(12) STANDARD PATENT APPLICATION (11) Application No. **AU 2015205856 A1**
(19) AUSTRALIAN PATENT OFFICE

(54) Title
IMPROVEMENTS TO RECOVERY OF HYDROCARBONS

(51) International Patent Classification(s)
E21B 43/14 (2006.01) ***E21B 43/38*** (2006.01)
E21B 43/30 (2006.01) ***E21F 7/00*** (2006.01)

(21) Application No: **2015205856** (22) Date of Filing: **2015.07.21**

(30) Priority Data

(31) Number	(32) Date	(33) Country
2014902807	**2014.07.21**	**AU**

(43) Publication Date: **2016.02.04**
(43) Publication Journal Date: **2016.02.04**

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Abstract

The invention provides a method for the surface production of gas from a hydrocarbon resource including multiple vertically separated seams, including at least the steps of:

(a) forming a first well bore, extending from the surface to, or below, the level of the lowest targeted seam;

(b) forming a production bore upwards through the lowest seam and to a seam above the lowest seam;

(c) conducting gas and optionally water through said production well bore and said first well bore to the surface.

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IMPROVEMENTS TO RECOVERY OF HYDROCARBONS

Technical Field

[0001] The present invention relates to the drilling and extraction of hydrocarbons, particularly but not exclusively coal seam gas.

Background of the Invention

[0002] Coal Seam Gas (CSG) is an available source of hydrocarbon energy, mainly methane. It is sometimes called coal bed methane or coal-mine methane.

[0003] Coal is a source rock in which hydrocarbon gases have been generated or are capable of being generated. This is unlike conventional gas, which is trapped in sandstone and other rock reservoirs. The coal seam gas exists in the coal matrix, in open fractures or cleats in the coal formation and also dissolved in water within the coal. CSG typically contains few heavier hydrocarbons, such as propane or butane, and will often also contain CO_2 and other gases.

[0004] In a typical CSG extraction process, a hole is drilled through the overlying strata into a coal seam. The hole is usually less than 300 mm diameter, and the coal seams are typically 100 metres to 1,500 metres below ground. The hole is generally cased with steel or other materials. The CSG can flow freely through this hole to the surface under some circumstances and in other circumstances, the water pressure in the coal seam needs to be removed before the gas flows from the seam. Both gas and water come to the surface through drilled holes. Sometimes separate holes are drilled for water extraction. The water and gas are usually, but not always, separated at a separator unit, either on the surface or below the surface. The gas is typically sent to market via compressor stations and gas pipelines. The water is either reinjected into isolated formations, treated and released to local streams, treated and used for irrigation, or sent to evaporation ponds.

[0005] Two broad categories of techniques are used to drain gas from coal seams. That categorization is a function of the permeability of the coal. That is, how easily the gas flows through the coal seams to an extraction well. Typically, coals of high permeability, greater than 10 millidarcy (mD), allow the gas to flow relatively easily to a vertical well. Coals of a permeability less than 2mD generally require a hole to be drilled along the coal seam so that the path travelled by the gas molecules is shortened. Such coals are considered to be lower permeability coals. The technique used for coals with a permeability between 2mD and 10mD may require hybrid solutions depending on the coal.

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[0006] In some existing CSG sites, the drill hole is initially vertical or slanted and then follows the seam laterally. A "vertical" well does not need to be truly vertical. A vertical well is so called because it is drilled with a rig without tilting the rig. The rig stands vertical while the well itself may wander off the vertical. The limits of wander can vary depending on the formation. Slant wells are drilled using rigs that can tilt. They are generally drilled between 45 degrees to the horizontal and 60 degrees to the horizontal depending upon the geometry to be achieved.

[0007] The extraction wells for high permeability coals are generally vertical, or slant wells up to 45 degrees to the vertical. These extraction wells are usually no more than 600 metres apart, with many wells and well sites required. This has a significant impact on the landscape because each well needs infrastructure such as wellhead piping and pumps, a fenced gravel well pad, a gas/water separator, separate gas and water pipelines to take the gas and water to a central field collection point, and all-weather road access.

[0008] Extraction wells for lower permeability coals are generally horizontal wells drilled along the coal seams. One well can be in excess of 2000 metres long. Thus, fewer well sites are required. A problem with such horizontal wells in lower permeability coal formations is that drilling must be perpendicular to the major cleats in the coal structure. Therefore, these wells are best drilled in only one direction. As would be understood by a person skilled in the art, horizontal wells are not often used in high permeability coals because the coals are often unstable and break up easily, due to the typical loose structure of the formation which provides the high permeability.

[0009] Laterals from the main drill hole may be branched horizontally or vertically and the lateral often intercepts or is intercepted by a vertical or slanted hole to facilitate the removal of water. The laterals tend to be drilled against the dominant cleats unless the coal has high permeability. The laterals are usually less than 250 mm diameter.

[0010] At each wellhead location, there are generally wellhead facilities, a pad, a separator, a pump driver, piping and valves, power unit, electrics, fences, and an access road. Where vertical wells are used without horizontal laterals, the well spacing is relatively close such that well sites and access roads are pronounced on the landscape. Vertical or slanted wells from which horizontal laterals follow the seams are usually more widely spaced apart such that there are fewer well head locations and there is consequently less impact on the landscape.

[0011] Vertical wells have an advantage over horizontal laterals in that the vertical wells can intersect and produce CSG from many vertically separated coal seams at one time

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or in a staged sequence. Horizontal laterals tend to be limited to individual seams. In a conventional coal seam gas extraction process, gas flows both upwards and downwards between the individual seams. Liquid water only flows downward due to gravity. When a vertical or slanted well is drilled down from the surface into vertically separated coal seams, a pump is required at each well to extract the water to allow the gas to flow to the surface. This can add significantly to the cost and energy requirement of the gas extraction operation.

[0012] Similar issues arise in other hydrocarbon drilling and extraction operations in which the resource in present in multiple separated layers.

[0013] It is an object of the present invention to provide an improved method and system for extracting hydrocarbons from multi-layered structures.

Summary of the Invention

[0014] In a first broad form, the present invention provides an arrangement in which vertically separated coal seams are intersected by slanted branches from one or more laterals. The slanted branches are drilled upwards or downwards from the main lateral or laterals. The main laterals can be drilled in coal seams or in more stable formations above or below the coal seams. This way, multiple wells can be drilled from one well pad in multiple directions as the intersection of the coal seams does not need to be against the dominant cleat. The slanted branches or branch can be branched off the main horizontal lateral in a variety of configurations.

[0015] According to one aspect of the invention, there is provided a method for the surface production of gas from a resource including multiple vertically separated coal seams, including at least the steps of:

(a) forming a first well bore, extending from the surface to, or below, the level of the lowest targeted coal seam;

(b) forming a production bore upwards through the lowest coal seam and to a coal seam above the lowest coal seam;

(c) conducting gas and optionally water through said production well bore and said first well bore to the surface.

[0016] The first well bore is typically connected to one or more production bores, each extending upwards through the lowest coal seam and through several coal seams above the lowest coal seam, so that gas and optionally water from the various production bores are conducted back through said first well bore.

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[0017] The production bores are preferably slanted to extend upwards in varying directions through the lowest coal seam and/or one or more coal seams above the lowest coal seam.

[0018] Additional laterals may be formed in different directions, each with one or more associated production bores, all of said production bores being connected to a single set of surface infrastructure.

[0019] Production bores are advantageously positioned and formed so as to allow the extraction from many positions within a CSG resource at a single set of surface infrastructure. More than 10, preferably more than 30, production bores are formed within the resource. In a particularly preferred form of the invention, production bores are formed into multiple coal seams from one well pad and one main well bore.

[0020] In preferred implementations of the invention, a single pump is required remove water from multiple production bores. The single pump is located at or near the lowest point in a network of connected bores. The pump removes the water from the coal such that the gas is allowed to flow from the coal.

[0021] According to another aspect of the invention, there is provided a method for the surface production of gas from a resource including multiple coal seams, each coal seam being highly permeable, including at least the steps of:

(a) forming a first vertical well bore having one well pad, extending from the surface to, or below, the level of the lowest targeted coal seam;

(b) forming one or more slanted production bores upwards through the lowest coal seam and to a coal seam above the lowest coal seam;

(c) wherein the first well bore is connected to one or more production bores, each extending upwards in varying directions through the lowest coal seam and/or to one or more coal seams above the lowest coal seam, so that gas and optionally water from all the production bores are conducted through said first well bore.

[0022] More than 10 production bores may be formed within the resource, while preferably more than 30 production bores are formed within the resource.

[0023] In preferred implementations of the invention, a single pump is required to remove water from multiple production bores, using a pump located at or near the lowest point in a network of connected bores.

[0024] According to a further aspect of the invention, the present invention relates to gas produced from a coal seam according to the method of the first or second aspect.

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[0025] In suitable implementations, this arrangement avoids the need for many individual vertical well bores at the surface, instead using well bores through the coal seams which extend up from the main lateral well bore at positions which allow effective penetration of and extraction from the resource. Further, in preferred implementations the infrastructure can be concentrated at one site, and drilling operations largely conducted from a single site or a number of single sites. Thus, implementations of the present invention allow for more efficient ongoing operations, maintenance, gas pipeline connections and site access can be achieved with considerably less impact on the landscape. The arrangement particularly suits coal seams of higher permeability, unstable coals seams as defined herein, or multiple coal seams unsuitable for horizontal drilling for structural or economic reasons. The method of the invention delivers multiple slant wells angled in varying directions into coals thereby avoiding the large number of well pads required by conventional techniques for higher permeability coal formations.

[0026] According to yet another aspect of the invention, there is provided a method for the surface production of gas from a hydrocarbon resource including multiple vertically separated seams, including at least the steps of:

(a) forming a first well bore, extending from the surface to, or below, the level of the lowest targeted seam;

(b) forming a production bore upwards through the lowest seam and to a seam above the lowest seam;

(c) conducting gas and optionally water through said production well bore and said first well bore to the surface.

[0027] The first well bore is connected to one or more production bores, each extending upwards through the lowest seam and through several seams above the lowest seam, so that gas and optionally water from the various production bores are conducted back through said first well bore.

[0028] Ina preferred implementation of the invention, the production bores are slanted to extend upwards in varying directions through the lowest seam and/or one or more seams above the lowest seam.

[0029] Additional laterals are formed in different directions, each with one or more associated production bores, all of said production bores being connected to a single set of surface infrastructure.

[0030] Production bores are advantageously positioned and formed so as to allow the extraction from many positions within a resource at a single set of surface infrastructure.

[0031] More than 10 production bores, preferably more than 30 production bores, are formed within the resource.

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[0032] In a particularly preferred implementation of the invention, the production bores are formed into multiple seams from one well pad and one main well bore.

[0033] A single pump is required remove water from multiple production bores, wherein the single pump is located at or near the lowest point in a network of connected bores.

[0034] According to another aspect of the invention, there is provided hydrocarbon gas produced from a seam according to the previous aspect.

Brief Description of the Drawings

[0035] An embodiment of the present invention will be described in connection with the accompanying figures, in which:

[0036] Figure 1 shows schematically in elevation a series of drilled bores according to the present invention; and

[0037] Figure 2 shows in plan a series of drilled bores over a resource of interest.

Detailed Description of the invention

[0038] Preferred implementations of the present invention will now be described. It will be appreciated that these are intended as illustrative and not limitative of the invention. While the examples below are in the context of CSG, it will be appreciated that with suitable modification, the methods and systems described may be applied to other hydrocarbon resources, for example multi-seam oil structures and shales.

[0039] The invention may be implemented with conventional drilling techniques, as are currently used for CSG and similar projects. As such, only a limited description will be provided. It will be appreciated that any suitable drilling equipment and approach may be used. Similarly, the well head equipment, separator, compressor, etc. may be of any conventional type or included new types.

[0040] The drilling is performed using readily available drilling rigs and tooling but may also encompass innovations to existing systems. The drilling will use a down hole motor or steered jetting tool. The position of the drilling head will be surveyed using readily available down hole survey tools and instruments but may also encompass new innovations. No rig, drilling equipment, tooling or instrument innovations are needed to apply the system.

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[0041] The skilled worker can implement the invention using equipment and drilling techniques commonly used in the drilling of surface to in-seam wells. Gas is drained from coal seams by drilling along the coal seams. By way of example, the equipment may be a Prime Drilling PD 150/70-C-RP rack drive drilling rig of 150 tonnes push-pull and 70,000 N-m torque with a Gardiner Denver PZ8 mud pump; 4½ inch diameter drill pipe, 4¾ inch diameter P100 Flexdrill down hole motor with monels; a 6 inch diameter roller cone drill bit; Arc-Gyde 141P-10WG Sonde with Gamma Detection 1.75 inch Cableless EM Telemetry Directional Steering Tool with Gamma Detection. Of course, it will be understood that any suitable alternative arrangement could be used, and this is described by way of example only.

[0042] Standard wellhead equipment, the facilities, the pads, fencing, and pumps can be used. Alternatively, new and innovative designs and systems can be incorporated, Referring to Figure 1, the drilling rig 16 is located on the surface 15 of the ground, under which the resource of interest lies. In this instance, there are three coal seams, 21, 22, 23, but this is purely an example -there could be more or less, angled in varying directions as will be understood by those skilled in the art.

[0043] From the rig, a directional bore 10 is drilled. This is typically 4 inches to 12 inches in diameter, and extends in the direction of the desired location in the resource. The position of the coal seams is generally mapped (as is conventional) by exploration wells, seismic investigations, or other geophysical investigations before production drilling starts. The coal is much softer than the surrounding rock and the drill operator will be aware of when the bit has intersected the seam. Further, a gamma ray measurement tool near the bit will identify when the tool is in coal.

[0044] As will be explained in more detail below, it is envisaged that multiple bores will extend to different locations in the resource from a single surface location. There are a number of alternatives for where along the lateral the branches commence, and multiple laterals are possible with individual or multiple branches. Of course, those skilled in the art will appreciate that the precise details of how any resource is exploited will vary with the nature, location, geometry and geology of that particular resource, and so the following is intended to be illustrative and by way of example only.

[0045] As is conventional, the bore through the overburden is cased and the casing is sealed to the surrounding formation by grout to maintain the integrity of the well. Various casing configurations may or may not be used for the lateral depending on the formation.

[0046] The drilled bore 10 extends below the coal seams 30, 31, 32. Alternatively, the drilled bore may be in a stable coal seam. The drill is then directed upwards to produce production bore 21. Additional production bores 22, 23, are separately drilled. It was found that drilling upwards from underneath the coal seams to create the production bores was

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a surprisingly effective way of creating access to coal seam formations, particularly in unstable coal seams. These are also significant advantages in creating even further production bores angled in varying directions from the first drilled bore and production bores.

[0047] The trajectory and termination of the boreholes will depend on the formation.

[0048] The down hole pump can be installed in a separate vertical borehole which intersects one or more of the laterals. Alternatively, the down hole pump can be placed in the drilled borehole or boreholes. A particular advantage of the method of the invention is that a single pump can service the gas and water removal from multiple production bores, resulting in a method with improved energy efficiency compared to a conventional CSG extraction process. That is, gas flows up and down between vertically separated coal seams while liquid water generally only flows downwards. Drilling a first bore from above come down, a pump is required in every production bore to extract water, thereby allowing the gas to flow from the coal. By drilling upwards from the first bore to create production bores, a single pump (for example, placed in a suitable sump) is required to extract water from multiple production bores. The method of the invention utilises the forces of gravity to minimise energy consumption as well as greatly reducing the impact on the landscape to extract the equivalent amount of coal seam gas.

[0049] A particular advantage of this approach is that it avoids the need to a large number of vertical wells, each with their associated wellhead equipment, gas pipeline connection, road, pad, separator and other facilities. Many bores can be drilled from the one location, and many coal seams intersected and their production concentrated at a single surface location. The invention also enables the advantages of long horizontal holes to be used for higher permeability coals and eliminates the need for drilling perpendicular to the cleats.

[0050] In practical terms, this limits the surface requirements and hence need for access to land owner's properties. It also allow for single location monitoring for a relatively large number of production bores, with attendant maintenance, staff and monitoring advantages. The reduced impact on the landscape is further complimented by the improved energy efficiency of the method of the invention in comparison with the prior art methods. That is, fewer pumps being required to extract water from the same number of coal seams

[0051] It will be appreciated that the directionally drilled bores may also branch horizontally, to cover the area of interest. This can be seen from figure 2. Dots 32 mark the location of wells that would be required in a conventional extraction system for the resource in question. In this example, there are 49, spread over an area of about 20 square km. According to the present invention, a single surface location 30 services bores

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31 drilled in all directions, and providing access to the same coal seam locations as the conventional system. However, there is only one surface facility, not 49.

[0052] The approach also has applications in production of other hydrocarbons such as from multi-seam oil structures and shales. The distance drilled is limited only by the torque and drag on the drill pipes and hydraulics of cuttings removal.

It will be appreciated by those skilled in the art that the above described embodiment is merely one example of how the inventive concept can be implemented. It will be understood that other embodiments may be conceived that, while differing in their detail, nevertheless fall within the same inventive concept and represent the same invention.

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Claims

1. A method for the surface production of gas from a resource including multiple vertically separated coal seams, including at least the steps of:
(a) forming a first well bore, extending from the surface to, or below, the level of the lowest targeted coal seam;
(b) forming a production bore upwards through the lowest coal seam and to a coal seam above the lowest coal seam;
(c) conducting gas and optionally water through said production well bore and said first well bore to the surface.

2. A method according to claim 1 wherein first well bore is connected to one or more production bores, each extending upwards through the lowest coal seam and through several coal seams above the lowest coal seam, so that gas and optionally water from the various production bores are conducted back through said first well bore.

3. A method according to claim 1 or claim 2 wherein the production bores are slanted to extend upwards in varying directions through the lowest coal seam and/or one or more coal seams above the lowest coal seam.

4. A method according to claim 3 wherein additional laterals are formed in different directions, each with one or more associated production bores, all of said production bores being connected to a single set of surface infrastructure.

5. A method according to any one of the preceding claims wherein production bores are positioned and formed so as to allow the extraction from many positions within a CSG resource at a single set of surface infrastructure.

6. A method according to claim 5 wherein more than 10 production bores are formed within the resource.

7. A method according to claim 6 wherein more than 30 production bores are formed within the resource.

8. A method according to any one of the preceding claims wherein production bores are formed into multiple coal seams from one well pad and one main well bore.

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9. A method according to any one of the preceding claims wherein a single pump is required remove water from multiple production bores.

10. A method according to claim 9 wherein the single pump is located at or near the lowest point in a network of connected bores.

11. A method for the surface production of gas from a resource including multiple coal seams, each coal seam being highly permeable, including at least the steps of:
(a) forming a first vertical well bore having one well pad, extending from the surface to, or below, the level of the lowest targeted coal seam;
(b) forming one or more slanted production bores upwards through the lowest coal seam and to a coal seam above the lowest coal seam;
(c) wherein the first well bore is connected to one or more production bores, each extending upwards in varying directions through the lowest coal seam and/or to one or more coal seams above the lowest coal seam, so that gas and optionally water from all the production bores are conducted through said first well bore.

12. A method according to claim 11 wherein more than 10 production bores are formed within the resource.

13. A method according to claim 12 wherein more than 30 production bores are formed within the resource.

14. A method according to any one of claims 11 to 13 wherein a single pump is required to remove water from multiple production bores, using a pump located at or near the lowest point in a network of connected bores.

15. Gas produced from a coal seam according to the method of any one of the preceding claims.

16. A method for the surface production of gas from a hydrocarbon resource including multiple vertically separated seams, including at least the steps of:
(a) forming a first well bore, extending from the surface to, or below, the level of the lowest targeted seam;
(b) forming a production bore upwards through the lowest seam and to a seam above the lowest seam;
(c) conducting gas and optionally water through said production well bore and said first well bore to the surface.

17. A method according to claim 16 wherein first well bore is connected to one or more production bores, each extending upwards through the lowest seam and through

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several seams above the lowest seam, so that gas and optionally water from the various production bores are conducted back through said first well bore.

18. A method according to claim 16 or claim 17 wherein the production bores are slanted to extend upwards in varying directions through the lowest seam and/or one or more seams above the lowest seam.

19. A method according to claim 18 wherein additional laterals are formed in different directions, each with one or more associated production bores, all of said production bores being connected to a single set of surface infrastructure.

20. A method according to any one of claims 16 to 19 wherein production bores are positioned and formed so as to allow the extraction from many positions within a resource at a single set of surface infrastructure.

21. A method according to claim 20 wherein more than 10 production bores are formed within the resource.

22. A method according to claim 21 wherein more than 30 production bores are formed within the resource.

23. A method according to any one of claims 16 to 22 wherein production bores are formed into multiple seams from one well pad and one main well bore.

24. A method according to any one of claims 16 to 23 wherein a single pump is required remove water from multiple production bores.

25. A method according to claim 24 wherein the single pump is located at or near the lowest point in a network of connected bores.

26. Hydrocarbon gas produced from a seam according to any one of claims 16 to 25.

Figure 1

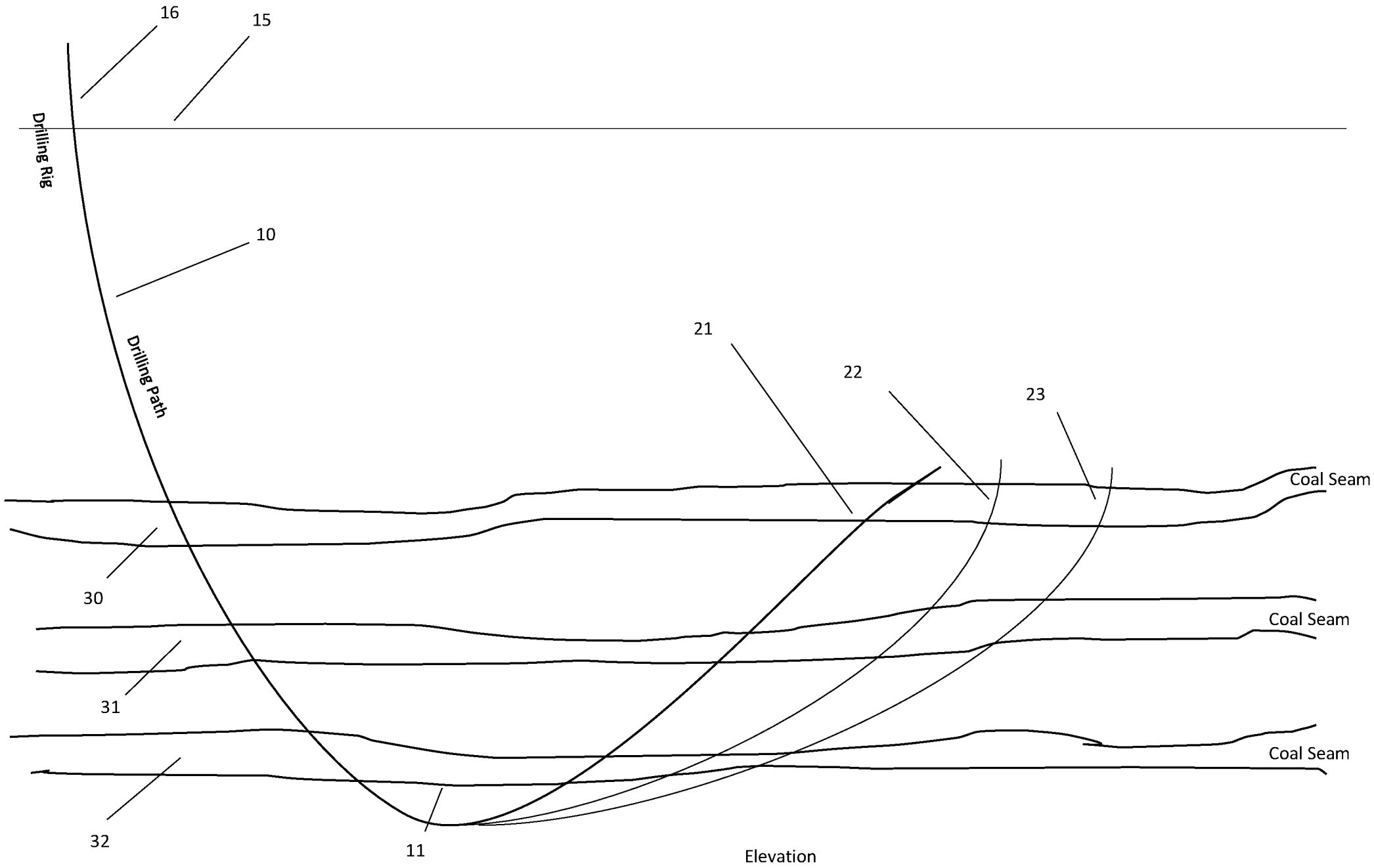
16
15
Drilling Rig
10
Drilling Path
21
22
23
Coal Seam
30
Coal Seam
31
Coal Seam
32
11
Elevation

Figure 2