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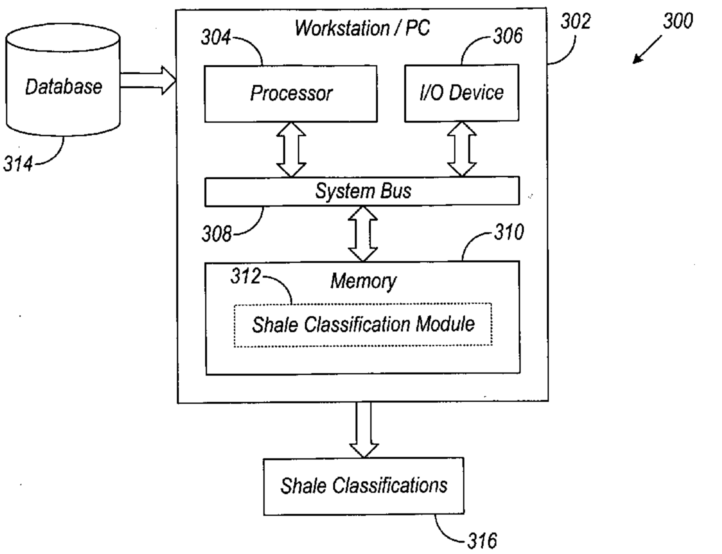

(57) Abstract: Methods, systems, and apparatuses are disclosed for classifying shale gas formations based on geochemical, petrophysical and/or petrological properties. In preferred embodiments, the methods, systems, and apparatuses classify gas shales according to the processes of hydrocarbon generation (i.e., thermogenic versus biogenic), the degree of clay maturation, the dominant composition of the gas shales, and the like. The methods, systems, and apparatuses also account for formation characteristics such as total organic carbon, degree of Kerogen maturity, and the like. Such an arrangement allows for consistent and reliable identification of productive (and likely profitable) types of shale gas reservoirs.

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SYSTEM AND METHOD FOR IDENTIFYING PRODUCTIVE GAS SHALE FORMATIONS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application for patent claims priority to, and hereby incorporates by reference, U.S. Provisional Application Serial No. 60/882853, entitled "System and Method for Identifying Productive Gas Shale Formations," filed December 29, 2006, with the United States Patent and Trademark Office.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to techniques for evaluating a subterranean formation in an oilfield or gasfield to locate and recover hydrocarbons. More particularly, the invention relates to methods, systems, and apparatuses for classifying shale from such subterranean formations.

2. Background of the Related Art

Wellbores are drilled in a subterranean formation to locate and recover hydrocarbons, such as oil, gas, and the like. Typically, a downhole drilling tool with a drill bit at an end thereof is advanced into the formation to form a wellbore. As the drilling tool is advanced, a drilling mud is pumped from a surface mud pit through the drilling tool and out the drill bit to cool the drilling tool and also to carry away formation cuttings. The drilling mud exits the drill bit and flows back up to the surface for recirculation through the drilling tool.

To facilitate locating and recovering of the hydrocarbons, various evaluations are performed on the formation penetrated by the drilling tool. From these evaluations, important information about the properties and characteristics of the formation may be derived. This information may then be used to decide drilling and production strategies. To this end, the drilling tool may be provided with devices for evaluating the surrounding formation. Alternatively, the drilling tool itself may be used to evaluate the surrounding formation. In still other cases, the drilling tool may be removed and a wireline tool may be deployed down the wellbore to evaluate the surrounding formation.

FIG. 1 is a schematic view, partially in cross-section, of a wireline operation 100 in which a wireline tool or sonde 104 is used to evaluate the subterranean formation. Typically, the wireline tool 104 is lowered down an open wellbore from a rig 102 to a depth corresponding to a desired interval 106 in a formation 108. Measurements of formation properties are then acquired using various sensors and detectors mounted on the wireline tool 104 as the wireline tool 104 is drawn up the wellbore. The acquired measurements are transmitted from the wireline tool 104 via a wired or wireless connection to recording devices in a data acquisition unit 110 at the surface where the measurements are recorded, usually in a well log. These measurements may include, for example, electrical properties (e.g., resistivity and conductivity at specific frequencies, etc.), gamma radiation, active and passive nuclear measurements, sonic properties, dimensional measurements of the wellbore, formation pressure measurements, and the like.

Measurements of formation properties are particularly important for locating and recovering natural gas. This is because a key source of natural gas is in shales, a very low permeability formation material from which it is often complicated to extract hydrocarbons. Indeed, until recently, shale was thought of only as a source rock or seal for oil and gas and not considered a significant reservoir or producible play. With the increase in demand for natural gas, however, shale gas has become an important component in the overall world energy supply. Organic-rich shale reservoirs, once ignored in favor of easier plays and faster returns on investment, are now being leased in hundreds of thousands of acres in the United States and other parts of the world by shale gas companies looking for the next big play.

Because shale gas is notoriously complicated to extract, it is important that shale formations be properly characterized using the various measurements of formation properties in order to consistently and reliably identify productive (and likely profitable) types of reservoirs of shale gas. While advances in technology have made it possible to obtain more precise measurements of formation properties, including shale formation properties, this has not translated to more accurate or useful shale classifications. On the contrary, existing models for classifying shale tend to be overly broad, failing to account for subtle characteristics that often constitute the difference between correctly identifying productive types of gas shale versus unproductive shale formations.

Thus, despite recent advances in subterranean formation evaluation techniques, there remains a need for more effective methods, systems, and apparatuses for classifying shale gas formations. In particular, there is a need for such methods, systems, and apparatuses to be able to provide, among other things, a way to account for formation characteristics that can consistently and reliably identify productive (and likely profitable) types of shale gas reservoirs.

SUMMARY OF THE INVENTION

The present invention relates to methods, systems, and apparatuses for classifying shale gas formations based on geochemical, petrophysical and/or petrological properties. In preferred embodiments, the methods, systems, and apparatuses classify gas shales according to the processes of hydrocarbon generation (i.e., thermogenic versus biogenic), the degree of clay maturation, the dominant composition of the gas shales, and the like. The methods, systems, and apparatuses also account for formation characteristics such as total organic carbon, degree of

Kerogen maturity, and the like. Such an arrangement allows for consistent and reliable identification of productive (and likely profitable) types of shale gas reservoirs.

In at least one aspect, the invention relates to a system for identifying potentially productive gas shale formations. The system comprises a database configured to store data representing formation properties for a gas shale formation and a workstation connected to the database. The workstation is adapted to receive the data representing the formation properties from the database, classify the gas shale formation based on the formation properties, and determine whether the gas shale formation is likely to be a productive gas shale formation according to one or more predefined criteria. Classification of the gas shale formation includes one of the following types: siliceous, siliceous cherty, clastic, hybrid hyperpycnal, hybrid hypopycnal, and hybrid homopycnal.

In another aspect, the invention relates to a method of identifying potentially productive gas shale formations. The method comprises storing data representing formation properties for a gas shale formation in a database and providing the data representing the formation properties to a workstation. The method further comprises classifying the gas shale formation based on the formation properties using the workstation and determining whether the gas shale formation is a potentially productive gas shale formation according to one or more predefined criteria using the workstation. Classification of the gas shale formation includes one of the following types: siliceous, siliceous cherty, clastic, hybrid hyperpycnal, hybrid hypopycnal, and hybrid homopycnal.

In yet another aspect, the invention relates to a computer-readable medium encoded with computer-readable instructions for causing a workstation to identify potentially productive types of gas shale formations. The computer-readable instructions comprises instructions for causing the workstation to receive data representing formation properties for a gas shale formation from a database and classify the gas shale formation based on the formation properties using the workstation. The computer-readable instructions further comprises instructions for causing the workstation to determine whether the gas shale formation is a potentially productive type of gas shale formation according to one or more predefined criteria using the workstation, wherein the gas shale formation is classified as one of the following types: siliceous, siliceous cherty, clastic, hybrid hyperpycnal, hybrid hypopycnal, or hybrid homopycnal.

In still another aspect, the invention relates to an article of manufacture for use in identifying potentially productive gas shale formations. The article a detector comprises a processor and computer-readable medium connected to the processor. The computer-readable medium is encoded with computer-readable instructions for causing the processor to receive data representing formation properties for a gas shale formation from a database and to classify the gas shale formation based on the formation properties. The computer-readable instructions further cause the processor to determine whether the gas shale formation is a potentially productive gas shale formation according to one or more predefined criteria, wherein the gas shale formation is classified as one of the following types: siliceous, siliceous cherty, clastic, hybrid hyperpycnal, hybrid hypopycnal, or hybrid homopycnal.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the above recited features and advantages of the invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof that are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

FIG. 1, described previously, illustrates an example of a standard wireline operation according to the prior art;

FIG. 2 illustrates an example of a shale classification model acco rding to preferred embodiments of the invention;

FIG. 3 illustrates an example of a system for classifying shale formations according to preferred embodiments of the invention; and

FIG. 4 illustrates an example of a method for classifying shale formations according to preferred embodiments of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

In the following detailed description of a preferred embodiment and other embodiments of the invention, reference is made to the accompanying drawings. It is to be understood that those of skill in the art will readily see that other embodiments and changes may be made without departing from the scope of the invention.

As mentioned above, existing shale classification techniques tend to be too broad, overlooking differences in shale formations that can help correctly identify productive types of shale versus likely unproductive shale gas reservoirs. (As used herein, the term "productive" refers to a reservoir with sufficient storage and permeability to be considered economically viable by those having ordinary skill in the art.) This is due at least in part to the fact that gas shales are unconventional plays with unconventional properties. As is well known to those having ordinary skill in the art, gas is stored in gas shales in both the interconnected pore space (free gas), including any open natural fractures, as well as within the organic material (adsorbed gas). Consequently, the maturity of the organic material (Kerogen) can have a significant impact on interstitial fluids, production limits, pore pressure, and reservoir quality. In addition, gas shales are often interbedded with other lithofacies, can be altered diagenetically, and often exhibit complex clay morphology, all of which can alter completion strategies and fluids. Finally, gas shales typically have very complex fracture networks and "in situ" stress relationships.

Embodiments of the invention provide more effective methods, systems, and apparatuses for classifying shale gas formations based on geochemical, petrophysical and/or petrological properties. In preferred embodiments, the methods, systems, and apparatuses classify gas shales according to the processes of hydrocarbon generation (i.e., thermogenic versus biogenic), the degree of clay maturation, the dominant composition of the gas shales, and the like. The methods, systems, and apparatuses also account for formation characteristics such as total organic carbon, degree of Kerogen maturity, and the like. Such an arrangement allows for consistent and reliable identification of productive (and likely profitable) types of shale gas reservoirs. Following is a description of exemplary embodiments of the invention, as illustrated by the accompanying drawings.

Referring now to FIG. 2, a shale classification model 200 according to preferred embodiments of the invention is shown. As can be seen, the shale classification model 200 divides shales into three main classifications: (A) thermogenic shales with generally mature clay, (B) biogenic shales with mature clay, and (C) biogenic shales with immature clay. Mature and immature clays are determined mainly by the level of diagenic alteration from Smectite to Illite and their associated expandabilities. Each of these classifications can be further divided into several subclasses, including (1) siliceous which is dominated by silica, (2) clastic which is dominated by silty/sandy mudstones, and (3) hybrids of the first two subclasses.

Within the siliceous subclass, shale can be further divided into two types: (1a) siliceous shales that typically contain amorphous silica and vary widely from siliceous dominated mudstones to argillaceous dominated mudstones, and (1b) siliceous cherty shales that are an interbedded mix of chert and generally siliceous mudstones. Clastic shales are often recognized as silty/sandy mudstones often dominated by its clastic material content, which is not limited to quartz grains, but may include carbonate, fossil, or other rock fragments. Hybrid shales can be further divided into three types depending on density relationships between the source of the deposited material and the environment in which it was deposited: (3a) hyperpycnal ("hyper" meaning more and "pycnal" meaning dense) shales, which are typically interbedded mudstones where the source of the clastic interbeds had a higher density than the dominantly deep marine environment and are easily recognized by their graded bedding or erosional contacts (clastic deposits are often represented by those skilled in the art as "density" or "turbidity" deposits); (3b) hypopycnal ("hypo" meaning less and "pycnal" meaning dense) shales, which are interbedded mudstones where the source of the clastic interbeds were often deposited within a dominantly deep marine environment by suspension settling; and (3c) homopycnal ("homo" meaning same and "pycnal" meaning dense) shales, which exist where the source material and environment of deposition had approximately equal densities during deposition. These three types of hybrid shales have significant differences. For example, in hypopycnal shales, the shale matures at the same time as the silt/sand interlayers, whereas in hyperpycnal shales, the density flows that are usually sands or silts can have different hydrocarbons or water present from what is contained in the associated interbedded Kerogen-rich mudstones.

Based on the above classification model 200 and well data, it may be determined which shale formations are considered to be more likely to be economically productive for recovering shale gas. Table 1 below summarizes the general characteristics for some of the shale classes, subclasses, and types that may be considered to be productive, where "TOC" is the total organic carbon, "MMcf" is million cubic feet, and "Mcf" is thousand cubic feet. As can be seen, thermogenic shales with generally mature clay, including the siliceous, siliceous cherty, clastic, and hybrid types; biogenic shales with mature clay, including the siliceous and clastic types; as well as biogenic shales with immature clay, including the clastic type, are all considered productive types of gas shale formations.

	Thermogenic (Generally Mature Clay)	Biogenic (Mature Clay)	Biogenic (Immature Clay)
Depth	Generally > 5,000 feet	Generally < 4,000 feet	Generally < 4,000 feet
Type	Siliceous, Siliceous Cherty, Clastic, Hybrid	Siliceous, Clastic	Clastic
Gas Source	Thermogenic Kerogen alteration, TOC > 2% for Siliceous, Cherty, and Hybrids; TOC < 3% for Clastic	Microbial, TOC varies with shale type	Microbial; TOC < 2%
Reservoir Pressure	Under to abnormal pressure	Under to normal pressure	Under to normal pressure
Storage	Typically interstitial and adsorbed	Both adsorbed-dominated and interstitial-dominated, depending on shale type	Typically interstitial

Production Rates	Siliceous, Cherty, and some Hybrid shale reservoirs typically produce > 200 Mcf/day and can exceed 1-20 MMcf/day; Clastic shale reservoirs typically produce between 50 Mcf/day and 1 MMcf/day	Typically < 100 Mcf/day	Typically < 200 Mcf/day

TABLE 1 – Productive Gas Shale Formations

In general, biogenic shales with immature clay, including the clastic type, provide excellent long-term production capability and better recovery factors than desorption plays. However, completion issues exist due to fluid-sensitive clays and the ability to develop sufficient fracture surface area for economical recovery rates. Also, current technology provides limited reliable data due to immature clay issues and also due to heterogeneity (lateral and vertical). Biogenic shales with mature clay, including the siliceous and clastic types, also provide excellent long-term production. Recovery factors vary between desorption and interstitial gas plays. Locating or developing sufficient fracture surface area for economic rates, as well as issues relating to Kerogen maturity, dominate their completion.

As for thermogenic shales with generally mature clay, including the siliceous, siliceous cherty, clastic, and hybrid types, in addition to some of the same completion and Kerogen maturity issues as the biogenic shales, these shale formations also have stress and seal containment issues. On the other hand, siliceous and siliceous cherty thermogenic shale formations have long-term production capability with high EUR (estimated ultimate recovery) and recompletion possibilities. Clastic thermogenic shale formations also have long-term production capability with generally moderate EUR's, but often include the benefit of generally massive sections. Finally, hybrid thermogenic shale formations such as hyperpycnal shales, which are a mixture of siliceous mudstones and turbidite sequences, allow deeper completions (due to the turbidite sequences) in addition to anticipated long-term production capability.

Turning next to FIG. 3, a system 300 for classifying shale according to embodiments of the invention is shown. The system 300 includes, among other things, a workstation 302, which may be a stand alone personal computer (PC), a workstation (e.g., a Unix-based Sun Microsystems workstation), two or more networked workstations, a mainframe computer, and the like. In one embodiment, the workstation 302 has a number of functional components, including at least one processor 304, an input/output (I/O) unit 306, a system bus 308, and a computer-readable system memory 310. These components of the workstation 302 are generally well known to those having ordinary skill in the art and therefore will not be described in great detail here. Furthermore, although multiple discrete components are shown in FIG. 3, those having ordinary skill in the art will understand that two or more of these components may be combined into a single component, and that a single component may be divided into several sub-components, as needed. Also present is a shale classification module 312 for recognizing and classifying the shales encountered in the subsurface formation. At least one database 314 is included for storing data used by the shale classification module 312, and a display 316 for displaying information generated by the shale classification module 312.

Briefly, the processor 304 is responsible for the overall operation of the workstation 302, including executing of the operating system software and any other software applications that may be present on the workstation 302. The I/O unit 306 controls the flow of data into and out of the workstation 302, for example, through various media reader devices and output devices.

The system bus 308 allows the various functional components of the workstation 302 to communicate and exchange data with one another. The system memory 310, which may be a magnetic, optical, and/or semiconductor memory, provides temporary and long-term storage for any information or data needed by the operating system and applications running on the workstation 302. Finally, the database(s) 314 stores data representing various formation properties used by the shale classification module 312, including depth, bulk and grain density, pore pressure, effective and gas-filled porosity, matrix permeability, mobile oil saturation, water saturation, percent bound hydrocarbons, percent bound clay water, total organic carbon, clay content, type, and/or maturity, Kerogen content, type, and/or maturity, mineral and/or chemical composition, gas composition (when measured), isotope studies (when done), and the like. Such data may be provided or acquired from any source known to those having ordinary skill in the art, including well log data, stimulation data, and the like.

Using the data from the database(s) 314, the shale classification module 312 is configured to recognize and classify the shales in a subsurface formation according to the model 200 set forth and described with respect to FIG. 2. The shale classification module 312 may perform the recognition and classification using, for example, a lookup table containing the various shale classes, subclasses, and types listed in the model 200. Such a lookup table is well within the knowledge and capability of those having ordinary skill in the art and is therefore not described in detail here. Other techniques (e.g., a logical algorithm) known to those having ordinary skill in the art for classifying the shales in a subsurface formation based on the model 200 may also be used without departing from the scope of the invention.

In preferred embodiments, the shale classification module 312 is also configured to determine which shale formations may be considered to be potentially productive for recovering shale gas. The shale classification module 312 may perform this additional function using, for example, a lookup table containing the various shale classes, subclasses, and types listed in Table 1. FIG. 4 illustrates a flow chart for a method 400 that may be used to identify potentially productive shale formations based on Table 1. It should be noted that although a number of discrete steps are shown in FIG. 4, those having ordinary skill in the art will understand that two or more steps may be combined into a single step, and that a single step may be divided into several constituent steps, without departing from the scope of the invention. Similarly, although the steps in FIG. 4 are shown in a particular sequence, those having ordinary skill in the art will understand that the ordering of the steps may be rearranged without departing from the scope of the invention.

The method 400 begins at step 402, where geochemical, petrophysical and/or petrological data representing various formation properties for a desired shale formation is received or otherwise acquired. As mentioned above, such data may include well log data, stimulation data, and the like. At step 404, a determination is made as to whether the shale formation is thermogenic with generally mature clay using, for example, the model 200 set forth and described in FIG. 2. If the answer at step 404 is negative, then at step 406, a determination is made as to whether the shale formation is biogenic with mature clay. If the answer at step 406 is negative, then at step 408, a determination is made as to whether the shale formation is biogenic with immature clay. If the answer at step 408 is negative, then a classification of "other" is recorded at step 410 (meaning that the shale formation is not one of the predefined classifications) and the method 400 is concluded.

On the other hand, if the answer at step 404 is positive, then at step 412, a determination is made as to whether the shale formation is siliceous, siliceous cherty, clastic, or hybrid, including hybrid hyperpycnal, hybrid hypopycnal, and hybrid homopycnal. If the answer at step 412 is negative, then a classification of "likely nonproductive" shale formation is recorded at step 418, and the method is concluded. Similarly, if the answer at step 406 is positive, then at step 414, a determination is made as to whether the shale formation is siliceous or clastic. If the answer at step 414 is negative, then a classification of "likely nonproductive" shale formation is again recorded at step 418, and the method is concluded. Likewise, if the answer at step 408 is positive, then at step 416, a determination is made as to whether the shale formation is clastic. If the answer at step 416 is negative, then a classification of "likely nonproductive" shale formation is once more recorded at step 418, and the method is concluded.

However, if the answer at any of the determination steps 412, 414, or 416 is positive, then in one preferred embodiment, a classification of "productive type" of shale formation is recorded at step 422, and the method is concluded. In an alternative embodiment, an optional determination may be made at step 420 as to whether one or more other productive shale formation characteristics may be present, such as those listed in Table 1. If the answer at the optional step 420 is negative, then a classification of "likely nonproductive" shale formation is recorded at step 418, and the method is concluded. But if the answer at the optional step 420 is positive, then a classification of "productive type" of shale formation is recorded at step 422, and the method is concluded.

The foregoing description is provided for purposes of illustrating, explaining and describing certain aspects of the invention in particular detail. Other shale formations besides the ones described herein may exist and may be classified and typed as needed according to acquired data. For example, although only a single class, subclass, and/or type was assigned to each shale formation herein, it is certainly possible to assign multiple classes, subclasses, and/or types to a shale formation, depending on the needs of a particular application. Thus, those having ordinary skill in the art will understand that modifications and adaptations to the described methods, systems and other embodiments may be made without departing from the scope or spirit of the invention.

CLAIMS

What is claimed is:

1. A system for identifying potentially productive gas shale formations, comprising:

a database configured to store data representing formation properties for a gas shale formation; and

a workstation connected to the database, the workstation being adapted to receive the data representing the formation properties from the database, classify the gas shale formation based on the formation properties, and determine whether the gas shale formation is likely to be a productive gas shale formation according to one or more predefined criteria;

wherein the gas shale formation is classified as one of the following types: siliceous, siliceous cherty, clastic, hybrid hyperpycnal, hybrid hypopycnal, or hybrid homopycnal.

2. The system of claim 1, wherein the workstation is adapted to further classify the gas shale formation as one of the following classes: thermogenic shale with generally mature clay, biogenic shale with mature clay, or biogenic shale with immature clay.

3. The system of claim 1, wherein the workstation is adapted to determine that the gas shale formation is a potentially productive gas shale formation in response to the gas shale formation being classified as thermogenic with generally mature clay and siliceous, siliceous cherty, clastic, hybrid hyperpycnal, hybrid hypopycnal, or hybrid homopycnal type.

4. The system of claim 1, wherein the workstation is adapted to determine that the gas shale formation is a potentially productive gas shale formation in response to the gas shale formation being classified as biogenic with mature clay and siliceous or clastic type.

5. The system of claim 1, wherein the workstation is adapted to determine that the gas shale formation is a potentially productive gas shale formation in response to the gas shale formation being classified as biogenic with immature clay and clastic type.

6. The system of claim 1, wherein the formation properties includes one or more of: depth, bulk and grain density, pore pressure, effective and gas-filled porosity, matrix permeability, mobile oil saturation, water saturation, percent bound hydrocarbons, percent bound clay water, total organic carbon, clay content, type, and/or maturity, Kerogen content, type, and/or maturity, mineral and/or chemical composition, gas composition, isotope studies.

7. A method of identifying potentially productive gas shale formations, comprising:

storing data representing formation properties for a gas shale formation in a database;

providing the data representing the formation properties to a workstation;

classifying the gas shale formation based on the formation properties using the workstation; and

determining whether the gas shale formation is a potentially productive gas shale formation according to one or more predefined criteria using the workstation;

wherein the gas shale formation is classified as one of the following types: siliceous, siliceous cherty, clastic, hybrid hyperpycnal, hybrid hypopycnal, or hybrid homopycnal.

8. The method of claim 7, wherein the workstation is adapted to further classify the gas shale formation as one of the following classes: thermogenic shale with generally mature clay, biogenic shale with mature clay, or biogenic shale with immature clay.

9. The method of claim 7, wherein the workstation is adapted to determine that the gas shale formation is a productive type of gas shale formation in response to the gas shale formation being classified as thermogenic with mature clay and siliceous, siliceous cherty, clastic, hybrid hyperpycnal, hybrid hypopycnal, or hybrid homopycnal type.

10. The method of claim 7, wherein the workstation is adapted to determine that the gas shale formation is a productive type of gas shale formation in response to the gas shale formation being classified as biogenic with mature clay and siliceous or clastic type.

11. The method of claim 7, wherein the workstation is adapted to determine that the gas shale formation is a productive type of gas shale formation in response to the gas shale formation being classified as biogenic with immature clay and clastic type.

12. The method of claim 7, wherein the formation properties include one or more of: depth, bulk and grain density, pore pressure, effective and gas-filled porosity, matrix permeability, mobile oil saturation, water saturation, percent bound hydrocarbons, percent bound clay water, total organic carbon, clay content, type, and/or maturity, Kerogen content, type, and/or maturity, mineral, and/or chemical composition, gas composition, isotope studies.

13. A computer-readable medium encoded with computer-readable instructions for causing a workstation to identify potentially productive types of gas shale formations, the computer-readable instructions comprising instructions for causing the workstation to:

receive data representing formation properties for a gas shale formation from a database;

classify the gas shale formation based on the formation properties using the workstation; and

determine whether the gas shale formation is a potentially productive type of gas shale formation according to one or more predefined criteria using the workstation;

wherein the gas shale formation is classified as one of the following types: siliceous, siliceous cherty, clastic, hybrid hyperpycnal, hybrid hypopycnal, or hybrid homopycnal.

14. The computer-readable medium of claim 13, wherein the computer-readable instructions further comprise instructions for causing the workstation to further classify the gas shale formation as one of the following classes: thermogenic shale with generally mature clay, biogenic shale with mature clay, and biogenic shale with immature clay.

15. The computer-readable medium of claim 13, wherein the computer-readable instructions further comprise instructions for causing the workstation to determine that the gas shale formation is a productive type of gas shale formation in response to the gas shale formation being classified as thermogenic with generally mature clay and siliceous, siliceous cherty, clastic, hybrid hyperpycnal, hybrid hypopycnal, or hybrid homopycnal type.

16. The computer-readable medium of claim 13, wherein the computer-readable instructions further comprise instructions for causing the workstation to determine that the gas shale formation is a productive type of gas shale formation in response to the gas shale formation being classified as biogenic with mature clay and siliceous or clastic type.

17. The computer-readable medium of claim 13, wherein the computer-readable instructions further comprise instructions for causing the workstation to determine that the gas shale formation is a productive type of gas shale formation in response to the gas shale formation being classified as biogenic with immature clay and clastic type.

18. The computer-readable medium of claim 13, wherein the formation properties include one or more of: depth, bulk and grain density, pore pressure, effective and gas-filled porosity, matrix permeability, mobile oil saturation, water saturation, percent bound hydrocarbons, percent bound clay water, total organic carbon, clay content, type, and/or maturity, Kerogen content, type, and/or maturity, mineral and/or chemical composition, gas composition, isotope studies.

19. An article of manufacture for use in identifying potentially productive gas shale formations, comprising:

a processor; and

computer-readable medium connected to the processor, the computer-readable medium encoded with computer-readable instructions for causing the processor to:

receive data representing formation properties for a gas shale formation from a database;

classify the gas shale formation based on the formation properties; and

determine whether the gas shale formation is a potentially productive gas shale formation according to one or more predefined criteria;

wherein the gas shale formation is classified as one of the following types: siliceous, siliceous cherty, clastic, hybrid hyperpycnal, hybrid hypopycnal, or hybrid homopycnal.

20. The article of manufacture of claim 19, wherein the computer-readable instructions further cause the processor to classify the gas shale formation as one of the following classes: thermogenic shale with generally mature clay, biogenic shale with mature clay, or biogenic shale with immature clay.

21. The article of manufacture of claim 19, wherein the computer-readable instructions further cause the processor to determine that the gas shale formation is a productive type of gas shale formation in response to the gas shale formation being classified as thermogenic with mature clay and siliceous, siliceous cherty, clastic, hybrid hyperpycnal, hybrid hypopycnal, or hybrid homopycnal type.

22. The article of manufacture of claim 19, wherein the computer-readable instructions further cause the processor to determine that the gas shale formation is a productive type of gas shale formation in response to the gas shale formation being classified as biogenic with mature clay and siliceous or clastic type.

23. The article of manufacture of claim 19, wherein the computer-readable instructions further cause the processor to determine that the gas shale formation is a productive

type of gas shale formation in response to the gas shale formation being classified as biogenic with immature clay and clastic type.

24. The article of manufacture of claim 19, wherein the formation properties include one or more of: depth, bulk and grain density, pore pressure, effective and gas-filled porosity, matrix permeability, mobile oil saturation, water saturation, percent bound hydrocarbons, percent bound clay water, total organic carbon, clay content, type, and/or maturity, Kerogen content, type, and/or maturity, mineral, and/or chemical composition, gas composition, isotope studies.

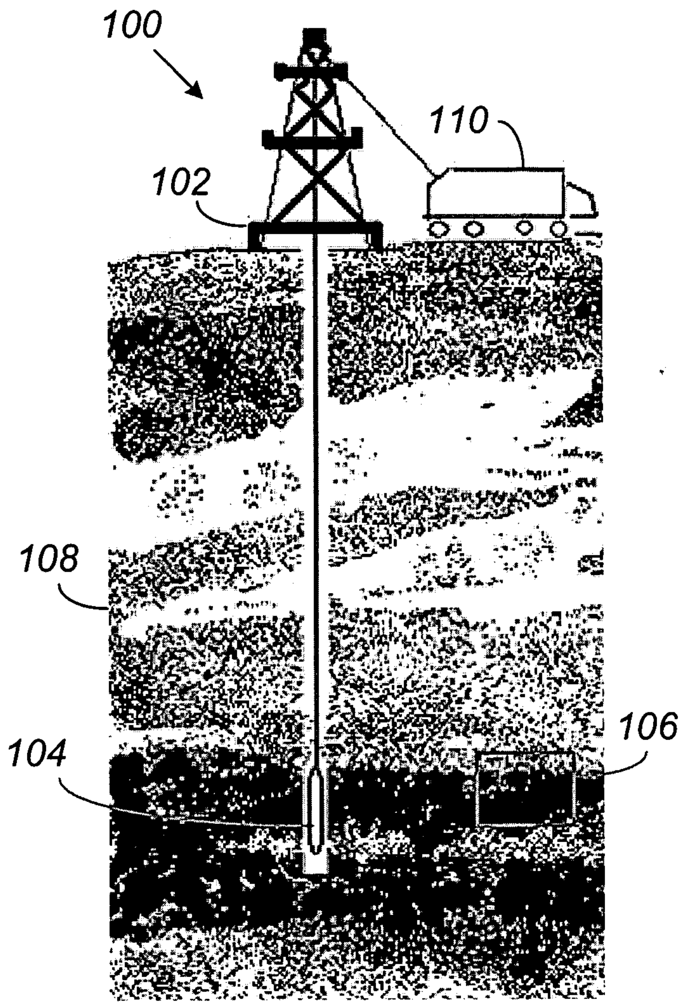


FIG. 1
(Prior Art)

A. Thermogenic Shales – Generally Mature Clay

- *1a. Siliceous (Typically Amorphous Silica)*
- *1b. Siliceous Cherty*
- *2. Clastic (Dominated by Silty/Sandy Mud Stones)*
- *3a. Hybrid Hyperpycnal*
- *3b. Hybrid Hypopycnal*
- *3c. Hybrid Homopycnal*

B. Biogenic Shales – Mature Clay

- *1a. Siliceous (Typically Amorphous Silica)*
- *1b. Siliceous Cherty*
- *2. Clastic (Dominated by Silty/Sandy Mud Stones)*
- *3a. Hybrid Hyperpycnal*
- *3b. Hybrid Hypopycnal*
- *3c. Hybrid Homopycnal*

C. Biogenic Shales – Immature Clay

- *1a. Siliceous (Typically Amorphous Silica)*
- *1b. Siliceous Cherty*
- *2. Clastic (Dominated by Silty/Sandy Mud Stones)*
- *3a. Hybrid Hyperpycnal*
- *3b. Hybrid Hypopycnal*
- *3c. Hybrid Homopycnal*

200

FIG. 2

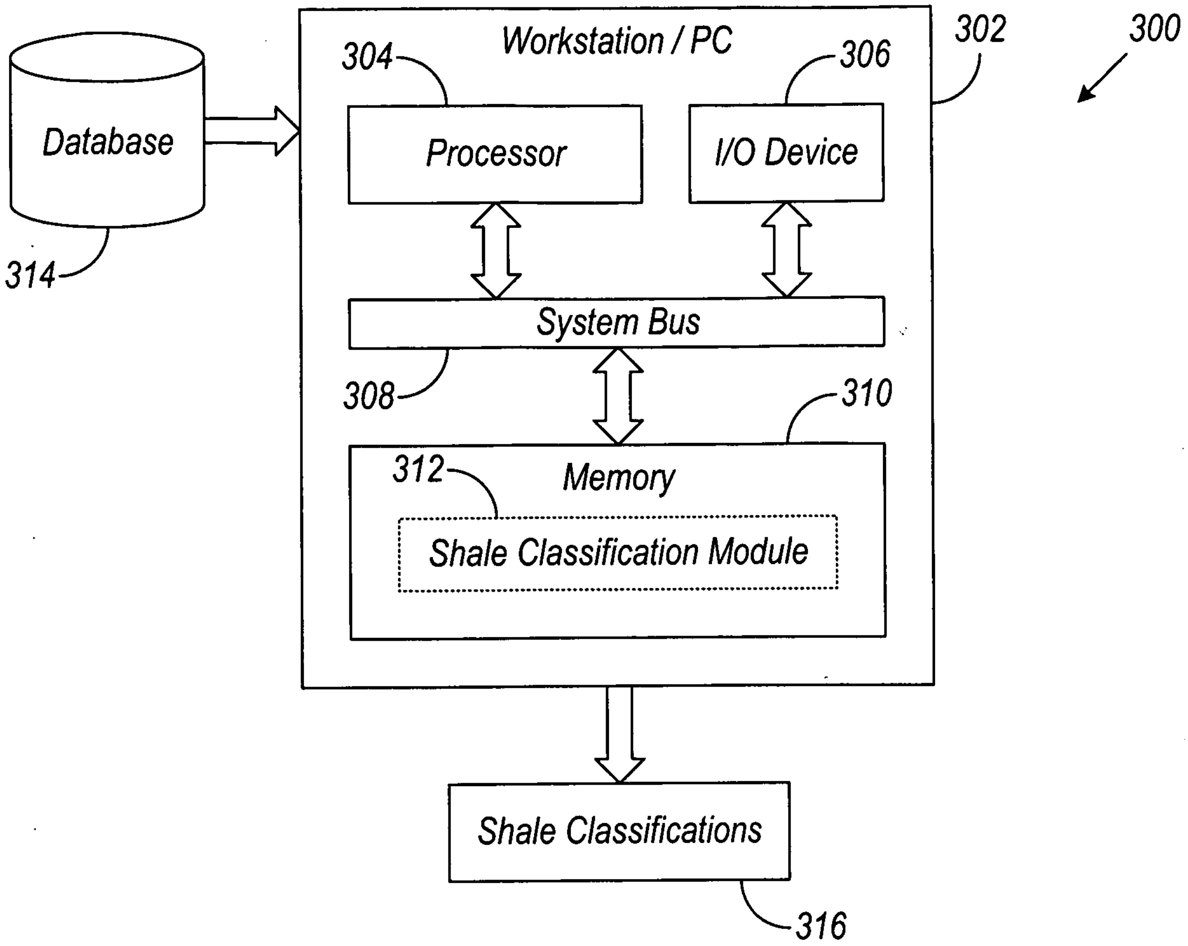
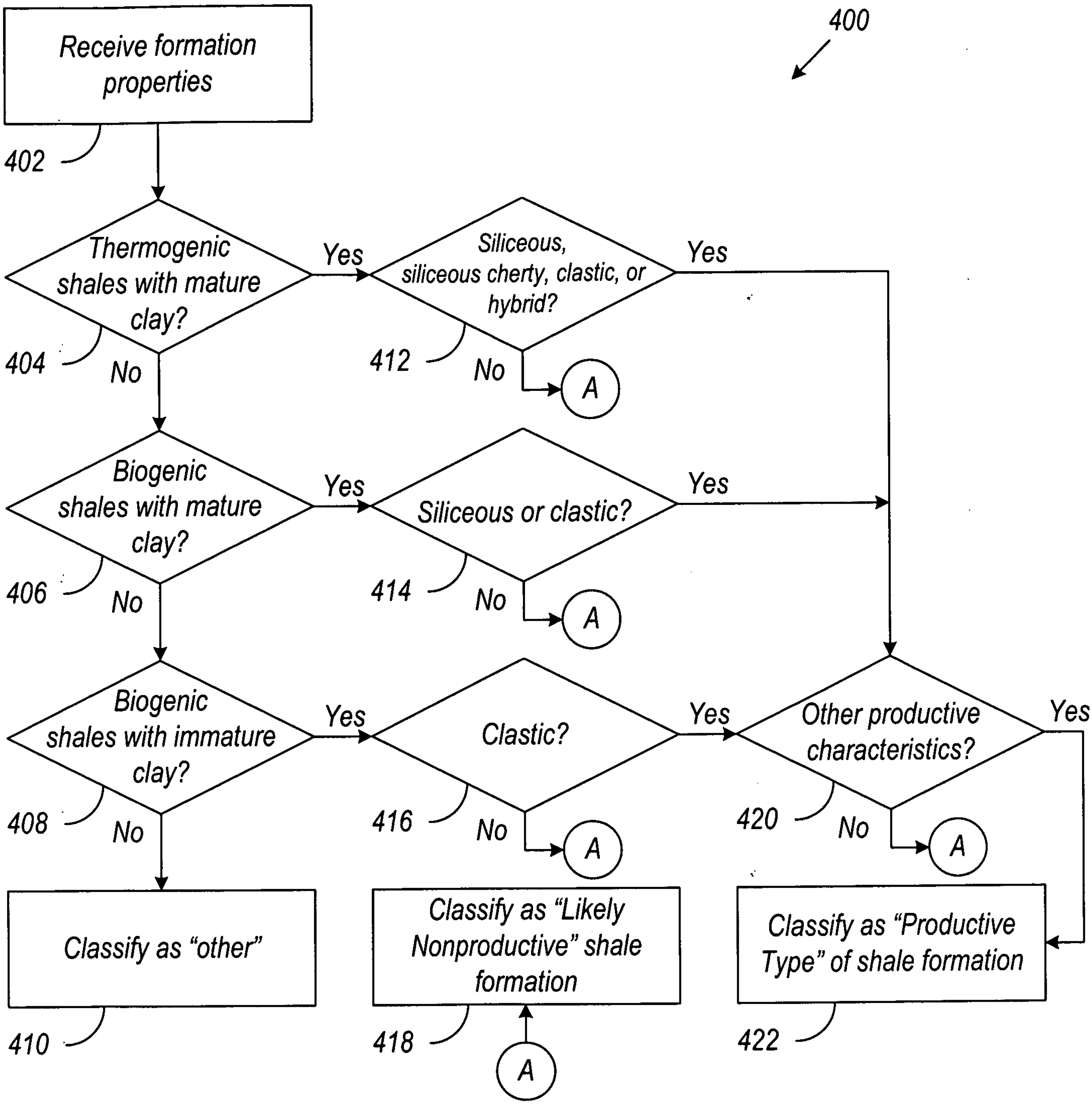

Workstation / PC
Database
Processor
I/O Device
System Bus
Memory
Shale Classification Module
Shale Classifications
300
302
304
306
308
310
312
314
316

FIG. 3



400
Receive formation properties
402
Thermogenic shales with mature clay?
404
Yes
No
Siliceous, siliceous cherty, clastic, or hybrid?
412
Yes
No
A
Biogenic shales with mature clay?
406
Yes
No
Siliceous or clastic?
414
Yes
No
A
Biogenic shales with immature clay?
408
Yes
No
Clastic?
416
Yes
No
A
Other productive characteristics?
420
Yes
No
A
Classify as "other"
410
Classify as "Likely Nonproductive" shale formation
418
A
Classify as "Productive Type" of shale formation
422

FIG. 4