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METHOD FOR CREATING A PERMEABLE FRAGMENTED
ZONE WITHIN AN OIL SHALE FORMATION
Filed July 13, 1967 Sheet 1 of 2

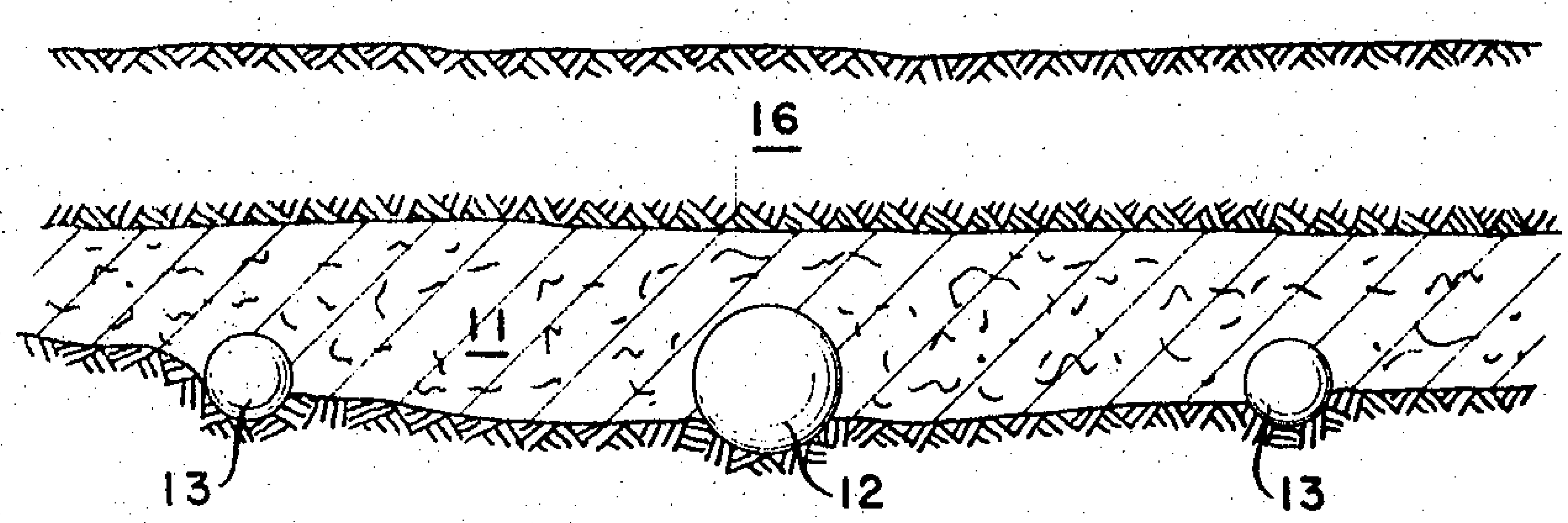

FIG. 1

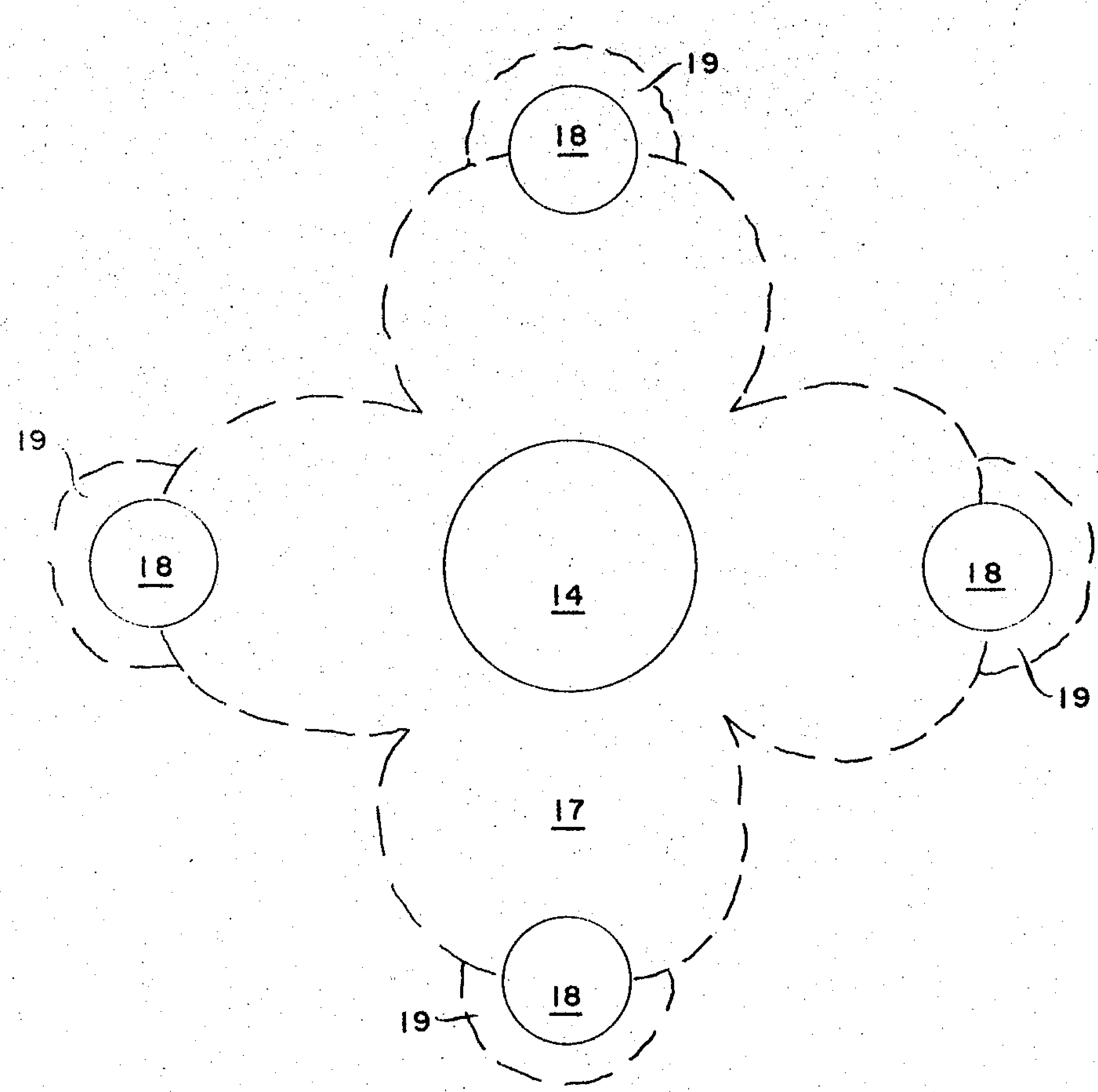

FIG. 2

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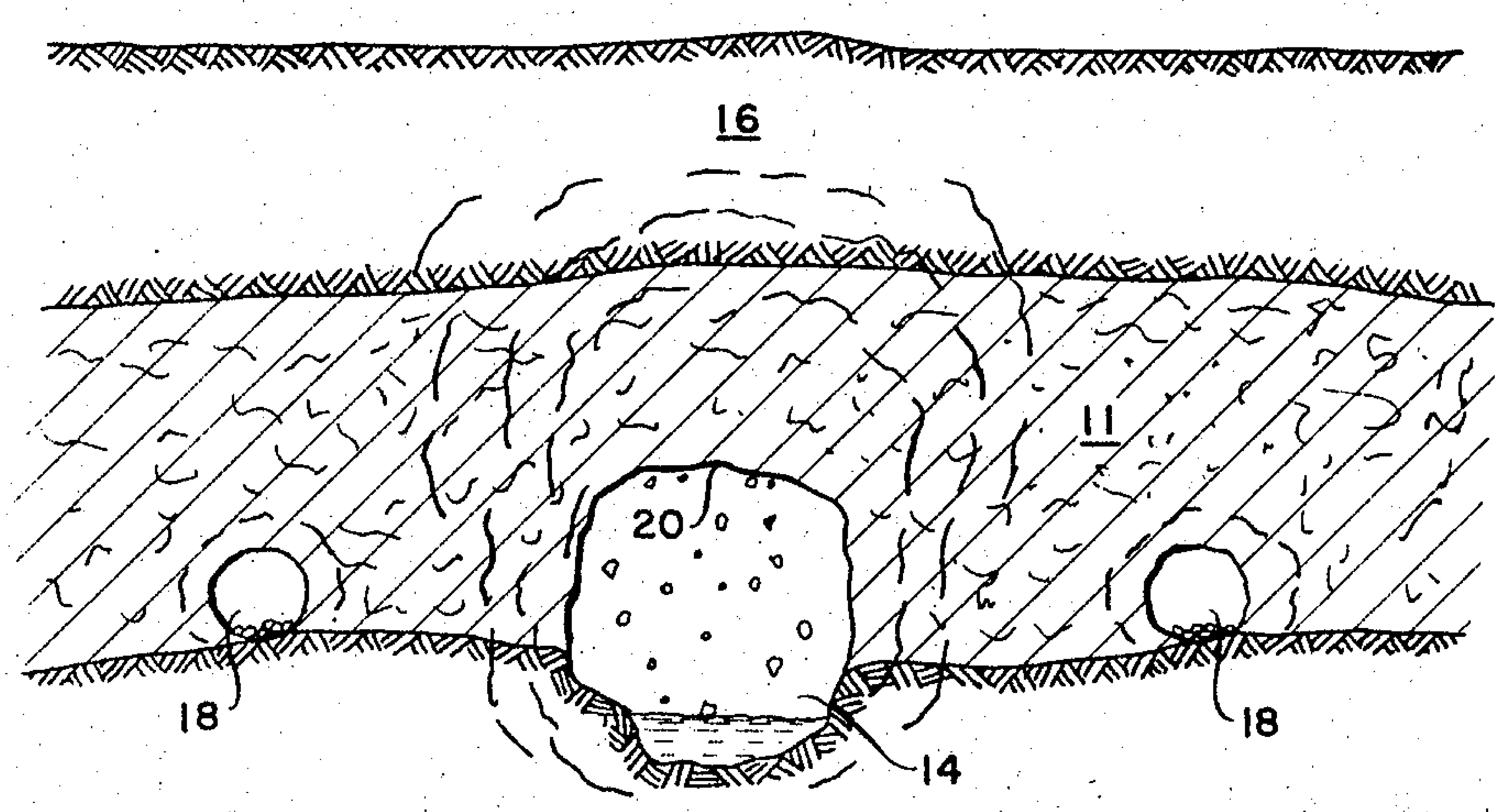

FIG. 3

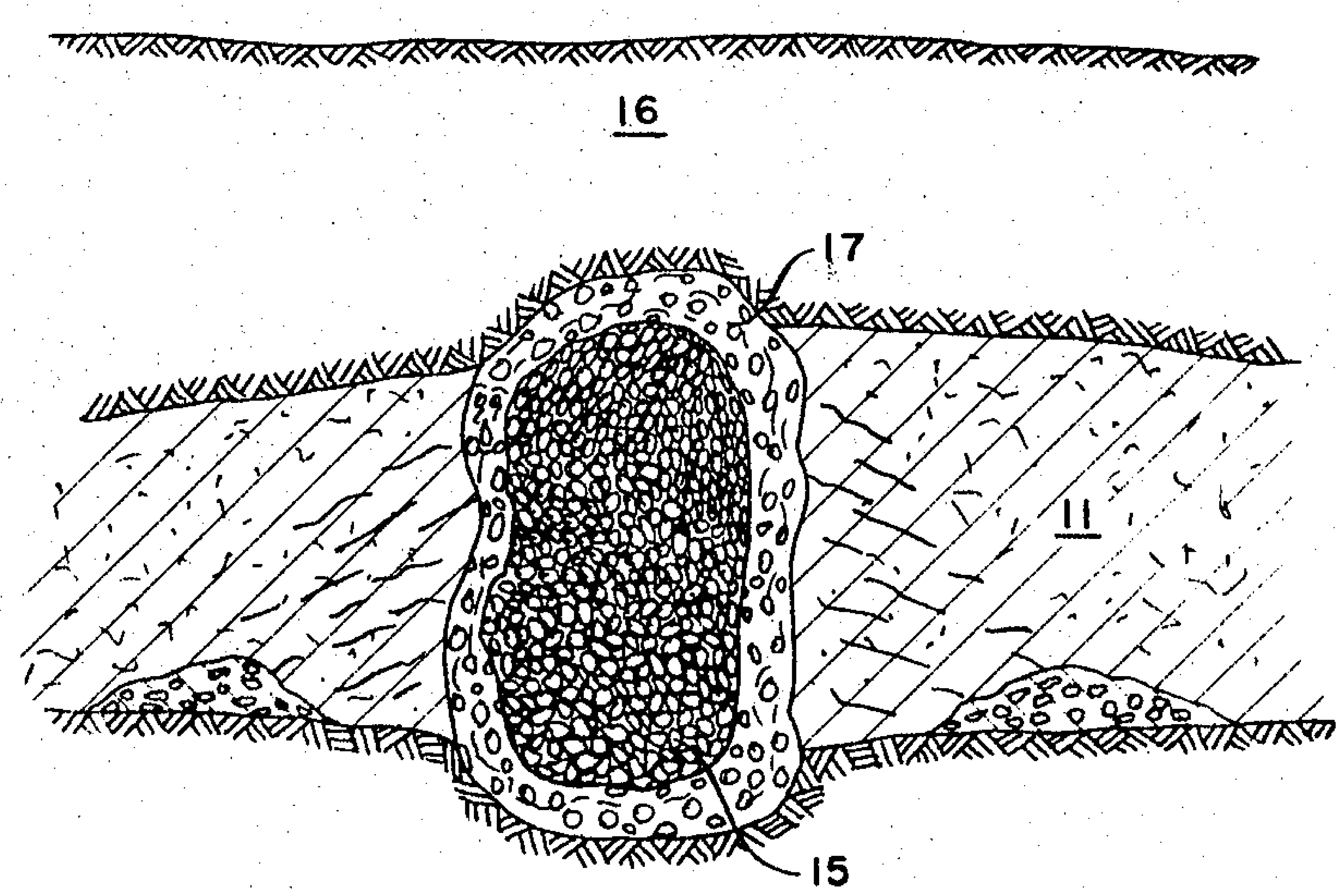

FIG. 4

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METHOD FOR CREATING A PERMEABLE FRAGMENTED ZONE WITHIN AN OIL SHALE FORMATION

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Int. Cl. E21b 43/25, 43/24
U.S. Cl. 166—247 9 Claims

ABSTRACT OF THE DISCLOSURE

A method for creating a permeable zone in a subterranean oil shale formation by utilizing a plurality of strategically placed explosive devices of varying energy. A very high energy explosive, such as a nuclear device, is first exploded; then a plurality of explosive devices of lesser energy, nuclear or non-nuclear, spaced radially from the high energy explosive, are detonated between the time the initial cavity within the oil shale formation begins to expand radially outward as a result of the detonation of the high energy explosive, and the time at which a chimney of rubble of the fragmentsd oil shale formation is formed by the collapsing of the cavity roof of the oil shale formation.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to a process for creating a zone of relatively high permeability in an oil shale; more particularly, it relates to a process of utilizing high and low energy explosives, strategically placed, to cause the formation of a fragmented rubble zone of the oil shale formation affected by systematically detonating the explosives.

Description of the prior art

The fact that thermonuclear explosives may become available for a fraction of a mill per kilowatt-hour equivalent has led to the realization that ultra-high energy explosives can be used in mining operations to break up formation and in the oil industry to increase or stimulate productivity by heating or raising the pressure of a reservoir.

One of the chief uncertainties with regard to the effects of nuclear explosions within a subterranean oil shale formation is the permeability distribution surrounding the cavity and subsequent chimney produced by a detonation. In prior tests, nuclear devices have been detonated within various subterranean formations, and, at first, an almost spherical cavity filled with hot gases was formed. This cavity expanded until the pressure within the cavity equaled that of the overburden. On cooling, the roof of the cavity collapsed, since it could not support itself and a so-called "chimney" developed within the formation. Chimney growth ceased when the rock pile either filled the cavity or when a stable arch developed. Thus, the void space, or porosity of the broken rock in the chimney had approximately the same volume as the cavity before the roof began to fall in.

At the same time, the shock wave resulting from such nuclear explosions created a highly fractured region surrounding the chimney which may become many times larger in volume than the chimney itself. In an oil shale, the shale oil within the fragmented rubble zone including both the chimney and the surrounding fractured region can be recovered by known oil recovery means, such as in-situ retorting. One recovery process would be to inject hot fluid into the zone so that the oil shale components

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are converted to oil-containing fluid which can then be recovered by known means.

Evidence from these prior tests suggests that permeability of the fragmented zone drops very rapidly with distance radially outward from the primary rubble zone. A high and uniform permeability is important in order to provide maximum sweep efficiency in any underground hydrocarbon recovery processes.

SUMMARY OF THE INVENTION

The invention relates to a method for increasing the permeability in the rigion immediately surrounding the primary rubble zone of an oil shale formation. In a preferred embodiment, a primary nuclear device is placed within a subterranean oil shale formation and is surrounded by a plurality of radially-placed devices of lesser explosive energy, nuclear or non-nuclear. The radially-placed devices are programmed to be detonated by either the main shock wave from the primary device or exploded by other means after the main shock wave has passed. The lesser explosive energy devices are preferably detonated between the time the spherical cavity caused by the explosion of the primary device begins to expand radially outward and the time at which a chimney is formed by the collapse of the cavity roof.

It is an object of this invention to increas the volume of a permeable zone of fragmented oil shale formation that is formed by detonating a high energy explosive device within the subterranean oil shale formation.

It is a further object to create a rubble zone of relatively high and uniform permeability within an oil shale formation.

Further objects of the invention will become apparent as the following description thereof proceeds in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 shows a vertical cross-sectional view of an oil shale formation prior to detonating a plurality of explosive devices within the formation;

FIGURE 2 is a diagrammatic view of the cavities formed by detonating the explosive devices within the oil shale formation of FIGURE 1 taken along a plane through the lines 2—2 of FIGURE 1;

FIGURE 3 is a vertical cross-sectional view of the oil shale formation of FIGURE 1 after the primary explosive device has been detonated; and

FIGURE 4 is a vertical cross-sectional view of the final rubble zone created by detonating all of the explosive devices of FIGURE 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIGURE 1 shows subterranean oil shale formation **11** having a primary explosive device **12** located within the formation **11**. Primary explosive device **12** is surrounded by a plurality of lesser energy explosive devices **13**. The device **12** can be either nuclear or non-nuclear; if a nuclear device is detonated in the subterranean oil shale formation **11**, a strong shock wave from the nuclear device begins to move radially outwardly, vaporizing, melting, crushing, cracking and displacing the oil shale formation **11**. After the shock wave has passed, the high-pressure vaporized material expands, and a generally spherical cavity (i.e., the central cavity **14** in FIGURES 2 and 3) is formed which continues to grow until the internal pressure is balanced by the lithostatic pressure. The cavity **14** persists for a variable time depending on the composition of the oil shale formation **11** and then collapses to form a chimney **15** (FIGURE 4). Collapse progresses upwardly until the volume initially in the cavity is distributed between the fragments of the oil shale of formation **11**. The size of the cylindrical rubble zone (i.e., the "chimney" **15**) formed by the collapse of the cavity **14** can be estimated from the fact that the initial cavity **14** expands to the pressure exerted by the overlying portions of earth formations **11** and **16**.

A zone of permeability **17** within the fragmented oil shale formation is formed surrounding the "chimney" **15** as can be seen in FIGURE 4. The permeability of this zone **17** can be increased by surrounding the primary explosive device which formed the central cavity with a plurality of devices **13** of lesser explosive energy. For example, in FIGURE 1, a primary nuclear explosive device **12** is surrounded by explosive devices **13**, equally spaced from each other and radially spaced from the primary explosive device **12**. These lesser energy devices **13** are preferably on substantially the same horizontal plane as the primary nuclear device (see FIGURE 1) and 500 to 1,000 feet from the nearest part of the outer wall of the central cavity **14** produced by the explosion of the high energy nuclear device **12**. The lesser energy devices **13** preferably have an energy yield no less than one-fourth of the primary high energy **12** nuclear device and can be either nuclear or non-nuclear. Of course, the high energy device **12** could be non-nuclear and the lesser energy devices **13** could be greater in number as long as the total of the individual energy yield of the latter was approximately equal to the total combined energy yield of the primary explosive device. Their individual energy yields (i.e., the lesser energy devices **13**) should be accordingly substantially equal to each other.

The lesser energy explosive devices **13** form cavities **18** (FIGURE 2) when detonated, surrounded by fractured zones **19** as can be seen in FIGURE 2. The lesser energy devices **13** are preferably preset with detonating means adjusted to explode upon arival of the main shock wave from the explosion of the primary explosive device **12**. Alternatively, the lesser energy devices **13** can be suitably delayed to explode after passage of the main shock wave. Of course, another characteristic of the explosion of the primary explosive device **12** can be utilized to detonate the lesser energy devices **13**, as, for example, changes in temperature or pressure as a result of the explosion of the primary explosive device.

Because of this time delay, either detonating the lesser energy devices **13** upon arrival of the main shock wave or after the main shock wave has passed but before the central cavity **14** becomes filled with rubble due to the chimney collapse from above, the shock waves from the secondary explosions (that is, the explosions of the lesser energy devices **13**) will cause spalling into the central cavity. The movement of rock towards the central cavity **14** due to the satellite explosions will enhance the permeability in the regions between these explosions and the central cavity **14**, by allowing development of a greater void space in this region. This void space, indicated as a zone of increased permeability **17** in the drawings, has a high and uniform permeability in the fragmented oil shale formation **11**.

It can be seen from the foregoing that the lesser energy explosives **13** are detonated substantially simultaneously with respect to each other so that the energies from the pluralities of the explosions are additively focused toward the cavity **14** formed by the central explosion of device **12**. The detonations of the satellite or lesser energy explosives **13** are actuated in response to the arrival of the pressure wave from the detonation of centrally located nuclear explosive device **12** at a location spaced generally horizontally from the central explosion. The time at which the lesser energy explosives **13** are detonated is preferably between about the time the shock wave arrives at the surrounding explosives and about the time the pressure in the central cavity **14** becomes as low as the pressure of overburden. Stated differently, this time period lies between the period at which the spherical cavity **14** (FIGURE 3) formed by the central explosion begins to expand radially outwardly and the time at which a chimney **15** is formed by the collapse of the cavity roof **20**. The lesser energy explosives **13** are thus spaced from the central cavity **14** by sufficient distances so that the explosions from the satellite explosions are capable of causing rock to move into the void space within the central cavity **14** formed by the higher energy explosive **12**. The main shock wave from the higher energy explosive **12**, in the case of a nuclear device, travels at about five meters per millisecond and the initial spherical cavity **14** persists for times that vary with the composition of the shale oil formation **11**. Very little rock falls into this central cavity **14** until its pressure has decreased to about the pressure of the overburden. The decrease in the pressure of the central cavity **14** allows the weight of the overburden to stress the arch of rock that forms the roof **20** of the cavity, and this initiates, or at least accelerates, the relatively extensive collapsing that converts the spherical cavity **14** to rubble-filled chimney **15**.

In the prior tests, the radius of the fractured zone outside the central cavity (the "zone of increased permeability" **17**) was approximately proportional to the radius of the central cavity **14**. This fractured zone **17**, created as disclosed in this application, has been found to have a relatively high and uniform permeability. Shale oil can be extracted from rubbled zones **15** and **17** by any known means, such as in situ retorting. Suitable materials and techniques for use in treating the fragmented oil shale **11** within the permeable zones **15** and **17** are disclosed in copending applications, Ser. No. 632,006, filed Apr. 19, 1967 and Ser. No. 656,815, filed July 28, 1967.

Various methods of carrying out the concepts of this invention may become apparent to one skilled in the art, and it is to be understood that such modifications fall within the spirit and scope of the appended claims.

We claim as our invention:

1. A method of creating a zone of relatively high permeability within a subterranean oil shale formation comprising the steps of:

placing a relatively high energy explosive device within the formation;

placing a plurality of devices of substantially lesser explosive energy within the formation;

spacing the plurality of devices such a distance from the relatively high energy device that the exploding of the plurality of devices can cause rubble from the oil shale formation to move into the area of the high energy explosive device;

exploding the relatively high energy explosive device within the oil shale formation, thereby forming a cavity within the oil shale formation having a roof beneath the overburden which subsequently collapses to form a chimney of rubble within the oil shale formation; and

exploding the plurality of devices between the time the initial cavity within the oil shale formation begins to expand radially outwardly as a result of the explosion of the high energy explosive device and the time at which the chimney of rubble of fragmented oil shale formation is formed by the collapsing of the cavity roof.

2. The method of claim **1** wherein the step of placing a relatively high energy explosive device within the formation includes placing a nuclear device within the formation.

3. The method of claim **1** wherein the step of exploding the plurality of devices includes the step of programming the plurality of devices to be detonated as a result of a characteristic of the explosion of the high energy explosive device.

4. The method of claim **1** wherein the placing of a plurality of devices includes placing a number of such devices whose energy yield are substantially equal to each other, the total energy yield of the plurality of devices being substantially equal to the energy yield of the high energy device.

5. The method of claim **4** wherein the placing of the plurality of devices comprises placing four such devices on the same horizontal plane as the high energy device and substantially equally spaced from the high energy explosive device and from each other.

6. The method of claim **5** wherein the placing of the plurality of devices includes placing such devices approximately 500 to 1,000 feet from the nearest part of the outer wall of the cavity to be formed within the oil shale formation.

7. The method of claim **1** wherein the exploding of the plurality of devices includes exploding such devices after the main shock wave from the high energy device has passed.

8. The method of claim **1** wherein the exploding of the plurality of devices further includes exploding such devices before the pressure created in the initial cavity within the oil shale formation becomes as low as the pressure of the overburden over the cavity.

9. The method of claim **1** including the step of extracting shale oil from the zone of relatively high permeability created within the oil shale formation.

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