wherein the break is large and is indicative of a seal.

7. The method of interpreting sampled mud gas compositional and isotopic data of claim 5 wherein the break is small and is indicative of a baffle or other barrier to hydrocarbon communication.

8. The method of interpreting sampled mud gas compositional and isotopic data of claim 1 further comprising the steps of:

incorporating the interpretation derived from a trend in a first well within a target area with a second interpretation derived from a trend in a second well; and

determining hydrocarbon communication zones or compartments from the incorporated interpretations.

9. The method of interpreting sampled mud gas compositional and isotopic data of claim 1 wherein the interpretation of the obtained mud gas samplings indicative of hydrocarbon communication or compartmentalization is indicative of missed-pay, charge recognition, biodegration or seal identification.

10. The method of interpreting sampled mud gas compositional and isotopic data of claim 1 wherein the interpretation of the obtained mud gas samplings indicative of hydrocarbon communication or compartmentalization indicates diffusion or other leakage of reservoir gases.

11. The method of interpreting sampled mud gas compositional and isotopic data of claim 1 wherein the interpretation of the obtained mud gas samplings indicative of hydrocarbon communication or compartmentalization indicates low or high gas reservoir saturations.

12. The method of interpreting sampled mud gas compositional and isotopic data of claim 1 further comprising the step of interpreting low and high gas saturations in stratigraphic zones wherein analysis of isotopic data is used to determine an effectiveness of sealing intervals associated with movement of hydrocarbons from oil and gas in the target area.

13. A method of interpreting sampled mud gas compositional and isotopic data in a drilling operation of a target area, the method comprising the steps of:

providing at least one template for defining a trend from analyzed mud gas samplings to a computing system;

profiling a plurality of analyzed mud gas samplings through a well bore at a plurality of incremental depths of the well bore;

inputting data from the plurality of mud gas samplings into the computing system;

analyzing, by the computing system, the data from the plurality of gas samplings to obtain a plurality of isotopic data points associated with hydrocarbon isotopic composition of the plurality of gas samplings, the plurality of isotopic data points includes data associated with a composition of hydrocarbons within each of the mud gas samplings;

determining geological information from the target area derived from the plotted plurality of isotopic data points;

analyzing the plurality of isotopic data points to geological interpret the geochemical information.

14. The method of interpreting sampled mud gas compositional and isotopic data of claim 13 wherein the derived interpretation includes gas isotopic data.

15. The method of interpreting sampled mud gas compositional and isotopic data of claim 13 wherein the isotope data points are utilized to verify information from the mudgas and geophysical and well log information.

16. A system for interpreting sampled mud gas compositional and isotopic data in a drilling operation of a target area, the system comprising:

means for providing at least one template for defining or identifying a trend from analyzed mud gas samplings to a computing system;

means for inputting data from a plurality of analyzed mud gas samplings in the computing system, the plurality of analyzed mud gas samplings obtained from a target area;

means for analyzing data from the plurality of mud gas samplings to obtain hydrocarbon compositional and isotopic data points associated with the plurality of gas samplings, the data points including information on composition of hydrocarbons within each of the mud gas samplings;

means for determining a trend of the data points associated with the template;

wherein an interpretation of the obtained mud gas samplings is indicative of hydrocarbon communication or compartmentalization.

17. The system for interpreting sampled mud gas compositional and isotopic data of claim 16 wherein the means for inputting a plurality of mud gas samplings in the computing system is a user interface.

18. The system for interpreting sampled mud gas compositional and isotopic data of claim 16 wherein the means for determining a trend of the data points is a trend analyzer.

19. The system for interpreting sampled mud gas compositional and isotopic data of claim 16 wherein the interpretation derived from a trend in a first well within a target area is incorporated with a second interpretation derived from a trend in a second well and hydrocarbon communication zones or compartments in a field are determined from the incorporated interpretations.

20. The system for interpreting sampled mud gas compositional and isotopic data of claim 16 wherein the interpretation of the obtained mud gas samplings indicative of hydrocarbon communication or compartmentalization is missed-pay, charge recognition, biodegration or seal identification

21. The system for interpreting sampled mud gas compositional and isotopic data of claim 16 wherein the interpretation of the obtained mud gas samplings indicative of hydrocarbon communication or compartmentalization indicates diffusion or other leakage of reservoir gases.

22. The system for interpreting sampled mud gas compositional and isotopic data of claim 16 wherein the interpretation of the obtained mud gas samplings indicative of hydrocarbon communication or compartmentalization indicates low or high gas reservoir saturations.

23. The system for interpreting sampled mud gas compositional and isotopic data of claim 16 further comprising:

means for identifying intact seals and seals that leak hydrocarbons from a charge in background isotopic signatures and identified isotopic trends;

means for calibration between physical property measurements of shale or other caprocks and the ability to seal; and

means for identifying oil and gas charge of the same type and maturity located in reservoir sands between identified local and regional seals.

24. The system for interpreting sampled mud gas compositional and isotopic data of claim 16 further comprising means for evaluating and predicting reservoir seals to verify a presence of any sealing lithology regardless of origin.

25. The system for interpreting sampled mud gas compositional and isotopic data of claim 16 further comprising:

means for interpreting isotopic measurements made on mudgas samplings from either side of a potentially sealing interval, said interpreting means having:

means for determine the effectiveness of a seal; and

means for establish likely migration pathways and reservoir compartmentalization;

means for measuring changes in background isotopic signals of intact seals versus seals that leak hydrocarbons; and

means for calibrating between physical property measurements of seals and the ability to seal by preventing or impeding movement of oil and gas hydrocarbons.

26. A method of displaying well log information in a drilling operation of a target area, said method comprising the steps of:

obtaining a plurality of mud gas samples from a target area;

analyzing the plurality of mud gas samples to obtain hydrocarbon compositional and isotopic data from the samples;

plotting the hydrocarbon compositional and isotopic data upon a chart or well log;

determining a trend of a plurality of points upon the chart;

deriving from the chart or log an interpretation of the log indicative of hydrocarbon communication; and

displaying the interpretation on a formation evaluation log.

27. The method of displaying well log information of claim 26 wherein mudgas and geophysical information is listed in column form adjacent the derived interpretation of the log at various depths of the targeted area.

28. The method of displaying well log information of claim 27 wherein the derived interpretation of the log includes gas isotopic data.

29. The method of displaying well log information of claim 27 wherein the gas isotope data is utilized to verify information from the mudgas and geophysical information.

30. A method of displaying well log information in a drilling operation of a target area, said method comprising the steps of:

profiling a plurality of mud gas samples through a well bore at a plurality of incremental depths of the well bore;

analyzing the plurality of gas samples to obtain a plurality of isotopic data points associated with hydrocarbon isotopic composition of the plurality of gas samples. the plurality of isotopic data points includes data associated with a composition of ethane and methane within each of the mud gas samples;

plotting the plurality of isotopic data points;

determining geological information from the target area derived from the plotted plurality of isotopic data points;

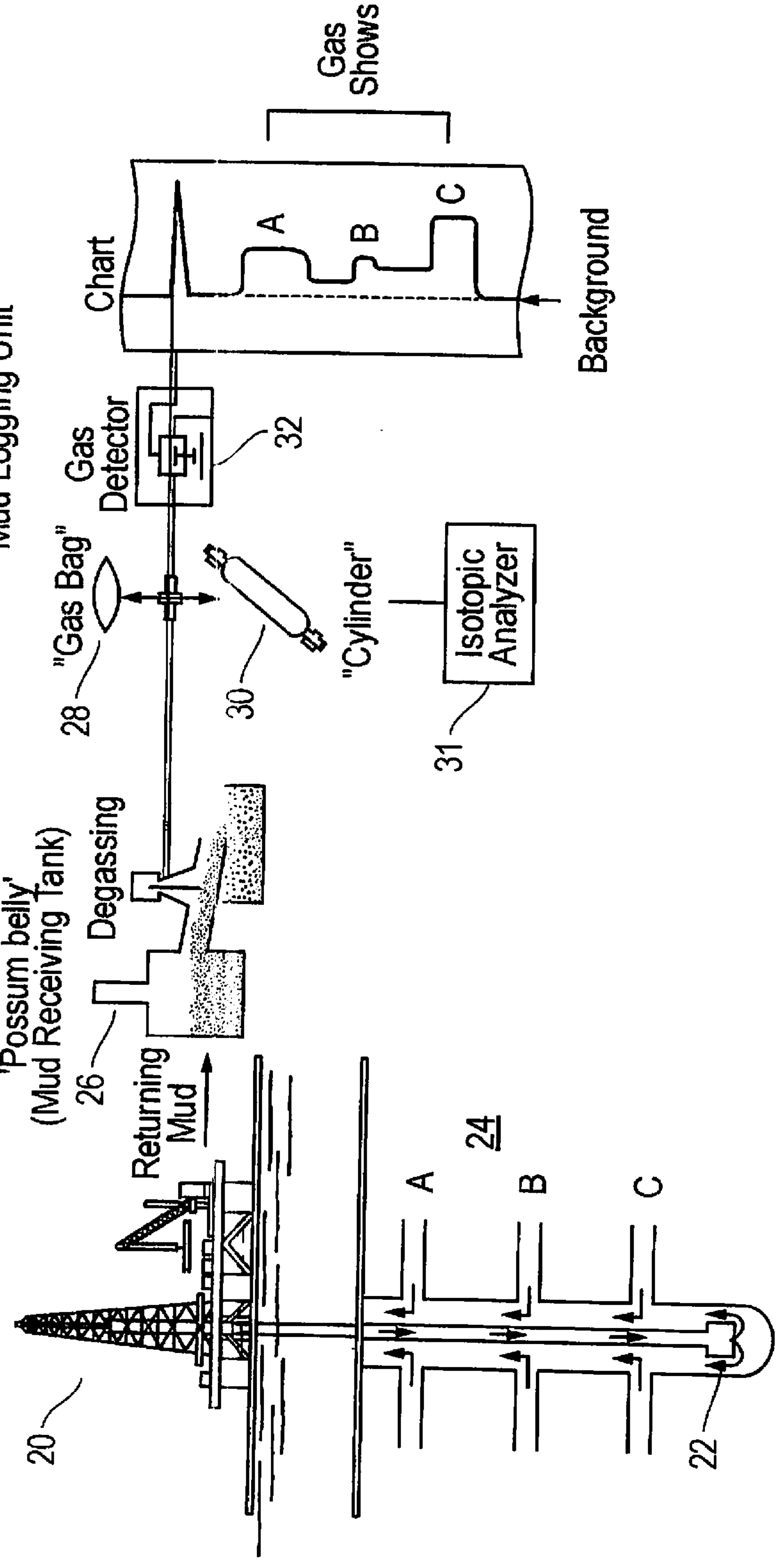
analyzing the plurality of isotopic data points to geochemically interpret the geological information; and

displaying the interpretation on a formation evaluation log.

32. The method of displaying well log information of claim 31 wherein mudgas and geophysical information is listed in column form adjacent the derived interpretation of the log at various depths of the targeted area.

33 The method of displaying well log information of claim 32 wherein the derived interpretation of the log includes gas isotopic data.

34. The method of displaying well log information of claim 32 wherein the gas isotope data is utilized to verify information from the mudgas and geophysical information.



Mud Logging Unit
Chart
Gas Shows
A
B
C
Background
Gas Detector
32
"Gas Bag"
28
30
"Cylinder"
Isotopic Analyzer
31
'Possum belly' (Mud Receiving Tank)
26
Degassing
Returning Mud
24
A
B
C
20
22

FIG. 1

Depth (ft)	Total Gas (Rig. units)	Total HC (Lab. vol%)	Gas Composition Data %C1	%C2	%C3	%IC4	%NC4	%IC5	%NC5	%C6+	Dryness %C1/Cn	Wetness %C2/Cn	Carbon Isotope Data $\delta^{13}C1$	$\delta^{13}C2$	$\delta^{13}C3$
2150		0.22	0.21		0.001		0.001	0.001	0.002		97.54		-58.6		
2300	19	0.26	0.26								100		-52.0		
2450		0.99	0.97	0.014	0.002	0.001					98.26	1.42	-45.1		
2600	65	1.10	1.08	0.012	0.006	0.002					98.19	1.09	-44.1		
2750		0.89	0.87	0.007	0.004	0.001	0.001	0.001	0.001		98.13	0.82	-46.6		
2900		0.01	0.01								100				
3050		1.15	1.13	0.011	0.004		0.001	0.001	0.001		98.42	0.96	-48.4		
3200	136	2.19	2.16	0.018	0.004	0.001	0.001	0.001	0.001		98.79	0.82	-49.2		
3350		0.79	0.79	0.003							99.61	0.39	-49.0		
3500		0.65	0.65	0.003							99.49	0.51	-48.2		
3650	54	0.83	0.82	0.008	0.002				0.001		98.62	1.00	-47.3		
3800		0.36	0.35	0.006	0.003		0.001	0.001	0.001		96.77	1.58	-46.6		
3950		0.82	0.78	0.024	0.013	0.002	0.002	0.002	0.002		94.58	2.91	-44.7		
4100		0.91	0.85	0.031	0.020	0.003	0.002	0.002	0.002		93.51	3.41	-44.4		
4250		0.97	0.87	0.051	0..025	0.006	0.005	0.005	0.005		90.00	5.28	-41.6		
4293	550	7.73	6.71	0.470	0.280	0.071	0.061	0.061	0.074		86.84	6.03	-42.0	-34.7	-33.1
4311	760	9.81	8.59	0.600	0.340	0.081	0.063	0.063	0.070		87.59	6.42	-42.0		
4326	120	1.30	1.16	0.071	0.038	0.010	0.008	0.008	0.010		88.00	5.44	-42.2		
4360	200	2.44	2.14	0.140	0.081	0.019	0.018	0.018	0.021		87.81	5.74	-42.1		
4423	125	1.42	1.24	0.086	0.047	0.011	0.010	0.010	0.012		87.57	5.07	-41.9		
4514	700	13.41	12.6	0.430	0.220	0.037	0.025	0.025	0.030		94.28	3.21	-42.5	-33.7	-32.7
4565	390	4.57	3.97	0.280	0.100	0.037	0.029	0.029	0.034		86.89	6.13	-41.6		
4576	850	11.16	9.91	0.610	0.400	0.077	0.053	0.053	0.059		88.78	5.46	-42.9	-34.0	-32.9
4600	220	2.38	2.11	0.140	0.080	0.015	0.011	0.011	0.014		88.62	5.88	-42.4		
4650		1.58	1.40	0.091	0.059	0.019	0.009	0.009	0.012		88.43	5.75	-42.6		
4700		2.61	2.33	0.140	0.078	0.015	0.014	0.014	0.018		89.34	5.37	-42.8		
4714	1700	45.61	43.2	1.530	0..350	0.100	0.046	0.046	0.041		94.71	3.35	-43.9	-33.5	-32.5
4900	140	1.93	1.78	0.089	0.033	0.008	0.006	0.006	0.007		92.32	4.62	-43.8		
5050		0.30	0.27	0.014	0.005	0.002	0.003	0.003	0.004		89.79	4.66	-44.2		

FIG. 2A

5350		1.19	1.15	0.024	0.007	0.001	0.002	0.002	0.003	96.73	2.02	-46.9
5500	80	1.21	1.17	0.025	0.008	0.002	0.002	0.002	0.003	96.60	2.06	-48.0
5650	80	1.38	1.33	0.033	0.012					96.73	2.40	-48.1
5800	60	0.98	0.94	0.030	0.013	0.001				95.54	3.05	-48.4
5950		0.95	0.89	0.037	0.017	0.001			0.001	94.06	3.91	-48.5
6100	92	1.44	1.32	0.074	0.039	0.004	0.002	0.002	0.001	91.53	5.13	-48.4
6250	42	0.80	0.73	0.039	0.023	0.003	0.002	0.002	0.002	91.11	4.87	-47.6
6400		1.10	0.96	0.074	0.048	0.007	0.005	0.005	0.005	87.02	6.71	-48.8
6550		0.72	0.62	0.047	0.033	0.004	0.004	0.004	0.004	86.65	6.57	-48.4
6700		1.16	1.02	0.078	0.047	0.006	0.004	0.004	0.003	87.83	6.72	-48.9
6850		0.83	0.72	0.060	0.037	0.004	0.003	0.003	0.004	86.67	7.22	-48.7

FIG. 2B

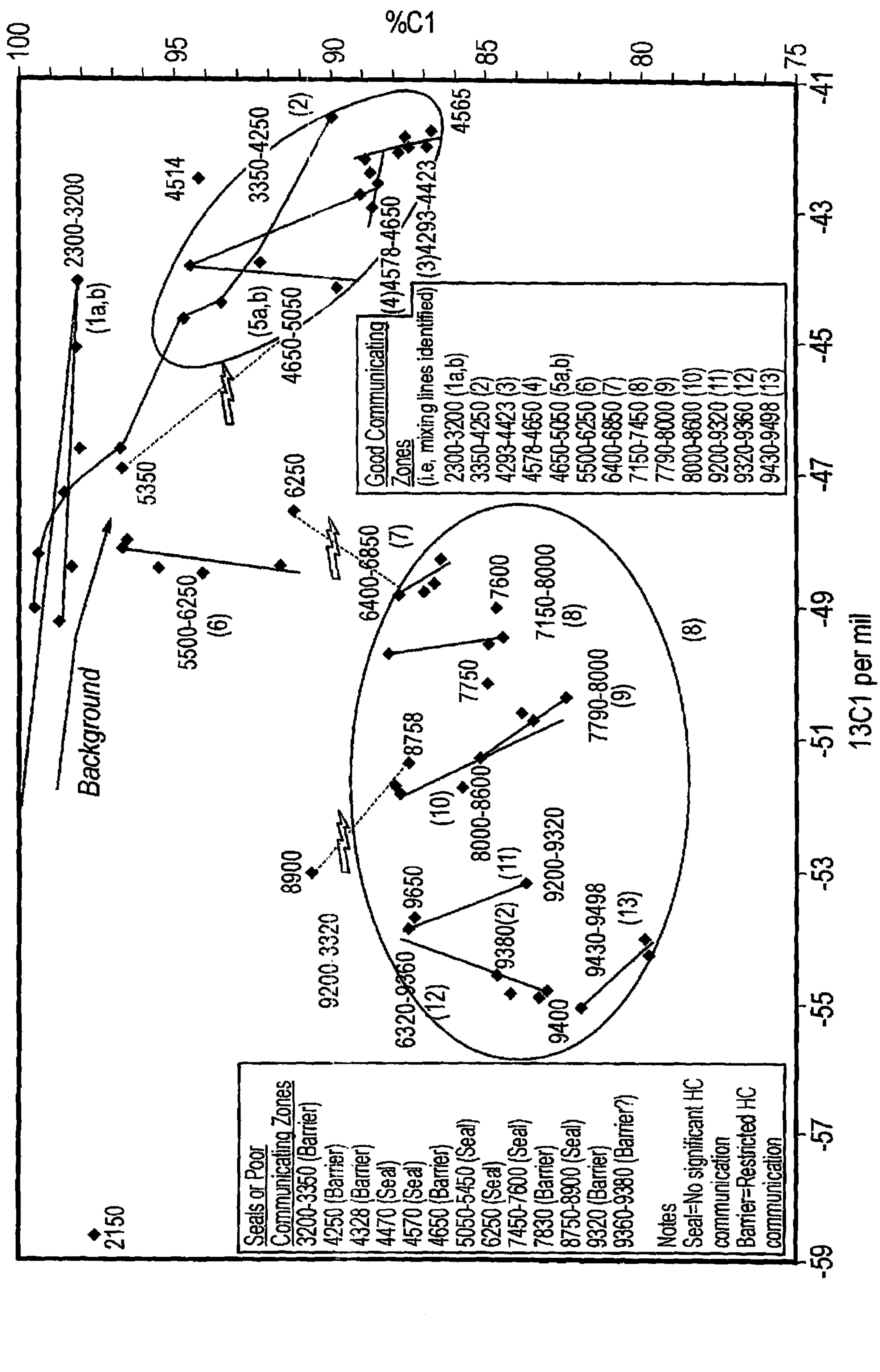

%C1
13C1 per mil
Background
Good Communicating Zones
(i.e, mixing lines identified)
2300-3200 (1a,b)
3350-4250 (2)
4293-4423 (3)
4578-4650 (4)
4650-5050 (5a,b)
5500-6250 (6)
6400-6850 (7)
7150-7450 (8)
7790-8000 (9)
8000-8600 (10)
9200-9320 (11)
9320-9360 (12)
9430-9498 (13)
Seals or Poor Communicating Zones
3200-3350 (Barrier)
4250 (Barrier)
4328 (Barrier)
4470 (Seal)
4570 (Seal)
4650 (Barrier)
5050-5450 (Seal)
6250 (Seal)
7450-7600 (Seal)
7830 (Barrier)
8750-8900 (Seal)
9320 (Barrier)
9360-9380 (Barrier?)
Notes
Seal=No significant HC communication
Barrier=Restricted HC communication

FIG. 3

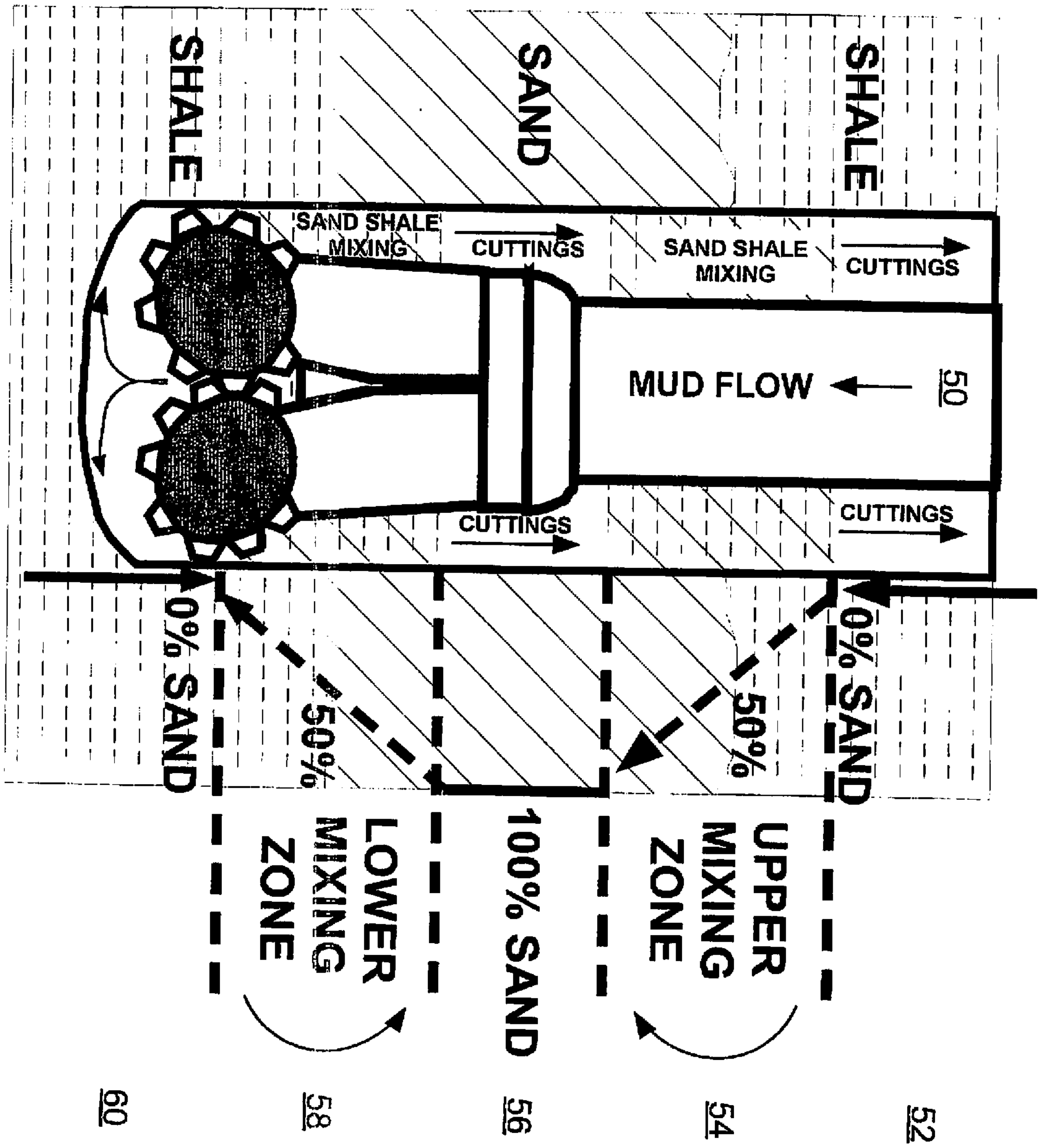

SHALE
SAND
SHALE
SAND SHALE MIXING
CUTTINGS
SAND SHALE MIXING
CUTTINGS
MUD FLOW
50
CUTTINGS
CUTTINGS
0% SAND
50%
0% SAND
50%
LOWER MIXING ZONE
100% SAND
UPPER MIXING ZONE
60
58
56
54
52

FIG. 4

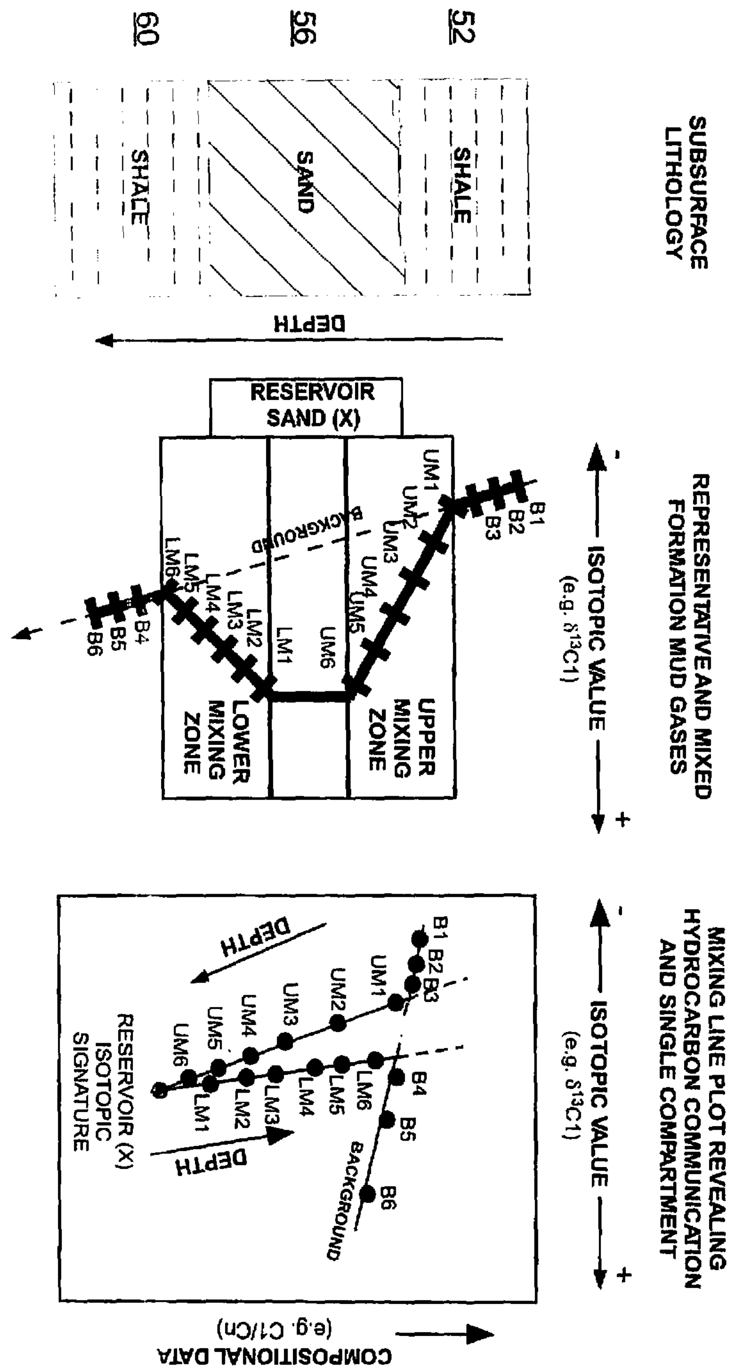


FIG 5A

FIG 5B

FIG 5C

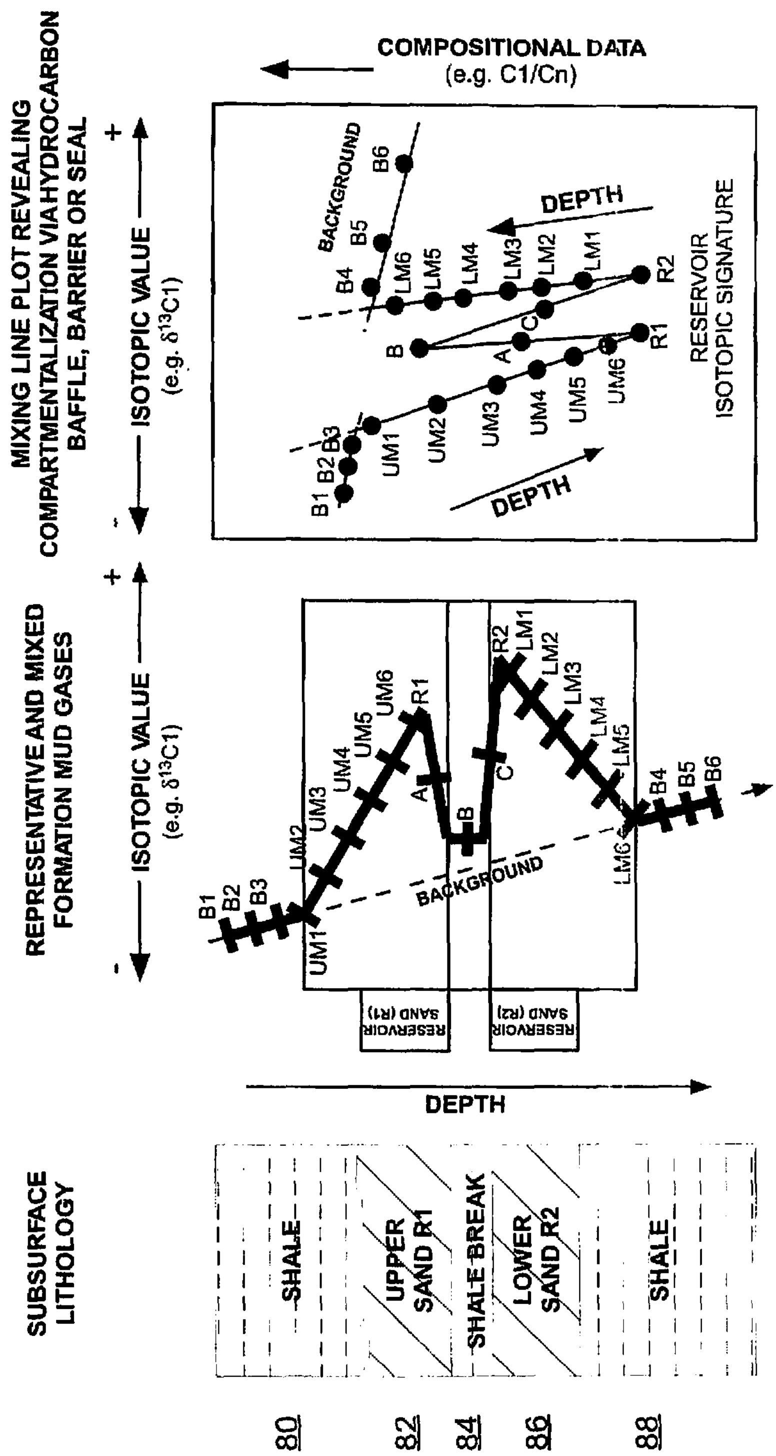


FIG 6A

FIG 6B

FIG 6C

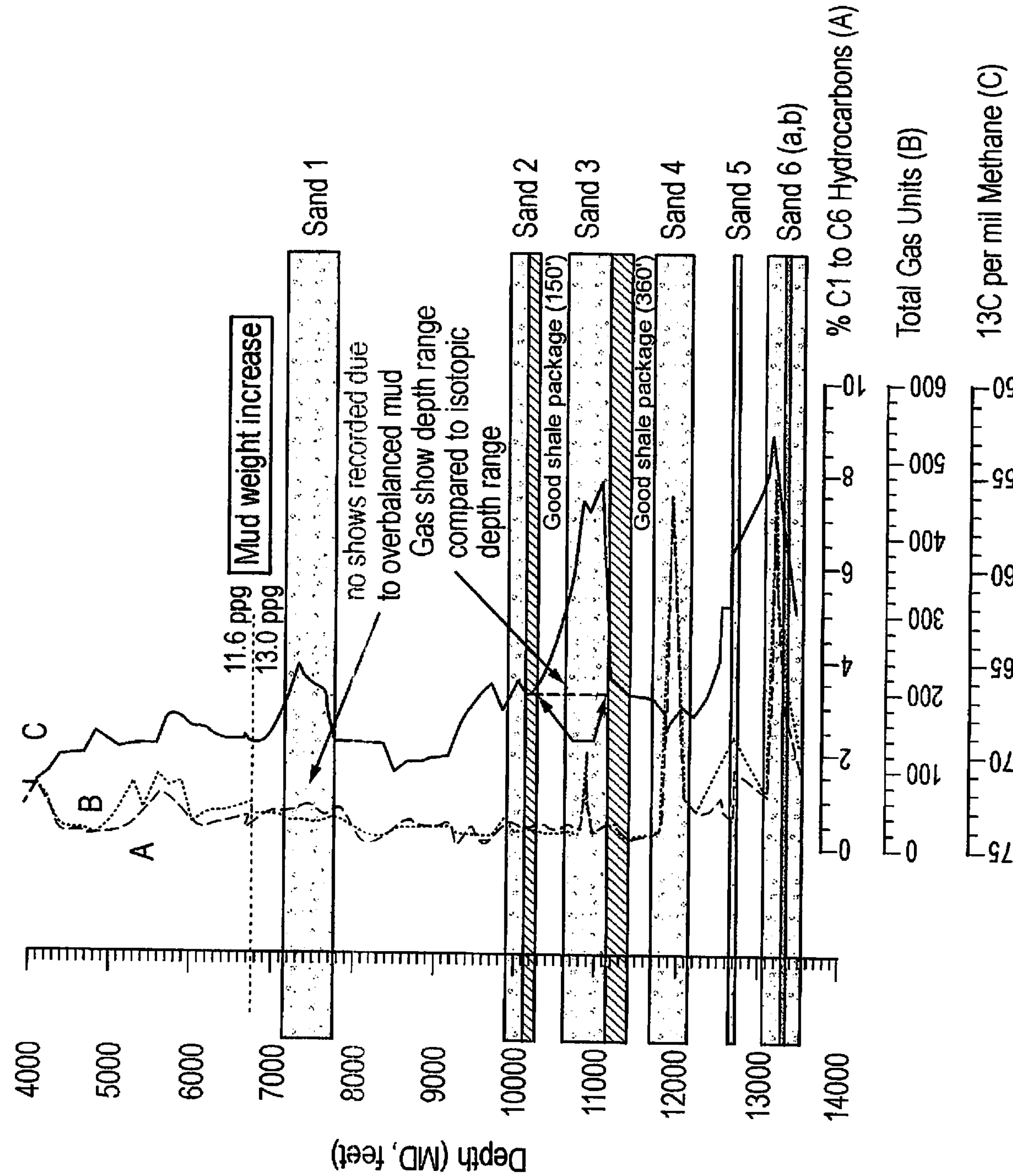

Depth (MD, feet)
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
A
B
C
11.6 ppg
13.0 ppg
Mud weight increase
no shows recorded due
to overbalanced mud
Gas show depth range
compared to isotopic
depth range
Good shale package (150')
Good shale package (360')
Sand 1
Sand 2
Sand 3
Sand 4
Sand 5
Sand 6 (a,b)
% C1 to C6 Hydrocarbons (A)
0
2
4
6
8
10
Total Gas Units (B)
0
100
200
300
400
500
600
13C per mil Methane (C)
-75
-70
-65
-60
-55
-50

FIG. 7

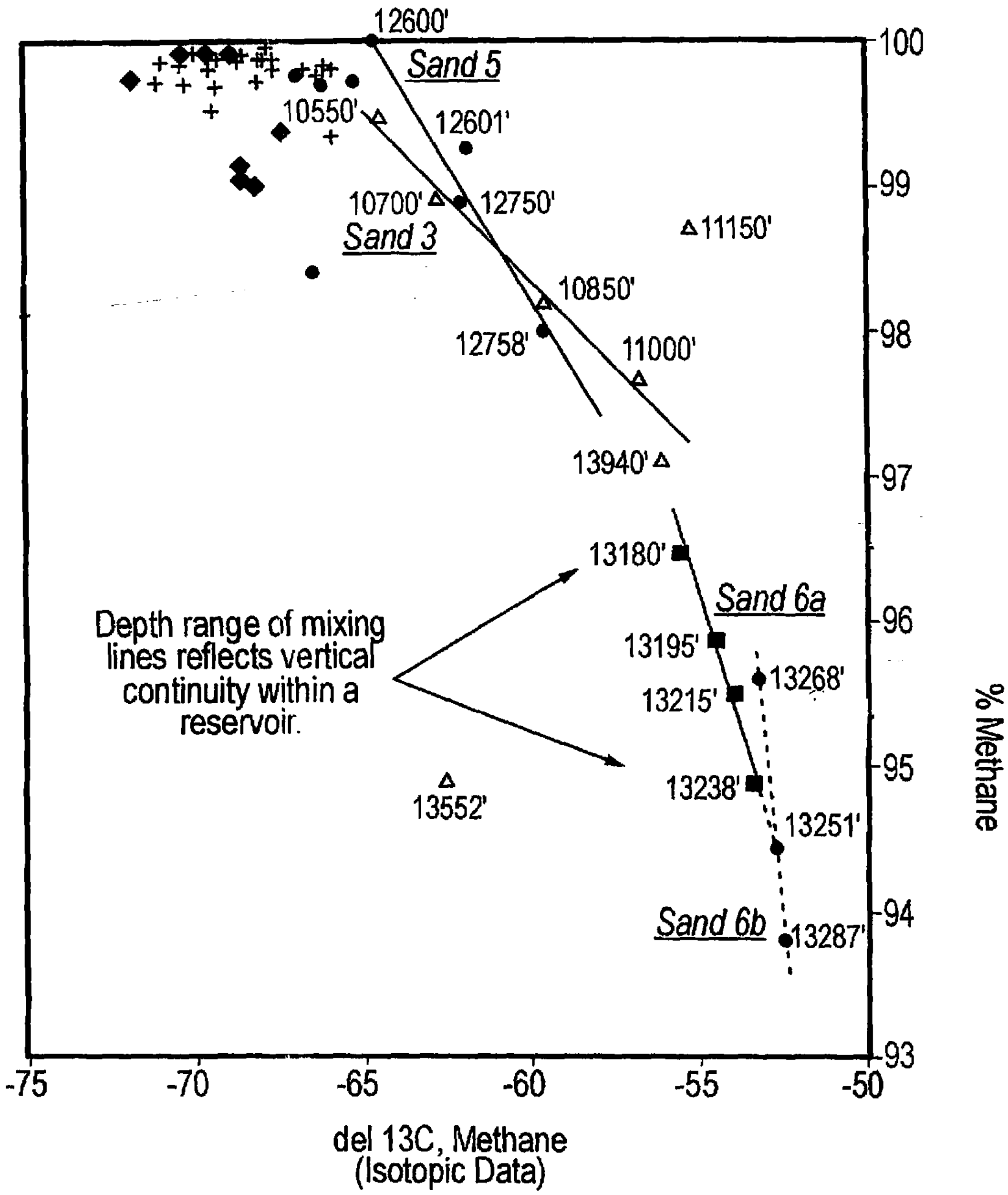

12600'
Sand 5
10550'
12601'
10700'
12750'
Sand 3
11150'
10850'
12758'
11000'
13940'
13180'
Sand 6a
Depth range of mixing lines reflects vertical continuity within a reservoir.
13195'
13268'
13215'
13238'
13552'
13251'
Sand 6b
13287'
100
99
98
97
96
95
94
93
% Methane
-75
-70
-65
-60
-55
-50
del 13C, Methane (Isotopic Data)

FIG. 8

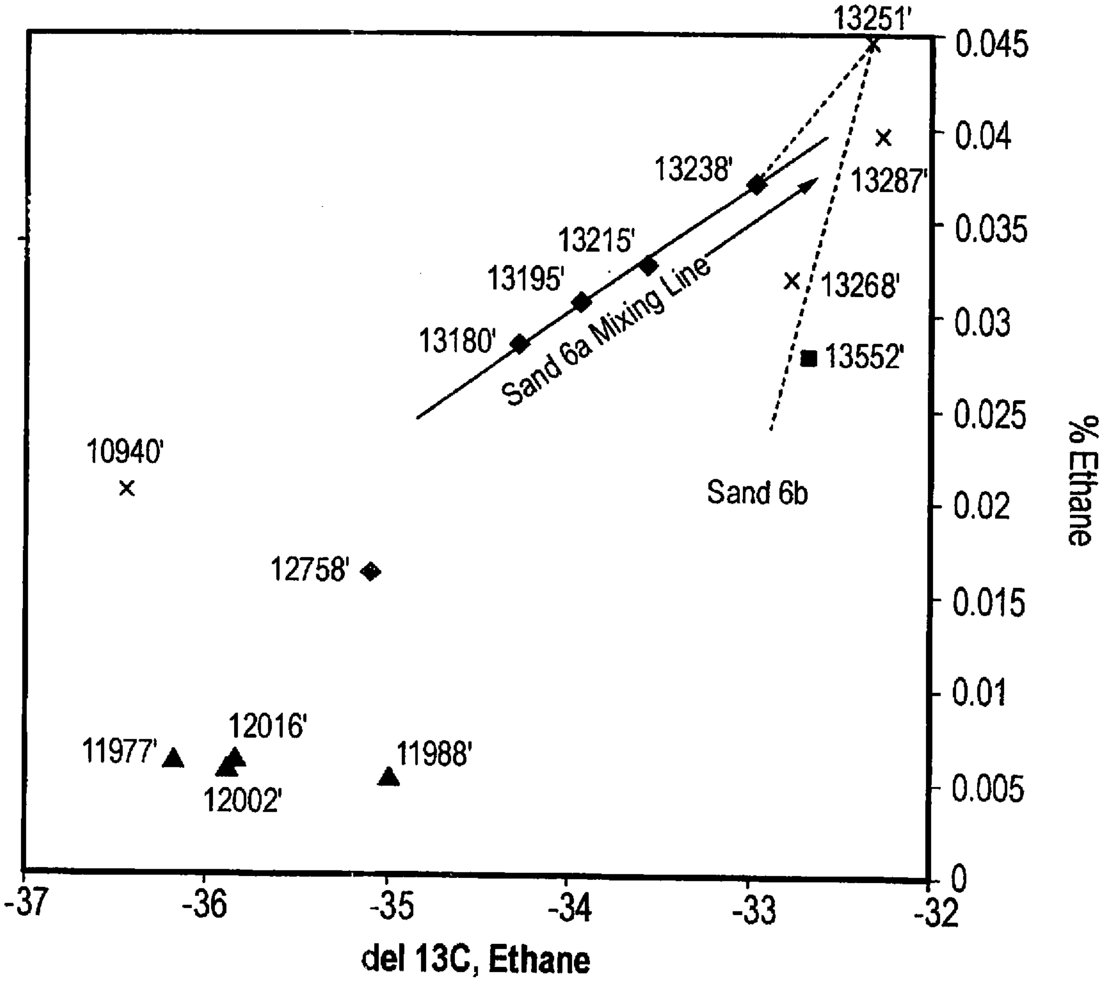
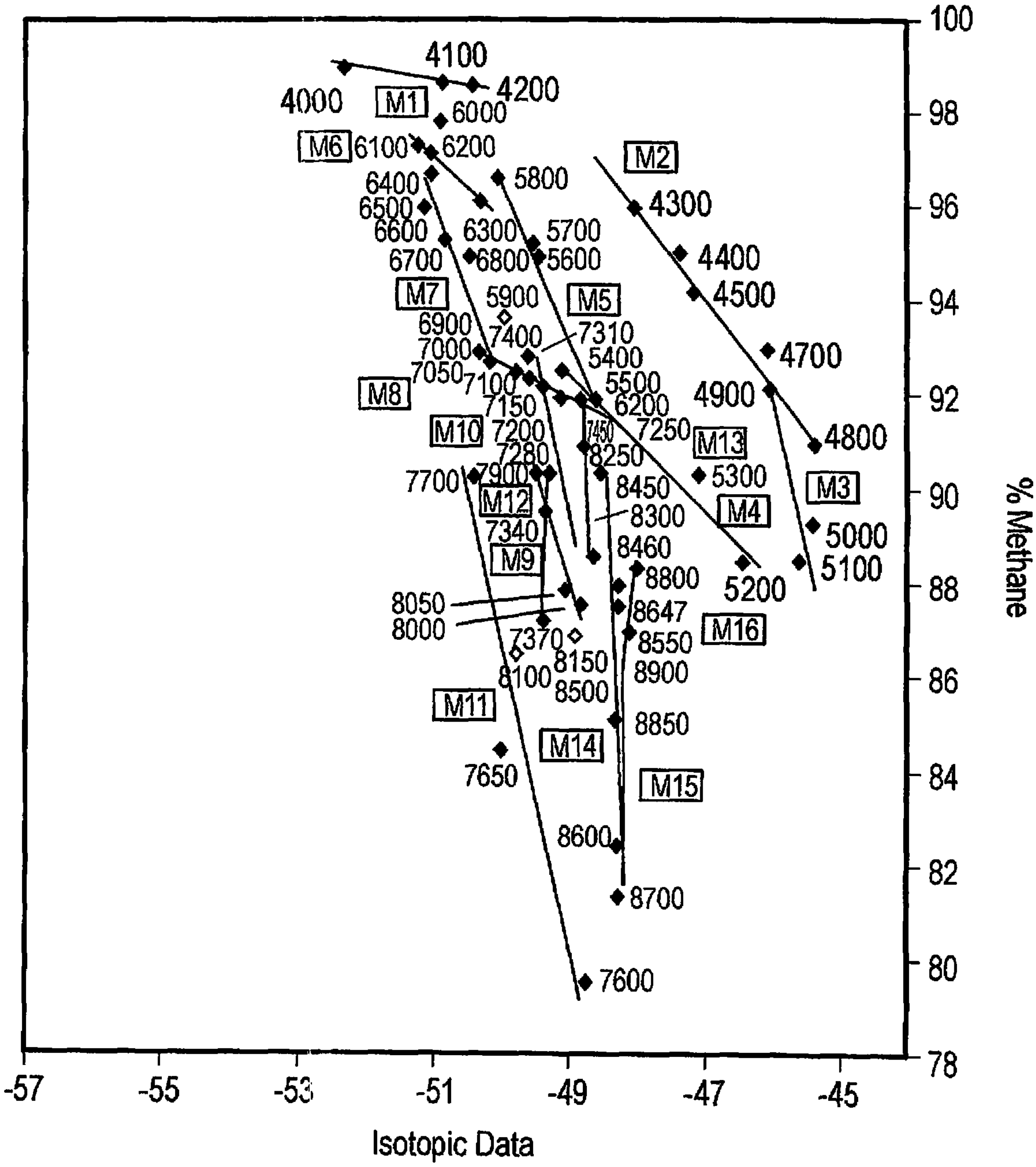
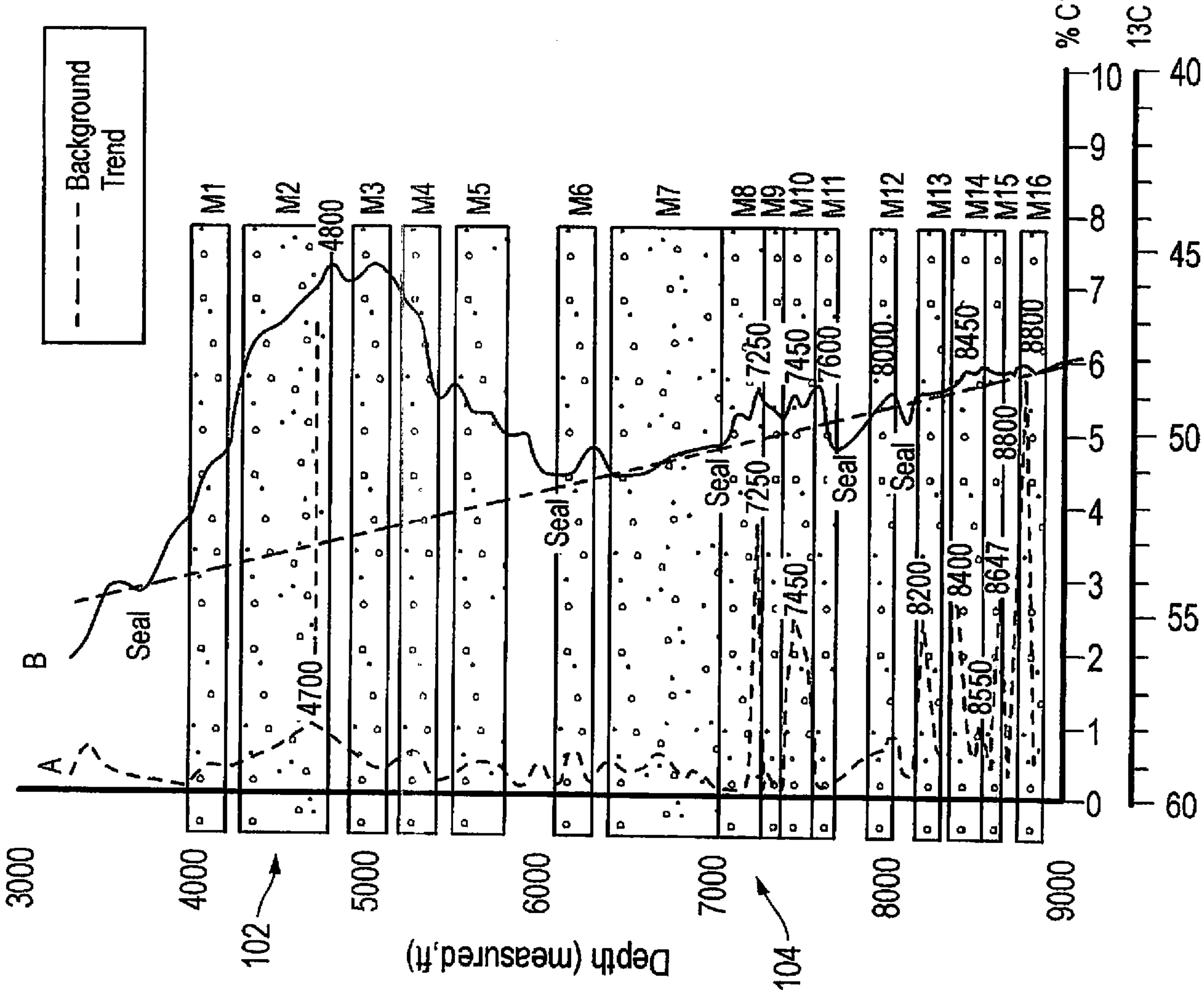

13251'
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
13238'
13287'
13215'
13195'
13268'
13180'
Sand 6a Mixing Line
13552'
10940'
Sand 6b
% Ethane
12758'
12016'
11977'
11988'
12002'
-37
-36
-35
-34
-33
-32
del 13C, Ethane

FIG. 9



4100
4000
4200
M1
6000
M6
6100
6200
M2
5800
6400
4300
6500
6600
6300
5700
4400
6700
6800
5600
4500
M7
5900
M5
6900
7400
7310
4700
7000
5400
7050
7100
5500
4900
M8
7150
6200
M10
7200
7450
7250
M13
4800
7280
8250
M3
7700
7900
5300
8450
M12
M4
8300
5000
7340
M9
8460
5100
8800
5200
8050
8000
8647
M16
7370
8550
8150
8900
8100
8500
M11
8850
M14
7650
M15
8600
8700
7600
-57
-55
-53
-51
-49
-47
-45
Isotopic Data
100
98
96
94
92
90
88
86
84
82
80
78
% Methane

FIG. 10



Background Trend
A
B
Seal
M1
M2
M3
M4
M5
M6
M7
M8
M9
M10
M11
M12
M13
M14
M15
M16
4700
4800
7250
7450
7600
8000
8200
8400
8450
8550
8647
8800
% C1-C6 Hydrocarbons (A)
13C per mil Methane (B)
0
1
2
3
4
5
6
7
8
9
10
40
45
50
55
60
3000
4000
5000
6000
7000
8000
9000
Depth (measured,ft)
102
104

FIG. 11

FIG. 12

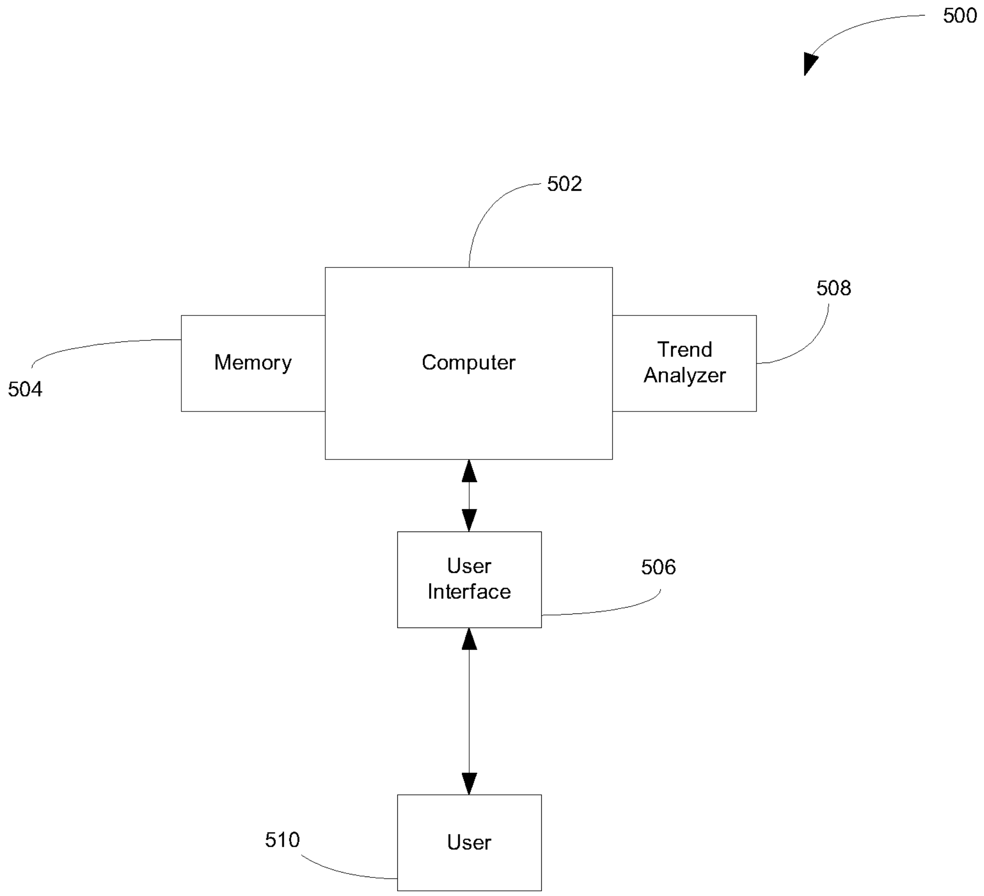
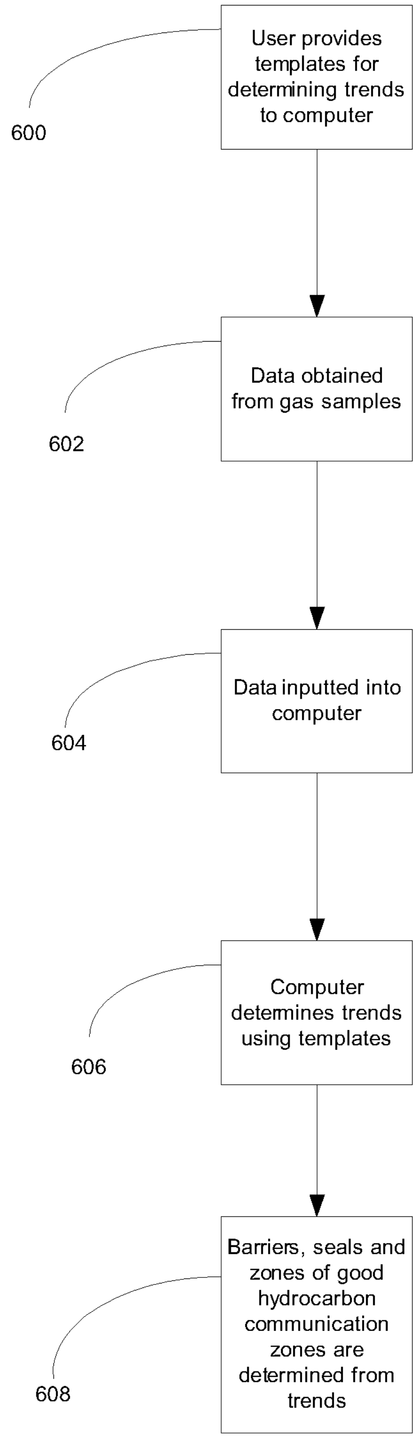

500
502
508
Memory
Computer
Trend Analyzer
504
User Interface
506
510
User

FIG. 13


User provides templates for determining trends to computer
600
Data obtained from gas samples
602
Data inputted into computer
604
Computer determines trends using templates
606
Barriers, seals and zones of good hydrocarbon communication zones are determined from trends
608

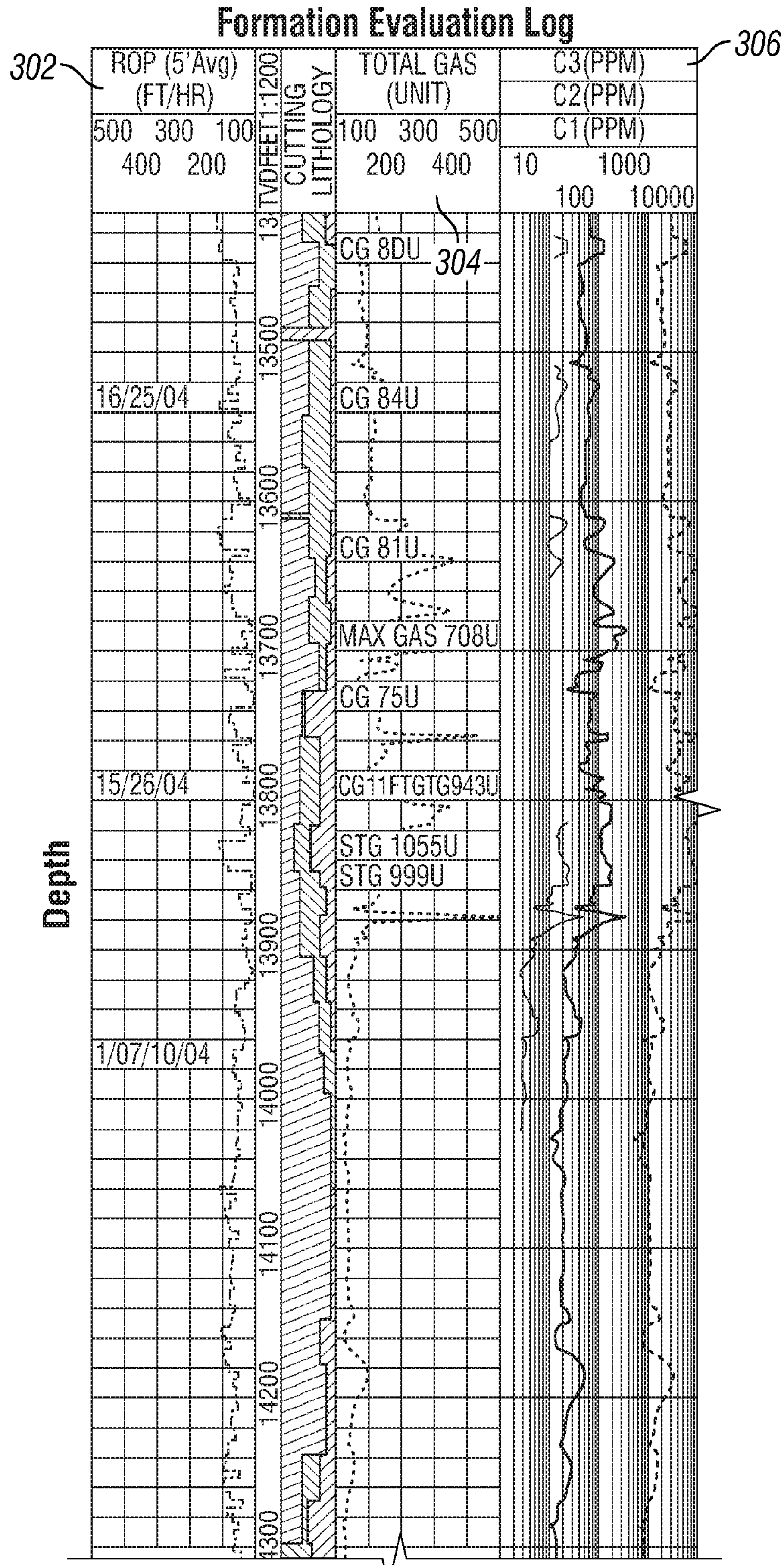

Formation Evaluation Log
302
306
ROP (5'Avg) (FT/HR)
500 300 100
400 200
TVDFEET1:1200
CUTTING LITHOLOGY
TOTAL GAS (UNIT)
100 300 500
200 400
C3(PPM)
C2(PPM)
C1(PPM)
10 1000
100 10000
304
CG 8DU
16/25/04
CG 84U
CG 81U
MAX GAS 708U
CG 75U
15/26/04
CG11FTGTG943U
STG 1055U
STG 999U
1/07/10/04
13500
13600
13700
13800
13900
14000
14100
14200
Depth

FIG. 14A

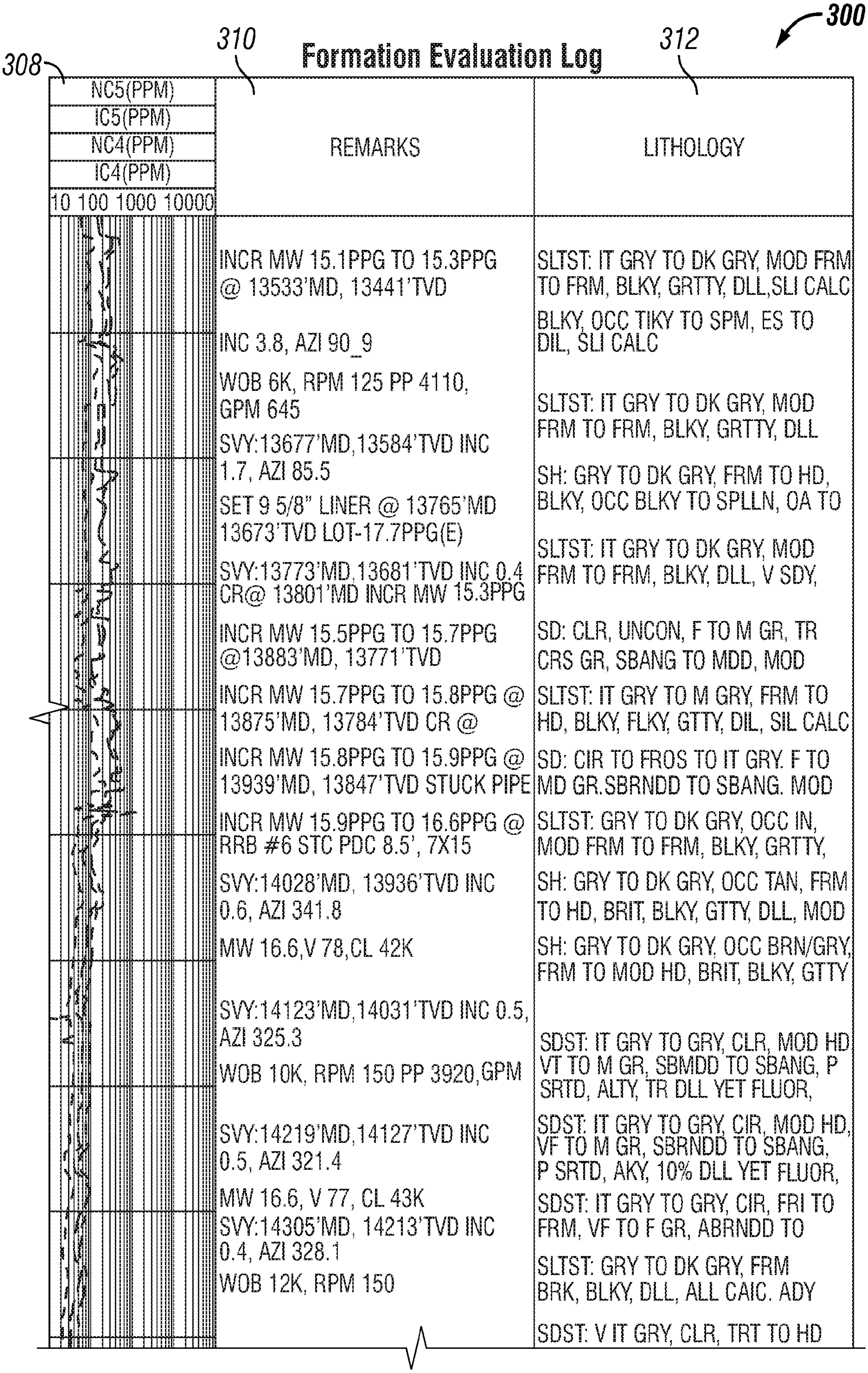

300
308
310
312
Formation Evaluation Log
NC5(PPM)
IC5(PPM)
NC4(PPM)
IC4(PPM)
10 100 1000 10000
REMARKS
LITHOLOGY
INCR MW 15.1PPG TO 15.3PPG @ 13533'MD, 13441'TVD
INC 3.8, AZI 90_9
WOB 6K, RPM 125 PP 4110, GPM 645
SVY:13677'MD,13584'TVD INC 1.7, AZI 85.5
SET 9 5/8" LINER @ 13765'MD 13673'TVD LOT-17.7PPG(E)
SVY:13773'MD,13681'TVD INC 0.4 CR@ 13801'MD INCR MW 15.3PPG
INCR MW 15.5PPG TO 15.7PPG @13883'MD, 13771'TVD
INCR MW 15.7PPG TO 15.8PPG @ 13875'MD, 13784'TVD CR @
INCR MW 15.8PPG TO 15.9PPG @ 13939'MD, 13847'TVD STUCK PIPE
INCR MW 15.9PPG TO 16.6PPG @ RRB #6 STC PDC 8.5', 7X15
SVY:14028'MD, 13936'TVD INC 0.6, AZI 341.8
MW 16.6,V 78,CL 42K
SVY:14123'MD,14031'TVD INC 0.5, AZI 325.3
WOB 10K, RPM 150 PP 3920,GPM
SVY:14219'MD,14127'TVD INC 0.5, AZI 321.4
MW 16.6, V 77, CL 43K
SVY:14305'MD, 14213'TVD INC 0.4, AZI 328.1
WOB 12K, RPM 150
SLTST: IT GRY TO DK GRY, MOD FRM TO FRM, BLKY, GRTTY, DLL,SLI CALC
BLKY, OCC TIKY TO SPM, ES TO DIL, SLI CALC
SLTST: IT GRY TO DK GRY, MOD FRM TO FRM, BLKY, GRTTY, DLL
SH: GRY TO DK GRY, FRM TO HD, BLKY, OCC BLKY TO SPLLN, OA TO
SLTST: IT GRY TO DK GRY, MOD FRM TO FRM, BLKY, DLL, V SDY,
SD: CLR, UNCON, F TO M GR, TR CRS GR, SBANG TO MDD, MOD
SLTST: IT GRY TO M GRY, FRM TO HD, BLKY, FLKY, GTTY, DIL, SIL CALC
SD: CIR TO FROS TO IT GRY. F TO MD GR.SBRNDD TO SBANG. MOD
SLTST: GRY TO DK GRY, OCC IN, MOD FRM TO FRM, BLKY, GRTTY,
SH: GRY TO DK GRY, OCC TAN, FRM TO HD, BRIT, BLKY, GTTY, DLL, MOD
SH: GRY TO DK GRY, OCC BRN/GRY, FRM TO MOD HD, BRIT, BLKY, GTTY
SDST: IT GRY TO GRY, CLR, MOD HD VT TO M GR, SBMDD TO SBANG, P SRTD, ALTY, TR DLL YET FLUOR,
SDST: IT GRY TO GRY, CIR, MOD HD, VF TO M GR, SBRNDD TO SBANG, P SRTD, AKY, 10% DLL YET FLUOR,
SDST: IT GRY TO GRY, CIR, FRI TO FRM, VF TO F GR, ABRNDD TO
SLTST: GRY TO DK GRY, FRM BRK, BLKY, DLL, ALL CAIC. ADY
SDST: V IT GRY, CLR, TRT TO HD

FIG. 14B

400

402 DURING DRILLING	TYPICALLY AFTER DRILLING UNLESS USING LWD/ MWD TOOLS 404	DURING DRILLING FROM MUD STREAM 406
MUDLOG LOG	**GEOPHYSICAL LOG**	**GAS ISOTOPE LOG**
E.G. GAS LOGS, ROP, LITHOLOGY ETC. TYPES TOTAL GAS, C2/C1, C1,C2,C3 ETC %SHALE/SAND ETC.	E.G. COMPLETION LOGS, ELECTRIC, SONIC, RADIOACTIVE, NMR ETC. TYPES RESISTIVITY, SONIC, GAMMARAY NMR NEUTRON ETC.	13CN (CARBON ISOTOPES, N= 1 TO 5) 2H (HYDROGEN ISOTOPES) GAS MATURITY % THERMOGENIC %MICROBIAL (BIOGENIC) COMPARTMENTS (GOOD HYDROCARBON COMMUNICATION IN STRATA DERIVED FROM MIXING LINES) SEALS, BARRIERS, BAFFLES (RESTRICTED HYDROCARBON COMMUNICATION IN STRATA DERIVED FROM MIXING LINES)

FIG. 15

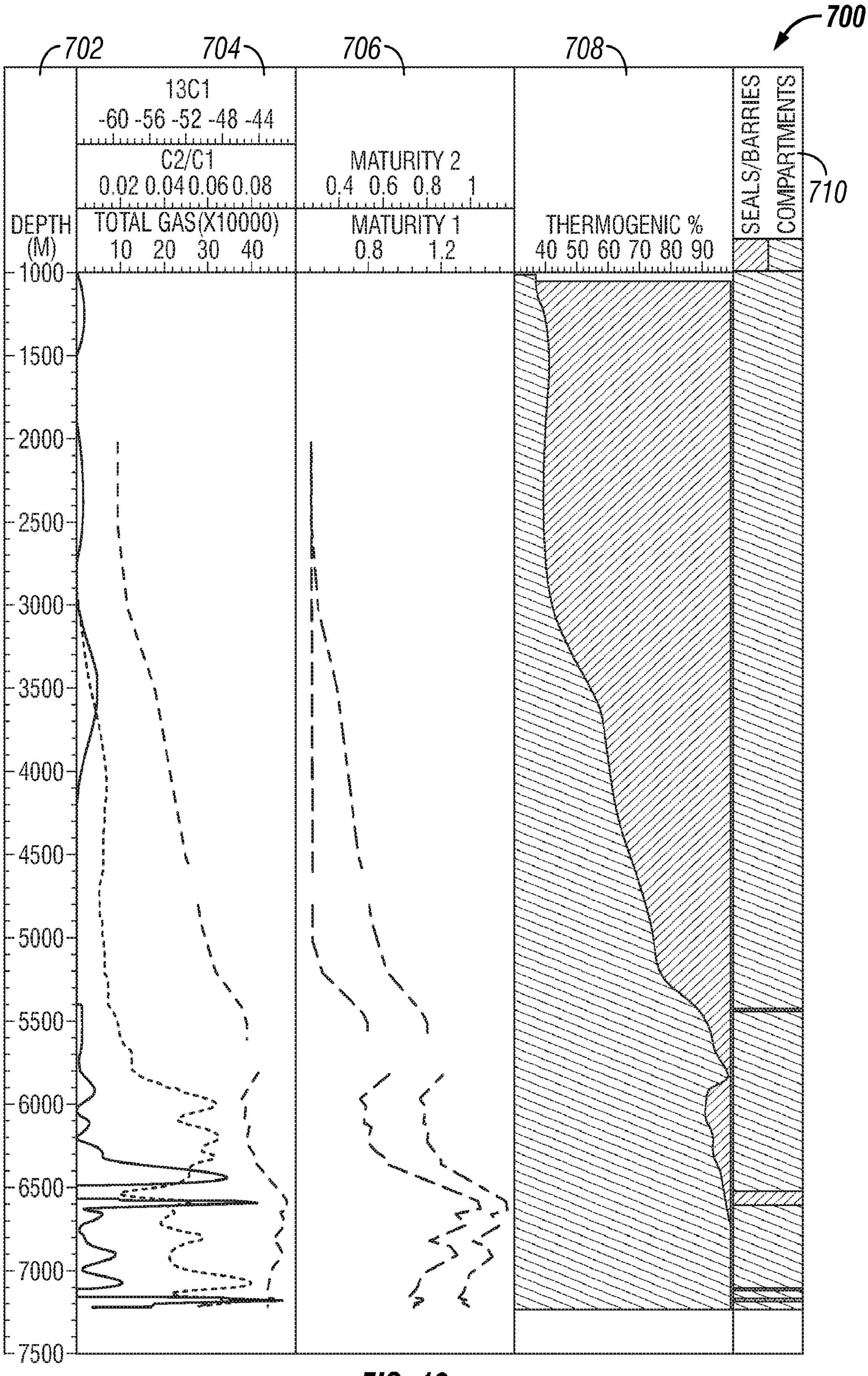

700
702
704
706
708
710
13C1
-60 -56 -52 -48 -44
C2/C1
0.02 0.04 0.06 0.08
MATURITY 2
0.4 0.6 0.8 1
DEPTH (M)
TOTAL GAS(X10000)
10 20 30 40
MATURITY 1
0.8 1.2
THERMOGENIC %
40 50 60 70 80 90
SEALS/BARRIES
COMPARTMENTS
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500

FIG. 16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 08/81989

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - E21B 49/08 (2009.01)
USPC - 166/254.2
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
USPC - 166/254.2

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 166/254.2, $
Search Terms Below

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PUBWest (USPT, PGPB, EPAB, JPAB); google.com
Search Terms Used: mud, gas, isotope, isotopic, analysis, analyzed, sample, sampling, sampled, computer, region, caprock, mudgas, seal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2006/0249288 A1 (Drozd et al.) 09 November 2006 (09.11.2006) entire document, especially Abstract; para [0025]; [0026]	1-30, 32-34
Y	US 2005/0256647 A1 (Ellis) 17 November 2005 (17.11.2005) entire document, especially Abstract; para [0007]; [0010]; [0029]; [0030]; [0031]; [0033]-[0038]	1-30, 32-34

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 January 2009 (07.01.2009)	21 JAN 2009

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774