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(54) COMBINED MIGRATION METHOD FOR BASIN MODELING

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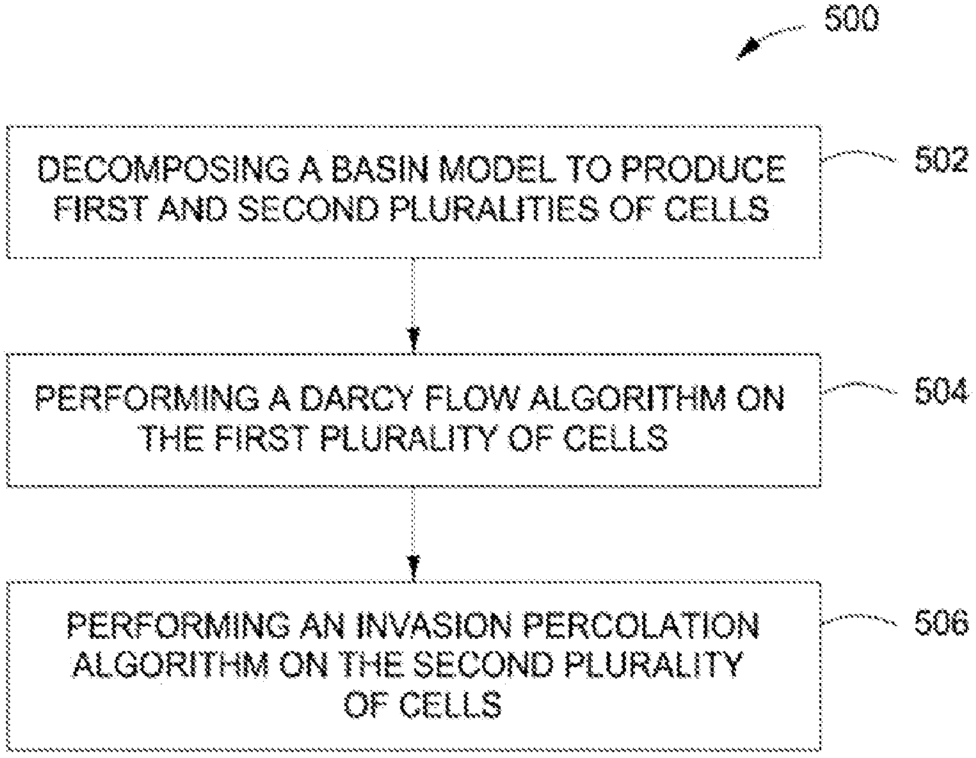
USPC **703/2**; 703/10

(57) ABSTRACT

A method for modeling a migration of hydrocarbon fluids. The method may include decomposing, by operation of a processor, a domain of a basin model to produce a first plurality of cells having a permeability below a threshold value and a second plurality of cells having a permeability above the threshold value. A first migration analysis may be performed to analyze a relatively slow migration starting in the first plurality of cells. A second migration analysis may be performed to analyze a relatively faster migration starting m the second plurality of cells.



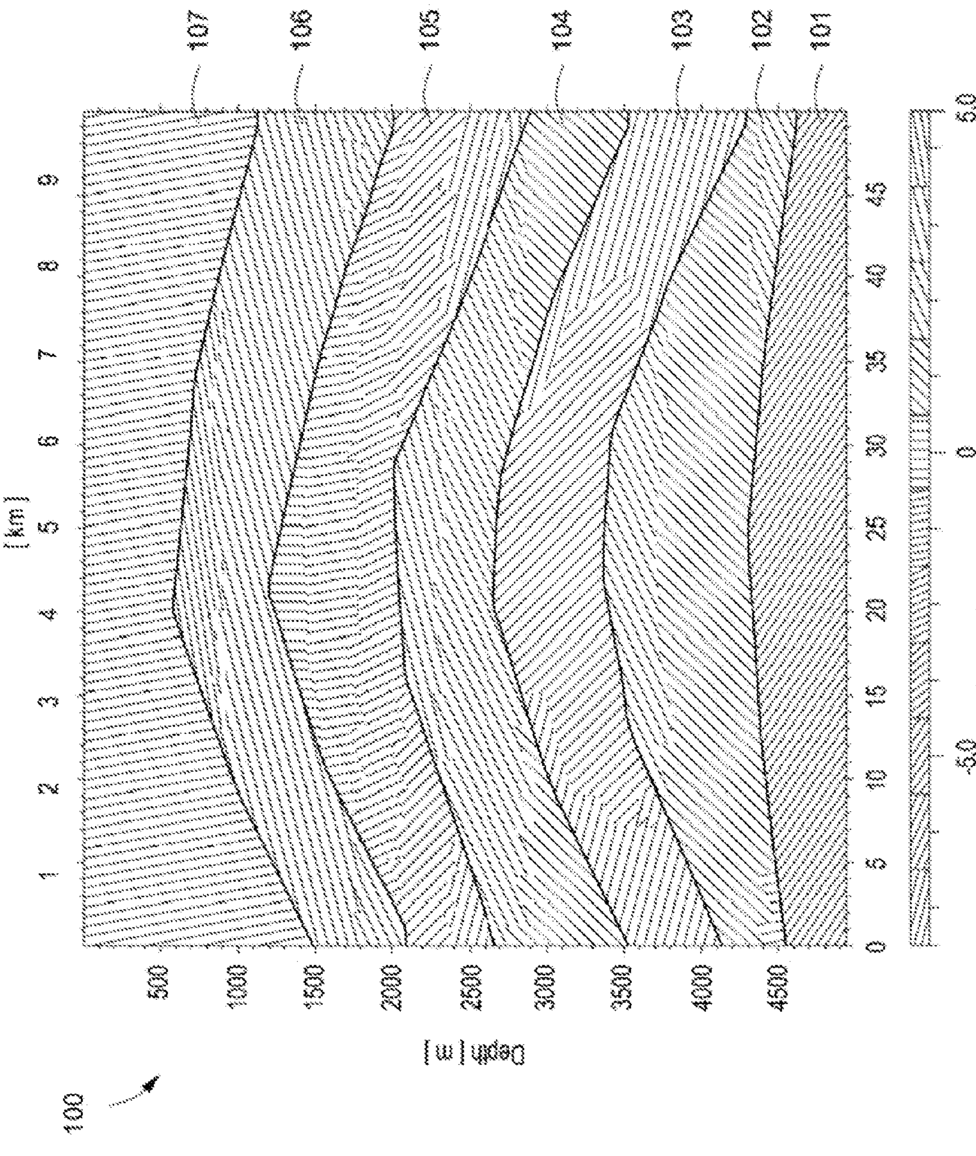

100
[km]
1
2
3
4
5
6
7
8
9
Depth [m]
500
1000
1500
2000
2500
3000
3500
4000
4500
0
5
10
15
20
25
30
35
40
45
107
106
105
104
103
102
101
Permeability [log(mD)]
-5.0
0
5.0

FIG. 1

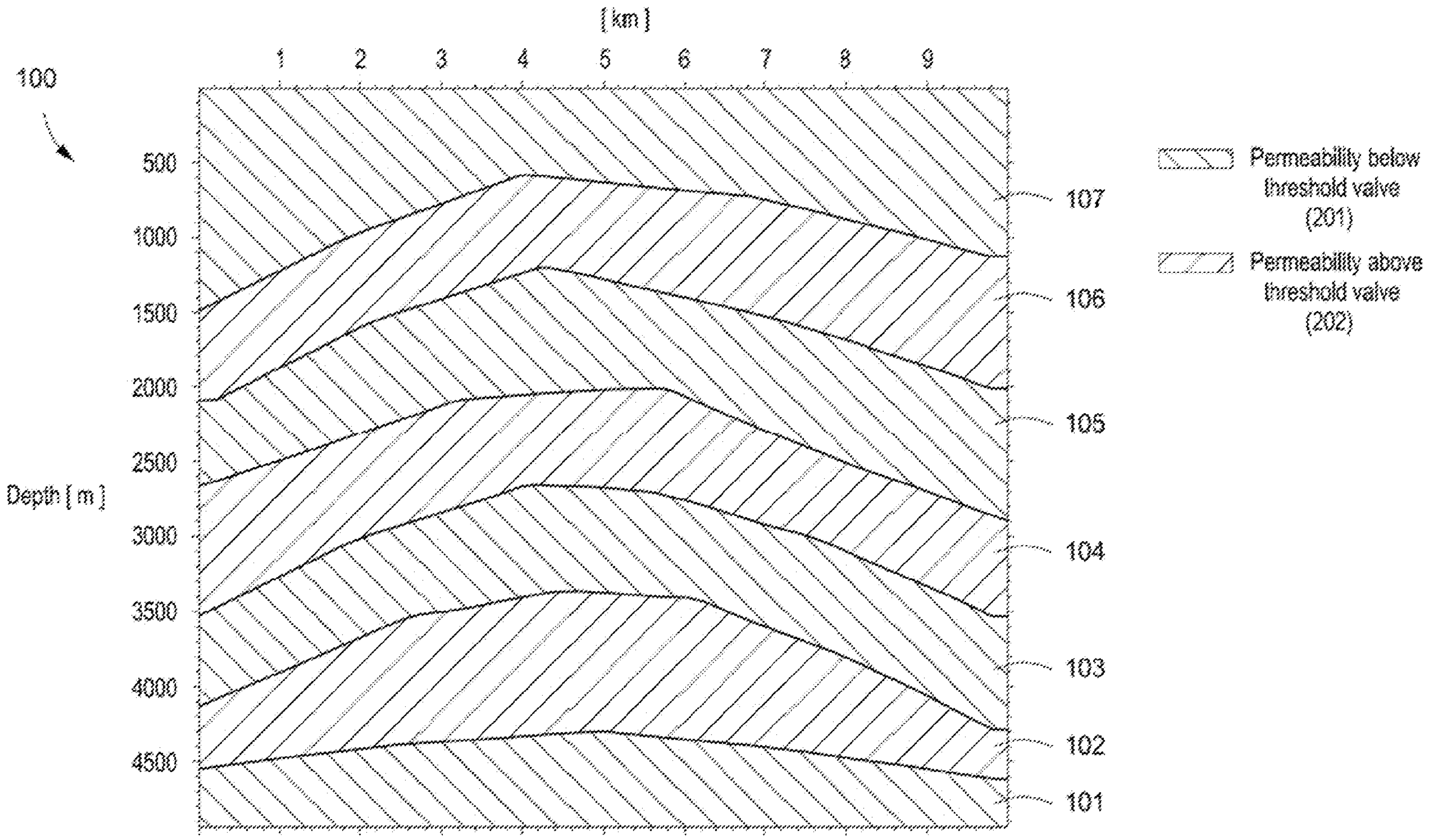

100
[km]
1
2
3
4
5
6
7
8
9
Depth [m]
500
1000
1500
2000
2500
3000
3500
4000
4500
107
106
105
104
103
102
101
Permeability below threshold valve (201)
Permeability above threshold valve (202)

FIG. 2

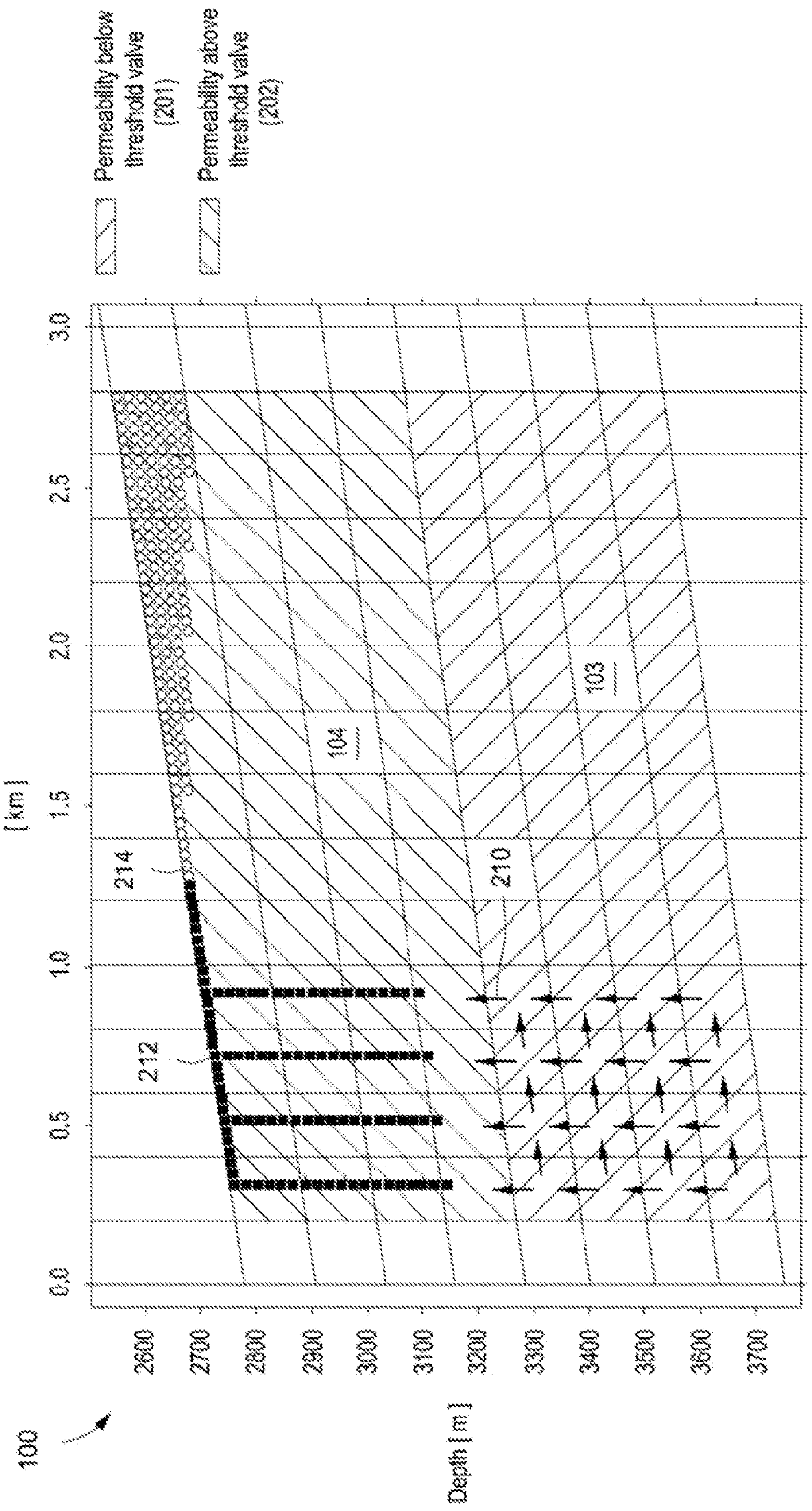

Permeability below threshold valve (201)
Permeability above threshold valve (202)
[km]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth [m]
2600
2700
2800
2900
3000
3100
3200
3300
3400
3500
3600
3700
100
212
214
210
104
103

FIG. 3

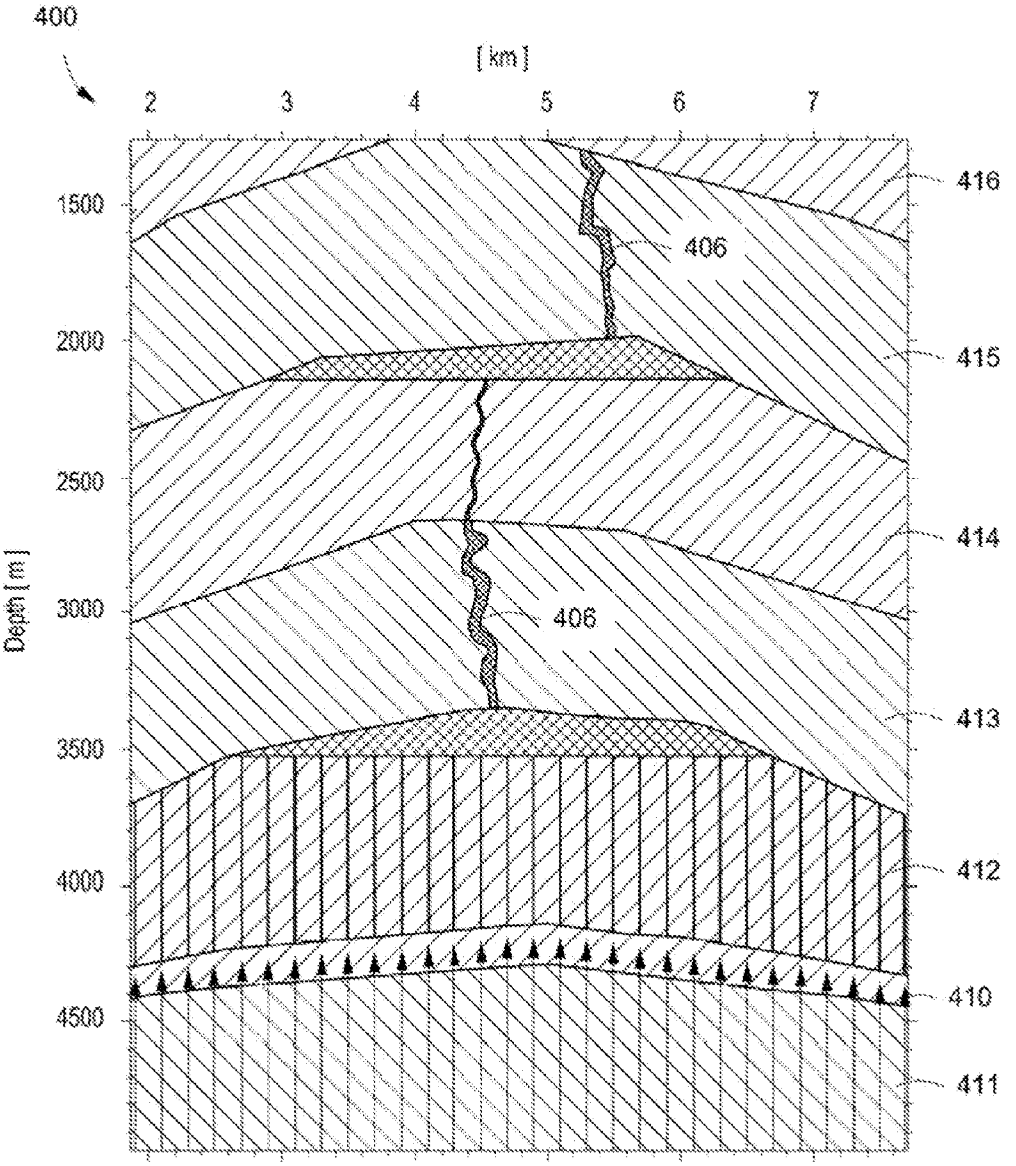


FIG. 4

▧ Permeability below threshold level (401)

▨ Permeability above threshold level (402)

▦ Hydrocarbon fluid

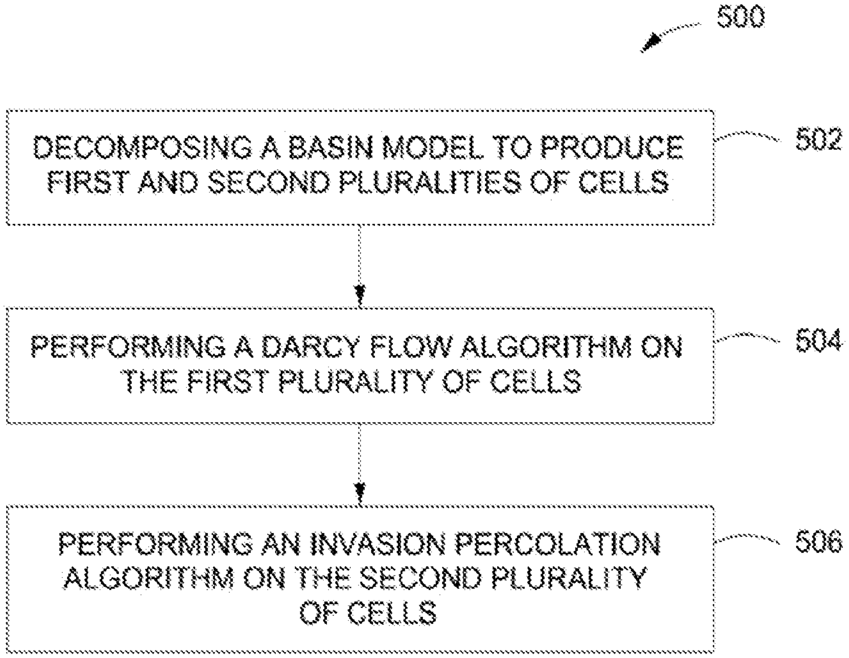

500
DECOMPOSING A BASIN MODEL TO PRODUCE FIRST AND SECOND PLURALITIES OF CELLS
502
PERFORMING A DARCY FLOW ALGORITHM ON THE FIRST PLURALITY OF CELLS
504
PERFORMING AN INVASION PERCOLATION ALGORITHM ON THE SECOND PLURALITY OF CELLS
506

FIG. 5

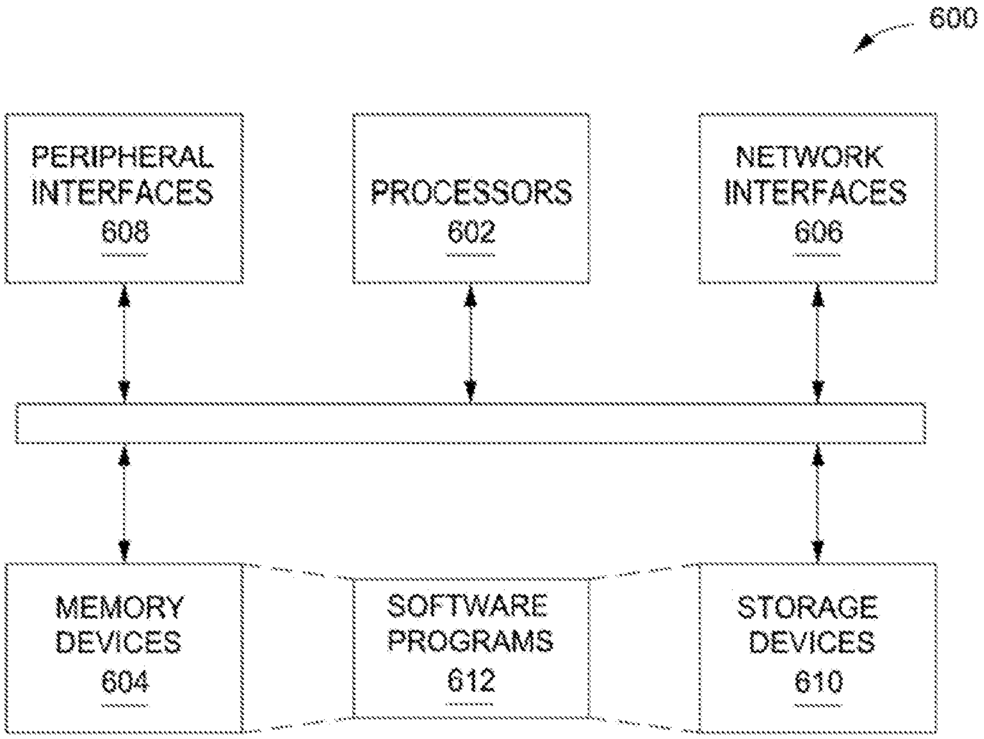

600
PERIPHERAL INTERFACES 608
PROCESSORS 602
NETWORK INTERFACES 606
MEMORY DEVICES 604
SOFTWARE PROGRAMS 612
STORAGE DEVICES 610

FIG. 6

COMBINED MIGRATION METHOD FOR BASIN MODELING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of a related U.S. Provisional Patent Application having Ser. No. 61/828,439 filed May 29, 2013, which is incorporated by reference herein in its entirety.

BACKGROUND

[0002] Basin modeling is used to assess the generation, migration, and accumulation of hydrocarbons in sedimentary basins. In basin modeling, the permeability may span several orders of magnitude. Highly permeable sandstones present in reservoir rocks have permeabilities up to the order of several Darcy (D), whereas for compacted shale, the permeability drops down to a few nano-Darcy (nD), i.e., approximately nine orders of magnitude difference. Using these permeabilities, the time-scales on which the hydrocarbon flow takes place may be estimated. These differences in the permeability introduce challenges m migration modeling.

[0003] Accurate treatment of the hydrocarbon flow within a sedimentary basin using Darcy's law without further approximation requires time-steps on the order of one year or smaller. However, this may not be feasible because simulation runtimes increase when the time-step duration is decreased. Accordingly, further approximations may be employed.

[0004] To handle Darcy's law numerically, the permeability may be limited such that the timescale of flow processes is at least on the order of the duration of the time-steps, thus limiting the flow within high-permeable rocks. By using the Darcy Flow algorithm,, migration in low-permeable rocks is considered more accurately, especially when timing effects of source rock expulsion are accurately treated. However, compared to other migration methods, smaller time-steps are used, again introducing high computational costs.

SUMMARY

[0005] A method for modeling a migration of hydrocarbon fluids is disclosed. The method may include decomposing, by operation of a processor, a domain of a basin model to produce a first plurality of cells having a permeability below a threshold value and a second plurality of cells having a permeability above the threshold value. A first migration analysis may be performed to analyze a relatively slow migration starting in the first plurality of cells. A second migration analysis may be performed to analyze a relatively faster migration starting in the second plurality of cells.

[0006] A computer readable medium is also disclosed. The computer readable medium may store instructions thereon that, when executed by a processor, are configured to cause the processor to perform operations. The operations may include decomposing a domain of a basin model to produce a first plurality of cells having a permeability below a threshold value and a second plurality of cells having a permeability above the threshold value. The operations may also include performing a Darcy Flow algorithm to analyze a relatively slow migration starting in the first plurality of cells. The operations may further include performing an invasion Percolation algorithm to analyze a relatively raster migration starting in the second plurality of cells.

[0007] A computing system is also disclosed. The computer system may include a processor and a memory system including one or more computer readable media storing instructions thereon that, when executed by the processor, are configured to cause the computing system to perform operations. The operations may include decomposing a domain of a basin model to produce a first plurality of cells having a permeability below a threshold value and a second plurality of cells having a permeability above the threshold value. The operations may also include performing a Darcy Flow algorithm to analyze a relatively slow migration starting in the first plurality of cells. The operations may further include performing an Invasion Percolation algorithm to analyze a relatively taster migration starting in the second plurality of cells.

[0008] It will be appreciated that the foregoing summary is merely intended to introduce a subset of the subject matter discussed below and is, therefore, not limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the present teachings and together with the description, serve to explain the principles of the present teachings. In the figures:

[0010] FIG. **1** illustrates a view of a domain of a basin model indicating permeability, according to an embodiment.

[0011] FIG. **2** illustrates a view of a decomposition of the domain of the basin model of FIG. **1**, according to an embodiment.

[0012] FIG. **3** illustrates a view of an enlarged portion of the basin model of FIG. **2**, according to an embodiment.

[0013] FIG. **4** illustrates a view of a decomposition of a domain of a basin model having a seal breakthrough, according to an embodiment.

[0014] FIG. **5** illustrates a flow chart of a method for modeling a migration of hydrocarbon fluids, according to an embodiment.

[0015] FIG. **6** illustrates a schematic view of a computing system, according to an embodiment.

DETAILED DESCRIPTION

[0016] The following detailed description refers to the accompanying drawings. Wherever convenient, the same reference numbers are used in the drawings and the following description to refer to the same or similar parts. While several embodiments and features of the present disclosure are described herein, modifications, adaptations, and other implementations are possible, without departing from the spirit and scope of the present disclosure.

[0017] Embodiments of the present disclosure provide a migration method, which may be based upon a domain decomposition of a basin model and systems for conducting such methods. FIG. **1** illustrates a basin model **100** having a high range of permeability among layers, according to an embodiment. As shown, the basin model **100** includes seven layers **101-107**; however, as may be appreciated, the number of layers in the model **100** may vary depending on the domain being mapped, the dimensions of the domain, and the like.

[0018] The permeability in the model **100** is measured in [log(mD)], as more than 12 orders of magnitude are spanned. In the illustrated basin model **100**, the first or "lower" layer **101** may have a permeability from about −6 to −4 [log(mD)]. The second layer **102** may have a permeability from about −1 to 3 [log(mD)]. The third layer **103** may have a permeability from about −7 to −3 [log(mD)]. The fourth layer **104** may have a permeability from about 1 to 4 [log(mD)]. The fifth layer **105** may have a permeability from about −7 to −2 [log(mD)]. The sixth layer **106** may have a permeability from about 2 to 5 [log(mD)]. The seventh or "upper" layer **107** may have a permeability from about −2 to −1 [log(mD)]. As may be appreciated, the layers **101-107** and the permeability of each layer **101-107** is illustrative and may vary torn model to model.

[0019] FIG. **2** illustrates the basis model **100** of FIG. **1**, but decomposed (e.g., partitioned or divided) into two portions **201**, **202** based on permeability, according to as embodiment. A threshold value for the permeability may be selected. The threshold value may be from about −5 log(mD) to about −3 log(mD), about −3 log(mD) to about −1 log(mD), about −1 log(mD) to about 1 log(mD), about 1 log(mD) to about 3 log(mD) or about 3 log(mD) to about 5 log(mD). in FIG. **2**, the selected threshold value is about 0 [log(mD)]. Once the threshold value is selected, the basin model **100** may be decomposed into a first portion **201** having a permeability below the threshold value (e.g., layers **101**, **103**, **105**, **107**) and a second portion **202** having a permeability above the threshold value (e.g., layers **102**, **104**, **106**). In other embodiments, a threshold of any other value may be selected, without limitation, according to a variety of factors for the basin model **100** being analyzed.

[0020] The portion **201** having the lower permeability may be source rocks, shales, or shaly siltstones. Source rocks refer to rocks from which hydrocarbon fluid has been generated or may-be generated. Shales refer to fine-grained rocks including a mixture of clay minerals and other minerals such as quartz, calcite, and the like. The portion **202** having the higher permeability may be reservoir rocks, sandstones, or permeable limestones (e.g. porous carbonates). Reservoir rocks refer to rocks that have sufficient porosity to contain hydrocarbon fluids.

[0021] FIG. **3** illustrates a view of an enlarged portion of the basin model **100** after the decomposition, according to an embodiment. Each layer (e.g.,. **103**, **104**) in the basin model **100** may be broken into a plurality of similarly sized cells. As shown in FIG. **3**, each cell spans about 0.2 km (along the X-axis) and about **120** in (along the Y-axis), however, the size of the cells may vary in one or both directions.

[0022] As shown in the lower left corner of FIG. **3**, hydrocarbon fluid is generated in the lower permeability portion **201** (e.g., layer **103**) of the basin model **100**. The hydrocarbon fluid flows or migrates upward through layer **103** and injection points (i.e., the interface between the layers **103**, **104**) to the higher permeability portion **202** (e.g., layer **104**), as indicated by the arrows **210**. The hydrocarbon fluid flows upward and to the right side of the higher permeability portion **202** (e.g., layer **104**), as indicated by the squares **212**. This may be referred to as a "migration stringer." The hydrocarbon fluid then accumulates in the upper right corner, as indicated by the circles **214**.

[0023] The hydrocarbon flow within the basin model **100** shown in FIG. **3** may be evaluated in time-steps. The time-steps may be the same in duration or may vary. The time-steps may range from a low of about 10 years, about 100 years, about 1,000 years, or about 10,000 yeas to a high of about 100,000 years, about 500,000 years, about 1,000,000 years, or more. For each time-step, a first migration analysis, such as a Darcy Flow algorithm, may be performed on each of the cells in the basin model **100** (i.e., both the lower permeability portions **201** and the higher permeability portions **202**). In another embodiment, the Darcy Flow algorithm may be performed on a targeted subset of the cells. For example, the Darcy Flow algorithm may be performed on the cells in the lower permeability portions **201**.

[0024] The Darcy Flow algorithm for calculating the flow of a viscous fluid (e.g., hydrocarbon liquid or gas) through porous media may be described by the following equation:

$$\vec{v} = -\mu \vec{\nabla} u,$$

where $\vec{v}$ denotes velocity of the flow, μ denotes the mobility tensor which is given by the quotient of the permeability of the rock matrix, k, and viscosity of the liquid/gas, ν, as

$$\mu = \frac{k}{\nu}.$$

The driving force $\vec{\nabla} u$ denotes a gradient, which points in the direction of the steepest decrease In of the potential field u. The gradient $\vec{\nabla} u$ is a mathematical formulation of pressure potential differences over infinitesimally small distances in spatial directions.

[0025] When more than one component is considered, additional effects may be taken into account, such as capillary pressures, relative permeabilities, etc. Capillary pressures may play a role in water-oil-gas systems and introduce non-linear effects. In general, equations characterizing such models that include consideration of multiple effects may not be analytically solvable. Therefore, a numerical treatment may be used, which is based on a discretization of both space (i.e., the model is decomposed into a set of spatial cells with equal properties) and time (introduction of time-steps). A variety of numerical methods may thus be used in order to handle the flow of hydrocarbons through porous media such as Finite Element Methods or Finite Volume Methods.

[0026] The spatial size of cells describing the flow processes is given by the scale on which physical properties (e.g., permeability, viscosity, and/or porosity) changes. The scale on which saturations significantly change should be larger than the size of the grid cells. Typical cell sizes are on the order of 1 km horizontally and 100 m vertically. A reasonable maximum duration of time-steps may be estimated by the flow rate obtained by Darcy's law. When a pure Darcy Flow algorithm is considered, one may choose a time-step such that the hydrocarbon composition of a cell is not altered significantly within one time-step. If the time-steps are too big, one may limit the flow in higher permeability portions to stabilize the algorithm, for instance, by reducing the permeability in these areas.

[0027] After the Darcy Flow algorithm has been performed, a second migration analysis, such as an Invasion Percolation algorithm, may be performed on the cells in the higher permeability portions **202** (e.g., layer **104**) for the first step. Like the Darcy Flow algorithm, the invasion Percolation algorithm may be used to calculate the flow of a viscous fluid (e.g., hydrocarbon liquid or gas) through porous media.

[0028] Modeling of fluid flow with Invasion Percolation may neglect timing during fluid movement. Instead, a balance of buoyant hydrocarbon forces with capillary pressure thresholds, (e.g., below a seal) may be searched. It may be assumed that in permeable rocks an equilibrium will be reached after sufficient time. Geological timescales within basin modeling, which cover the overall evolution of sedimentary basins, usually exceed such time ranges. The Invasion Percolation algorithm is described in greater detail in: T. Hantschel & A. Kauerauf (2009); "Fundamentals of Basin and Petroleum Systems Modeling," Chapter 6.8, Springer, which is incorporated by reference herein in its entirety.

[0029] The Invasion Percolation algorithm is thus based on two approximations. First, any viscous effects of the hydrocarbons may be neglected, and thus, migration may be viewed as occurring instantaneously, i.e., all timing effects of the migration may not be taken into account. Secondly, it assumes that the migration takes places in migration pathways, also called "stringers." For example, the migration pathways may be one-dimensional pathways or stringers.

[0030] The Invasion Percolation algorithm may accurately consider the fast migration in highly permeable rocks. As the permeability is high, all flow processes within these rocks may be considered instantaneous on geological timescales. Thus, neglecting all viscous effects is a good approximation for highly permeable rocks. Further, spatial resolution may be increased, yielding an accurate representation of complex geometries, including complex fault structures. Breakthroughs, i.e., losses of hydrocarbon fluid through seal layers, may be assumed to take place in stringer-like migration pathways, which may be accurately described by the Invasion Percolation algorithm than the Darcy Flow algorithm.

[0031] The Invasion Percolation algorithm may be performed on a finer grid (i.e., smaller cells) than the Darcy Flow algorithm. More particularly, the Invasion Percolation algorithm may be processed on a grid with about 10 to about 100 times higher resolution than the Darcy Flow algorithm grid. For example the cells in the basin model 100 for the Invasion Percolation algorithm may be about 25 m, about 50 m, or about 100 m (along the horizontal X-axis) and about 5 m, about 10 m, or about 20 m (along the vertical Y-axis).

[0032] As noted above, the flow analyzed by the invasion Percolation algorithm in the higher permeability portion **202** may occur instantaneously (i.e., be approximated as instantaneous) from the perspective of the Darcy Flow algorithm, as the permeability in the higher permeability portion **202** is above the threshold value. Thus, the timescale on which migration takes place may be shorter than the duration of the time-steps employed by the numerical analysis of the basin model **100**.

[0033] As the migration of hydrocarbons in higher permeability portions **202** is handled by the Invasion Percolation algorithm, it is possible to increase the duration of time-steps of the Darcy Flow algorithm, which are in this case limited by the flow in the lower permeability portions **201** only. The time-step duration may be increased by a factor of about 1 up to a factor of about 1000 and even beyond, thus allowing to utilize time-steps of 1,000 years up to 10 million years, and more. This may yield significant runtime performance improvements.

[0034] FIG. **4** illustrates a view of a decomposition of a domain of a basin model **400** having one or more seal breakthroughs **406**, according to an embodiment. As in FIG. **3**, the arrows **410** indicate a migration from a lower permeability portion **401** to a higher permeability portion **402**. This migration may be performed by the Darcy Flow algorithm. The resolution of the flow calculated by the Invasion Percolation algorithm is high, and accumulations may appear as a connected cloud of dots.

[0035] Seal breakthroughs **406** may be better described by stringer-like migration pathways. Therefore, such pathways may be considered by the Invasion Percolation algorithm. To achieve this, the method may include imposing an additional condition for the Darcy Flow algorithm. Specifically, flow from higher permeability portions **402** into lower permeability portions **401** (i.e., from the reservoir into toe seal layer), as shown in FIG. **4**, may be prohibited Hydrocarbon fluid accumulations in the lower permeability portions **401** created by seal breakthroughs **406** may then be analyzed or re-injected using the Invasion Percolation algorithm in later time-steps.

[0036] FIG. **5** illustrates a flowchart of a method **500** for modeling a migration of hydrocarbon fluids in a sedimentary basin, according to an embodiment. The method **500** may include decomposing a basin model to produce first and second pluralities of cells, as shown at **502**. The basin model may be decomposed by first selecting a threshold permeability value. The first plurality of cells may have a permeability less than the threshold value, and the second plurality of cells may have a permeability greater than the threshold value.

[0037] A Darcy Flow algorithm may then be performed to analyze a relatively slow migration starting in the first plurality of cells, as shown at **504**. The Darcy Flow algorithm may also be performed starting in the second plurality of cells. The Darcy Flow algorithm may be performed according to the time-stepping of the first plurality of cells only (e.g., fewer and longer time-steps). Once the Darcy Flow algorithm is complete, an Invasion Percolation algorithm may be performed to analyze a relatively faster migration starting in the second plurality of cells (i.e., having the permeability above the threshold value), as shown at **506**. Furthermore, complex reservoir structures including complex facies distributions and faults can be modeled using the Invasion Percolation algorithm. The method **500** may promote enhanced efficiency and performance. Compared to a pure Darcy Flow algorithm, the time-steps may be larger (as the high-permeable reservoirs are not accounted for the scaling of the Darcy Flow algorithm), thereby decreasing the computation requirements, while retaining sufficient accuracy.

[0038] Embodiments of the disclosure may also include one or more systems for implementing one or more embodiments of the method of the present disclosure. FIG. **6** illustrates a schematic view of such a computing or processor system **600**, according to an embodiment. The processor system **600** may include one or more processors **602** of varying core (including multiple cores) configurations and clock frequencies. The one or more processors **602** may be operable to execute instructions, apply logic, etc. It will be appreciated that these functions may be provided by multiple processors or multiple cores on a single chip operating in parallel and/or communicably linked together.

[0039] The processor system **600** may also include a memory system, which may be or include one or more memory devices and/or computer-readable media **604** (e.g., non-transitory computer-readable media) of varying physical dimensions, accessibility, storage capacities, etc. such as flash drives, hard drives, disks, random, access memory, etc, for storing data, such as images, files, and program instructions for execution by the processor **602**. In an embodiment, the computer-readable media **604** may store instructions that, when executed by the processor **602**, are configured to cause the processor system **600** to perform operations. For example, execution of such instructions may cause the processor system **600** to implement one or more portions and/or embodiments of the methods) **500** described above.

[0040] The processor system **600** may also include one or more network interfaces **606**. The network interfaces **606** may include any hardware, applications, and/or other software. Accordingly, the network interfaces **606** may include Ethernet adapters, wireless transceivers, PCI Interfaces, and/or serial network components, for communicating over wired or wireless media using protocols, such as Ethernet, wireless Ethernet, etc.

[0041] The processor system **600** may further include one or more peripheral interfaces **608**, for communication with a display screen, projector, keyboards, mice, touchpads, sensors, other types of input and/or output peripherals, and/or the like. In some implementations, the components of processor system **600** need not be enclosed within a single enclosure or even located in close proximity to one another, but in other implementations, the components and/or others may be provided in a single enclosure.

[0042] The computer-readable media **604** may be physically or logically arranged or configured to store data on one or more storage devices **610**. The storage device **610** may include one or more file systems or databases in any suitable format. The storage device **610** may also include one or more software programs **612**, which may contain interpretable or executable instructions for performing one or more of the disclosed processes. When requested by the processor **602**, one or more of the software programs **612**, or a portion thereof, may be loaded from the storage devices **610** to the computer-readable media **604** for execution by the processor **602**.

[0043] Those skilled in the art will appreciate that the above-described componentry is merely one example of a hardware configuration, as the processor system **600** may include any type of hardware components, including any necessary accompanying firmware or software, for performing the disclosed implementations. The processor system **600** may also be implemented in part or in whole by electronic circuit components or processors, such as application-specific integrated circuits (ASICs) or field-programmable gate arrays (FPGAs).

[0044] The foregoing description of the present disclosure, along with its associated embodiments and examples, has been presented tor purposes of illustration only. It is not exhaustive and does not limit the present disclosure to the precise form disclosed. Those skilled in the art will appreciate from the foregoing description that modifications and variations are possible in light of the above teachings or may be acquired from practicing the disclosed embodiments.

[0045] For example, the same techniques described herein with reference to the processor system **600** may be used to execute programs according to instructions received from another program or from another processor system altogether. Similarly, commands may be received, executed, and their output returned entirely within the processing and/or memory of the processor system **600**. Accordingly, neither a visual interface command terminal nor any terminal at all is strictly necessary for performing the described embodiments.

[0046] Likewise, the steps described need not be performed in the same sequence discussed or with the same degree of separation. Various steps may be omitted, repeated, combined, or divided, as necessary to achieve the same or similar objectives or enhancements. Accordingly, the present disclosure is not limited to the above-described embodiments, but instead is defined by the appended claims in light of their full scope of equivalents. Further, in the above description and in the below claims, unless specified otherwise, the term "execute" and its variants are to be interpreted as pertaining to any operation of program code or instructions on a device, whether compiled, interpreted, or run using other techniques.

What is claimed is:

1. A method for modeling a migration of hydrocarbon fluids, comprising:

decomposing, by operation of a processor, a domain of a basin model to produce a first plurality of cells having a permeability below a threshold value and a second plurality of cells having a permeability above the threshold value;

performing a first migration analysis to analyze a relatively slow migration starting in the first plurality of cells; and

performing a second migration analysis to analyze a relatively faster migration starting in the second plurality of cells.

2. The method of claim **1**, wherein a flow analyzed by the second migration analysis occurs instantaneously from a perspective of the first migration analysis.

3. The method of claim **1**, further comprising performing the first migration analysis starting in the first and second pluralities of cells.

4. The method of claim **1**, further comprising performing the first migration analysis and the second migration analysis for a plurality of time steps.

5. The method of claim **1**, wherein the first migration analysis comprises a Darcy Flow algorithm, and wherein the second migration analysis comprises an Invasion Percolation algorithm.

6. The method of claim **1**, wherein the second migration analysis is not performed starting in the first plurality of cells.

7. The method of claim **1**, wherein the second plurality of cells comprises a seal breakthrough through a layer comprising the first plurality of cells.

8. The method of claim **1**, wherein the first plurality of cells comprises source rocks, shales, or a combination thereof.

9. The method of claim **1**, wherein the second plurality of cells comprises reservoir rocks.

10. The method of claim **1**, wherein the threshold value is from about −3 log (mD) to about 3 log(mD).

11. A computer readable medium storing instructions thereon that, when executed by a processor, are configured to cause the processor to perform operations, the operations comprising:

decomposing a domain of a basin model to produce a first plurality of cells having a permeability below a threshold value and a second plurality of cells having a permeability above the threshold value;

performing a Darcy Flow algorithm to analyze a relatively slow migration starting in the first plurality of cells; and

performing an Invasion Percolation algorithm to analyze a relatively faster migration starting in the second plurality of cells.

12. The computer readable medium of claim **11**, wherein the operations further comprise performing the Darcy Flow algorithm starting in the second plurality of cells.

13. The computer readable medium of claim **11**, wherein the operations further comprise performing the Invasion Percolation algorithm alter the Darcy Flow algorithm is performed.

14. The computer readable medium of claim **11**, further comprising performing the Darcy Flow algorithm starting in the first and second pluralities of cells.

15. The computer readable medium of claim **11**, wherein the second plurality of cells comprises a seal breakthrough through a layer comprising the first plurality of cells.

16. A computing system, comprising:

a processor; and

a memory system comprising one or more computer readable media storing instructions thereon that, when executed by the processor, are configured to cause the computing system to perform operations, the operations comprising:

decomposing a domain of a basin model to produce a first plurality of cells having a permeability below a threshold value and a second plurality of cells having a permeability above the threshold value;

performing a Darcy Flow algorithm to analyze a relatively slow migration starting in the first plurality of cells; and

performing an Invasion Percolation algorithm to analyze a relatively faster migration starting in the second plurality of cells.

17. The computer system of claim **16**, wherein the operations further comprise performing the Darcy Flow algorithm starting in the second plurality of cells.

18. The computer system of claim **16**, wherein the operations further comprise performing the Invasion Percolation algorithm after the Darcy Flow algorithm is performed.

19. The computer system of claim **16**, wherein the Darcy Flow algorithm and the Invasion Percolation algorithm are performed for a plurality of time steps.

20. The computer system of claim **16**, wherein the second plurality of cells comprises a seal breakthrough through a layer comprising the first plurality of cells.

* * * * *