HORIZONTAL BOREHOLE MINING SYSTEM AND METHOD

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Abstract
A method and system are provided for horizontal borehole mining a seam of material, in which a substantially horizontal borehole is provided through a seam of material, a retractable casing is disposed within the seam, and a high pressure drilling tool is disposed within said casing for excavation of the seam material to form an excavation cavity, the high pressure drilling tool having a high pressure jet, the direction of the high pressure jet being adjustable during the mining operation. As mining progresses the casing and high pressure drilling tool are retracted, so that the excavation cavity is extended along the length of the borehole back toward the origin of the borehole. The high pressure drilling tool can be either hydraulic or pneumatic.
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CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Patent Application Ser. No. 61/552,102 filed Oct. 27, 2011, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

This invention relates to a method and system for mining an underground material using a substantially horizontal borehole and high pressure fluidic means for drilling and excavating said material for conveyance through said borehole.

The recovery of material located in underground geological strata or seams has been the subject of extensive technological development. Where the desired material is located relatively close to the surface of the earth, it is possible to recover the material by open pit mining, in which large areas of land are cleared of the surface overburden to allow access to the desired material by heavy-duty surface mining equipment. Depending on the location of the site to be excavated, this overburden can include roots, stumps and thicknesses of clays, sands, muds, and other materials. Depending on the depth of the desired material, additional earth may have to be removed to a depth of 100 feet or more. The removal of this overburden and additional earth can be time-consuming and expensive. The displacement of the overburden and additional earth can create water flow and drainage issues. Replacement of the removed earth and restoration of the overburden to its pre-mined state also can be expensive and time-consuming. It thus would be desirable to provide a means for recovering desired materials located underground by a means that does not create extensive disturbance of the surface.

Methods for excavating underground materials without strip mining include techniques in which vertical or oblique boreholes are provided to a desired depth, and regions are excavated hydraulically. Typically, such systems involve a drill rig that operates a vertically directed drilling head having a drill bit on the far end, and a nozzle several feet back from the drill bit that emits a jet of high pressure water at a right angle to the direction of the drilling head. Thus when the drilling head bores vertically downward to a desired depth, the nozzle excavates a substantially horizontal cavity. Vertical borehole mining also has been suggested for solution mining, and for recovery of hydrocarbons.

Such vertical borehole methods may yield only limited quantities of desired material, because the radius of the substantially horizontal excavated cavity is limited by the reach of the high pressure water jet flowing from the nozzle. In addition, the creation of an excavation cavity directly beneath a drill rig can create instability in the overburden at the surface, posing a possible danger to the crew and the drill rig.

Excavation methods involving horizontal borehole drilling also have been disclosed in the art. For example, U.S. Pat. No. 5,879,057 discloses a system for mining a relatively narrow seam of coal, wherein a water jet cutting head at the end of a drill string is used to drill an excavation cavity substantially horizontally through the coal seam. U.S. Pat. No. 6,088,702 discloses a borehole mining method in which a borehole is driven first vertically downward and then into a production zone at a low-degree angle $\alpha$, and a hydromonitores directs a water-jet at an angle $\beta$ to the horizontal plane to create a cavity, with the mining continuing as the hydromonitores progresses through the production zone. During the mining operation the hydromonitor is inserted or removed from the borehole without rotation.

The present invention provides a system and method for efficiently mining materials from a remote underground site, without excessive disturbance of the surface, and which system is adaptable for use with a wide variety of underground materials.

SUMMARY OF THE INVENTION

In accordance with the invention, a method and system are provided for excavating a quantity of material from a seam of material to be mined, wherein a substantially horizontal borehole is drilled into the seam of material, a retractable casing is disposed along the borehole, and a high pressure fluidic drilling tool extends through and can protrude through the end of the casing, the drilling tool comprising one or more nozzles for emitting a high pressure fluidic jet, the drilling tool being operable to adjust the direction of the high pressure fluidic jet, the high pressure fluidic jet cutting into the material to be excavated, causing the material to be disaggregated from the seam. The volume of the excavation cavity created by the disaggregation is determined in part by the pressure of the high pressure fluidic jet and the adjustments made to the direction of the high pressure fluidic jet. The high pressure fluidic jet can be either pneumatic (air) or hydraulic (water). The disaggregated material combines with water which can be either water from the hydraulic drilling tool, naturally occurring groundwater, water pumped from an external source, or any combination thereof, to form a slurry which is directed back through the casing toward the surface. The return of the slurry to the surface can be actuated by a pumping means such as an eductor, or it can be directed pneumatically. As mining proceeds the drilling tool, pumping or pneumatic return means, and casing are retracted back through the borehole. The system of the invention comprises a drill rig disposed at the wellhead and remote from the material to be excavated, the drill rig operating a borehole drilling tool for boring a substantially horizontal borehole through the seam of material. The system further comprises a retractable casing adapted to be disposed within and extending the length of the borehole, a high pressure fluidic drilling tool comprising one or more high pressure fluid jetting nozzles adapted to be movably disposed within the casing,
and a pumping or pneumatic slurry return means, the system being operable to adjust the direction of the high pressure fluidic jet.

[0012] In accordance with the method of the invention, a substantially horizontal borehole is bored into the seam of material to be mined, and the retractable casing is disposed along the length of the borehole. The high pressure fluidic drilling tool is extended to the far end of the casing, and is used to direct high pressure fluidic jets against the material of the seam to disaggregate the material, which falls to the bottom of the cavity and forms a slurry. The direction of the high pressure fluidic jets is adjusted from one orientation to another over the course of the mining operation so that the jets contact different regions of the seam of material to be mined. The pumping or pneumatic return means directs the slurry back toward the drill rig where it can be collected so that the desired seam material can be recovered. In one embodiment of the invention, a single retractable casing houses both a conveyance means for conveying the high pressure fluid to the drilling tool and a conveyance means for conveying the slurry back toward the well head. In an alternative embodiment of the invention, the borehole can accommodate two parallel casings, one of which accommodates the high pressure drilling tool and conveyance means for the high pressure fluid and the other of which accommodates the pumping or pneumatic return means and the return flow of slurry.

[0013] The drilling tool comprises one or more nozzles which emit high pressure jets that cut into the seam of material to create an excavation cavity. Advantageously, the direction of the high pressure jets are adjustable to impact the walls of the excavation cavity at different orientations, to create an excavation cavity of substantially greater volume than the borehole, the directions and movement of the high pressure jets being selected by the mine operator depending on the shape and characteristics of the seam of material to be mined. The excavation can continue either until walls of the cavity extend beyond the reach of the high pressure jets, or until the excavation cavity extends beyond the desired seam of material, or until the cavity collapses due to subsidence of the cavity walls. The casing, high pressure drilling tool, and pumping or pneumatic return means are then retracted to a portion of the borehole that has not yet been excavated, and the mining operation continues. If desired, the sequence of retracting the system and mining and extraction can continue until the casing, drilling tool, and pumping or pneumatic return means have been retracted to the site of the drill rig. Thus, when excavation of a seam is complete, no part of the drilling system remains underground.

DETAILED DESCRIPTION OF THE INVENTION

[0020] FIGS. 4A-4H schematically illustrate progressive stages in the excavation of a cavity within a seam of material being mined in accordance with the present invention.

[0021] FIG. 5 illustrates an embodiment in which a plurality of boreholes is disposed within a seam of material.

[0022] FIG. 6A illustrates an embodiment of the invention in which a single borehole houses both the hydraulic drilling tool and the return flow of the slurry.

[0023] FIG. 6B illustrates an embodiment of the invention in which two substantially parallel boreholes are provided, one for housing the hydraulic drilling tool, and the other for providing the return path for the slurry.

[0024] FIG. 7 illustrates an embodiment of the invention in which the drilling tool is pneumatic and high pressure air is also used to drive the slurry back toward the surface.

[0025] FIG. 7A is a cross-sectional view of an optional annular manifold disposed within about the inner circumference of the slurry return channel.

DESCRIPTION OF THE FIGURES

[0014] The present invention will be more readily understood with reference to the Figures herein, which are for purposes of illustration of the concepts disclosed herein and are not necessarily drawn to scale, in which:

[0015] FIG. 1 is a schematic illustration of the general location of the drill rig and the placement of the casing relative to a seam of material to be mined.

[0016] FIG. 2 illustrates a first embodiment of a hydraulic drilling tool and pump system for use in the present invention.

[0017] FIG. 3 is an enlarged view of an alternative embodiment of a hydraulic drilling tool for use with the present invention.

[0018] FIG. 3A is a view along line A-A of FIG. 3.

[0019] FIG. 3B is a view along line B-B of FIG. 3.

[0026] The present invention relates to a method and system for mining a material disposed in a location that may be difficult to access from the earth's surface. The material to be mined is capable of being disaggregated by high pressure fluid to form a slurry. Materials suitable for mining by this method include, for example, phosphate ores, potash ores, sulfur, trona, heavy mineral sands, soft coal-bearing deposits, and other sub-surface materials subject to disaggregation by the application of hydraulic pressure, as will be recognized by those skilled in the art. The following detailed description of the invention will be discussed in terms of excavation of a mineral ore, such as a phosphate ore. It will be understood, however, that this description is for purposes of illustration only, and that the materials that can be excavated by the method and system of the present invention are not so limited.

[0027] In accordance with the invention, the high pressure fluid used to disaggregate the underground material can be either hydraulic (liquid such as water), or pneumatic (air), or a combination of hydraulic and pneumatic. In addition the means for returning the slurry to the surface can be either a pump means, or a pneumatic means, or both.

[0028] The invention will be described first with respect to the embodiment in which the drilling means is hydraulic with the high pressure fluid being high pressure water, and the return means comprises a pumping means such as an eductor. Then other embodiments will be described in which pneumatic means are used in the drilling tool, the return means, or both.

[0029] FIG. 1 schematically illustrates the general layout of one embodiment of the system of the invention relative to the seam of material to be recovered. In the illustrated embodiment, a drill rig 15 is engaged on the earth's surface 10 above the layer of overburden 12. The drill rig is of the type well-known in the mining industry. Drill rig 15 includes a borehole drilling tool of the type well-known in the art for drilling a borehole 20 that initially slopes downward through the overburden 12 until it reaches seam 22 of phosphate ore to be mined, then levels out to be substantially horizontal through seam 22. In the illustrated embodiment, the seam 22 of phosphate ore is disposed between a caprock floor 24 and a roof 26, such as limestone. It will be understood by those skilled in the art that the composition of the roof and the floor of the seam of material to be recovered will vary depending on the particular geological features of the mining site of interest.
Those skilled in the art also will recognize that FIG. 1 is not drawn to scale, in that the seam 22 of ore to be mined may be below many geologic layers beneath overburden 12, the other geologic layers being omitted here for clarity, and the borehole 20 may be much narrower relative to the depth of the seam to be mined than illustrated here. In some areas, the ore seam 22 may begin 90 feet or more below the earth’s surface to a depth of up to about 130 feet. Thus the seam to be excavated can be 40 feet thick or more. As illustrated in FIG. 1, the borehole 20 is preferably disposed just above the floor 24 at the base of the seam 22. The borehole 20 can extend from the drill rig 15 for a distance as great as 6000 feet or more.

[0030] As is known in the art, means for boring a substantially horizontal borehole can include a guided borehole drilling tool, not shown. The guided borehole drilling tool can be controlled from the drill rig 15 to drill borehole 20 to a desired level with respect to seam 22. The drilling tool may comprise one or more rotating drill bits remotely operated from the drill rig 15. Those skilled in the art will understand how to select an appropriate drilling tool depending on the characteristics of the material being mined and the surrounding geological deposits. Following drilling of the borehole, the borehole may be provided with a retractable casing 30, not shown to scale.

[0031] FIG. 2 illustrates a first embodiment of the present invention. Retractable casing 30 is installed along the length of the borehole. Such retractable casings are known in the drilling art, as are means for their installation and retraction. The retractable casing 30 can be made of steel, ferrous or non-ferrous alloys, fiberglass, or plastics such as high density polyethylene. The retractable casing 30 can comprise, for example, cylindrical segments that are installed in borehole 20 as the hole is drilled, and linked together as each next section is installed to form an integral casing that runs the length of the borehole 20. The individual casing segment can be about 5-64 feet in length, and can be joined by known means such as welding, fusing, internal threads or threading and coupling. The joined segments are installed by pushing or pulling, as is known for rotary mud drilling installations. The casing can be retracted by standard rotary drilling and/or vibratory removal. During retraction, the segments can be separated by means selected according to the means by which they were joined during installation.

[0032] Casings can range in diameter from about 20 inches to about 72 inches, with wall thickness varying from about 1/8 to 2 inches, the particular casing dimensions depending on the dimensions of the ore seam 22 to be excavated and the nature of the material being collected. In one embodiment, retractable casing 30 will have an inner diameter large enough to accommodate a pumping means, and a return flow of slurry, as described in greater detail below.

[0033] FIG. 2 illustrates one embodiment of a casing and hydraulic tool system of the present invention, in which casing 30 is disposed within and extends substantially to the end of borehole 20. The outer circumference of casing 30 may be provided with one or more reamers 32 which assist in reaming out borehole 20. Extending through casing 30 and terminating near the end thereof is a hydraulic drilling tool 40. In one embodiment, hydraulic drilling tool 40 also comprises a channel means 45 disposed within casing 30. Channel means 45 defines an inner channel 48. The volume between the outer surface of channel means 45 and the inner surface of casing 30 defines an outer channel 46. At the end of channel means 45 is disposed pump means 35, which can be an eductor 37 with an electric pump and motor 39, as are known in the mining art for removing slurried material from a hydraulically aggregated subsurface ore matrix. In other embodiments the pump means 35 can be separate from hydraulic drilling tool 40. The intake of eductor 37 can be provided with a screen, not shown, for preventing the entry of undesirably large chunks of disaggregated material into the eductor 37.

[0034] Hydraulic drilling tool 40 is provided with one or more water jetting nozzles 42 each of which emits a high pressure water jet 44. In the illustrated embodiment the water jetting nozzles are positioned in the wall of casing 30, near the distal end thereof. High pressure water is delivered from drill rig 15 through outer channel 46 to nozzles 42 to provide the high pressure water jets 44 that impinge on the seam of ore 22 to disaggregate the material. Hydraulic drilling tool 40 is operable such that the direction of the high pressure water jet 44 is adjustable during the mining operation. In the illustrated embodiment, casing 30 or the distal portion thereof comprising nozzles 42 can be rotated to adjust the direction of the high pressure water jets 44. The intake of pump means 35 preferably is located rearward of rotate water jetting nozzles 42 of hydraulic drilling tool 40.

[0035] In the illustrated embodiment in FIG. 2 the nozzles 42 direct water jets 44 at an obtuse angle relative to the axis of borehole 20. Further, while only one nozzle 42 is shown for clarity in the embodiment of FIG. 2, hydraulic drilling tool 40 can include a plurality of nozzles 42 as may be desired for a particular installation. As water jet 44 impacts the material of seam 22, the material will become disaggregated, and will mix with the water to form slurry 28. The slurry 28 is then pumped by pump means 35 through inner channel 48 of casing 30 back toward drill rig 15, from which it can be delivered to a recovery means, not shown, for recovering the desired material from the slurry.

[0036] FIGS. 3, 3A and 3B illustrate an alternative embodiment of a hydraulic cutting tool in accordance with the present invention. In this embodiment, a hydraulic cutting tool 140 comprises an outer tubular member 145 and an inner tubular member 147, indicated by dotted lines in FIG. 3. The interior of inner tubular member 147 defines an inner channel 148. The space between the outer surface of inner tubular member 147 and the inner surface of outer tubular member 145 defines outer channel 146. The distal end of hydraulic tool 140 is provided with a plurality of nozzles in fluid communication with outer channel 146, and a pump means such as eductor 137 in fluid communication with inner channel 148. High pressure water is delivered from drill rig 15 through outer channel 146 to nozzles 142 to provide the high pressure water jets 144 that impinge on the seam of ore 22 to disaggregate the material. The nozzles are remotely operable to direct water jets 144 over a range of angles, the angles being illustrated in FIGS. 3, 3A, and 3B by short dotted lines emanating from the nozzles 142, which for the sake of clarity extend far less than the actual water jets 144. In addition, in a preferred embodiment the hydraulic cutting tool 140, or the distal portion thereof, can be rotated within casing 30 to further direct the high pressure water jets 144 at different angles against the walls of the seam of ore 22. As explained in greater detail below, the water from the water jets and the disaggregated material forms a slurry which is returned by eductor 137 through inner channel 148 back to drill rig 15, not shown.

[0037] FIGS. 4A-I schematically illustrate the horizontal borehole mining method of the present invention. In this set of
Figures the relative depth of the different geological layers is not shown to scale, and additional layers of overburden are omitted for the sake of clarity. In this set of Figures, the hydraulic mining tool 40 is represented schematically, and can be the embodiment of FIG. 2, or the embodiment of FIG. 3, or a different embodiment within the scope of the present invention. FIG. 4A illustrates the initial step of the mining method, wherein a borehole 20 has been drilled at the base of the seam 22 of material to be mined, the seam being defined by floor 24 and roof 26. In accordance with the invention, retractable casing 30 has been installed in the borehole, and the hydraulic drilling tool 40 has been installed within the casing. As shown in FIG. 4A, casing 30 is disposed in borehole 20 with the end of casing 30 substantially at the end of borehole 20. Borehole 20 is at or about floor 24 of seam 22 of the material to be excavated. FIG. 4B shows the beginning of the hydraulic mining operation, wherein nozzles 42 of hydraulic drilling tool 40 send one or more jets 44 of high pressure water upwards into the seam 22 of material, creating an excavation cavity 50 defined by walls 52. As illustrated in FIG. 4C, the impact of the high pressure jet 44 on cavity walls 52 causes the seam material to disaggregate and fall to the cavity floor, where it mixes with the water to form a slurry 28. Pump means (not shown) returns the slurry 28 back through inner channel 48 of casing 30. In FIG. 4D, the casing 30 and hydraulic cutting tool 40 have been retracted a relatively short distance from the end of borehole 20. Hydraulic mining of the ore seam 22 continues, with excavation cavity 50 becoming larger as the cavity walls 52 extend further from water jetting nozzle 42 as more of the seam is disaggregated and removed as slurry. It will be appreciated that in FIGS. 4B and 4D the orientations of the high pressure water jets can be rotated, either by rotating the casing 30 in the embodiment of FIG. 2 or by rotation of the nozzles or rotation of the drilling tool or the distal end thereof, in the embodiment of FIG. 3. FIG. 4E illustrates the volume of excavation cavity 50 becoming larger as more of the seam of ore is disaggregated to form the slurry that is returned to the drill rig through the casing. In FIGS. 4F and 4G the casing 30 and hydraulic drilling tool 40 are retracted still further in borehole 20, while hydraulic mining continues and the excavation cavity 50 now extends upward substantially close to limestone roof 26, such that the full depth of the ore seam 22 is excavated, converted into slurry 28, and returned to the drill rig 15 for recovery of the desired ore material.

It will be appreciated that as casing 30 is retracted the length of the extraction cavity 50 will increase, and the volume of slurry 28 in the cavity will increase correspondingly. In some uses of the present invention, the excavated cavity will be subject to subsidence by the effect of gravity. That is, the ceiling and surrounding walls of the cavity will naturally collapse by virtue of the absence of the material of seam 22. This subsidence is a helpful aspect of the mining process, because it limits the longitudinal dimension of the cavity, which allows the depth of the slurry to be maintained at a level that permits removal by the pump means. In installations in which subsidence does not occur spontaneously, then in order to limit the volume of slurry 28 that will be pumped through pump means 35, and in order to maintain the slurry at a sufficient concentration of ore to allow for acceptable operating efficiencies, it may become necessary over the course of the mining operation to effectively limit the length of the excavation cavity in which mining occurs and therefore the volume of slurry 28 that will be pumped by controlling the mining operation to induce subsidence of the cavity ceiling and walls as illustrated in FIG. 4H. The subsided material creates a barrier 60 that substantially spans the width of cavity 50 and extends suitably longitudinally and vertically to prevent the water emitted from nozzles 42 and the slurry 28 resulting therefrom from traveling the full longitudinal distance of cavity 50. In one embodiment barrier 60 can be created by subsidence of the upper wall 52 of cavity 50, so that the disaggregated material will remain in place and collect to a depth sufficient to serve a barrier function. In another embodiment of the invention, barrier 60 can be created by back-filling cavity 50, such as by reverse (outward) flow of a backfill material through inner channel 48 of casing 30 to deposit the material at a desired location in the excavation cavity. Such backfill material may include, for example, recycled ore materials after the desired minerals have been recovered from slurry 28. As mining continues and casing 30 is further retracted, additional barriers 60 can be created as needed or desired either by depositing backfill within cavity 52, or addition subsidence may be induced, in order to maintain operating efficiency of the mining method and system of the invention. The use of devices such as sonic probes to monitor underground subsidence is known in the art.

The method wherein subsidence of the cavity walls is used to create barriers finds particular utility in mining environments in which the seam 22 of material to be mined is readily disaggregated, such as materials having a substantial clay component, and in which the geological layer overlaying seam 22 contains a substantial sand component.

In one embodiment of the invention, the water recovered from the slurry at the drill rig 15 can be recycled as a source of water for hydraulic drilling tool 40.

In another embodiment of the invention, naturally occurring groundwater may be present, and may become part of the slurry that is returned to the drill rig for the recovery of the excavated material.

In another embodiment of the invention, additional water may be pumped into cavity 52 to become part of the slurry that is returned to the drill rig.

In another embodiment of the invention, the water that forms the slurry can be any combination of one or more of drilling water, groundwater, and water pumped into the cavity.

Referring once again to FIGS. 3, 3A, and 3B, the hydraulic drilling tool 140 can include a single water jetting nozzle 142 or a plurality of water jetting nozzles 412. In the embodiment illustrated in FIGS. 3, 3A, and 3B, the hydraulic drilling tool 140 further comprises one or more rotatable water-jetting nozzles 142 each of which directs a high pressure water jet 144 against the surrounding seam 22 of material. The choice of number of water nozzles 142 will depend on the pressure needed at a particular site and for a particular material to be mined, and the pressure level that can be achieved for each nozzle 142 given the equipment and resources available at the drilling site. The one or more nozzles 142 can be rotated along one or more axes of rotation. The nozzles 142 can be rotated in a vertical plane over a range of 90° to facilitate mining of the entire depth of the seam from the roof 26 to the level of the borehole. The nozzles 142 also can be rotated from side to side over a range of up to about 180°, thereby substantially increasing the volume of ore material that can be disaggregated and recovered as slurry. In some embodiments, the tool 140 can be rotated about its axis,
for example about 30 degrees in either direction, to facilitate contact of the high pressure water jets on different regions of the cavity walls.

The nozzles can be either recessed within tool or protruding therefrom, depending on the nature of the material to be mined. In some embodiments of the tool, the nozzles can be provided with sliding gate valves, not shown. When the tool is retracted in casing the gate valves can be closed, and when the tool is extended from the casing for drilling operations, the gate valves can be opened.

In the illustrated embodiment, casing serves as a protective housing for hydraulic drilling tool and pump. Casing also provides an outer channel for transporting pressurized water to water jetting nozzles, and an inner channel for transporting slurry back to drill rig. Casing is extended during installation and retracted during the mining process by means known in the drilling art. Thus, in the event that there is subsidence of the walls of excavation cavity, there is no danger that borehole will be compromised, or that the equipment disposed within the casing will be damaged.

The method and system of the present invention provide significant advantages over both vertical and horizontal borehole mining methods of the prior art. In the inventive method the mining is accomplished in the reverse direction, i.e., while the tools are withdrawn from the borehole and while the casing is being retracted, rather than while the borehole itself is being drilled. The rotating nozzles permit the excavation cavity to be expanded to a size and shape that can optimize ore extraction on a customized basis for each mining site. The method and system allow mining of ores to be accomplished over great distances without disturbance of the overburden, and with minimal impact to the immediate environment. The method and system of the present invention are particularly well adapted to the excavation and recovery of ores and other materials that are in substantially horizontal seams or strata beneath the earth's surface. Unlike prior art horizontal drilling methods, the borehole can be drilled with a gentle slope between the drill rig and the point of entry into the ore seam of interest instead of with a sharp angle between a vertical borehole and the horizontal borehole into the material of interest. The absence of a sharp angle can simplify the borehole drilling process, as well as the return of slurry to the drill rig. The rotation of the water nozzles during the excavation process allows for a larger volume of material to be extracted for each borehole that is drilled, thereby improving efficiency and reducing overall costs. The method has the advantage of safety in that the excavation operations are remote from the personnel at the drill rig.

A particular advantage of the present invention is that it permits continuous mining operations, rather than the intermittent operations that must be performed in open pit mining. This also permits continuous processing of the slurry that is recovered from the mine, thereby saving both time and costs. Moreover, the method and system of the invention can extend the productive life of a mining site by extracting useful ores that were inaccessible, or accessible only with great difficulty and expense, with prior art mining systems.

FIG. 5 schematically illustrates an embodiment in which several boreholes are drilled through a seam of material to be excavated. The number of boreholes and the distance between them will be determined by the breadth of the seam to be mined and the breadth of the excavation cavity that can be created given the hardness of the material to be mined and the pressure of the high pressure water used to generate the slurry. In such a multi-borehole installation, the boreholes can be drilled and excavated either simultaneously or sequentially, depending on the equipment and high pressure water available.

FIGS. 6A and 6B schematically illustrate alternate embodiments of casing. In FIG. 6A casing comprises two coaxial pipe members and, such that pipe defines the inner channel through which excavated slurry is transported from the site of excavation back to the drill rig, and the plenum between pipe member and defines outer channel that delivers high pressure water to hydraulic drilling tool. In FIG. 6B pipe members are in side-by-side parallel configuration rather than coaxial, with pipe member defining the channel that provides high pressure water to hydraulic drilling tool, and pipe member defining the channel through which excavated slurry is transported from the site of excavation back to the drill rig. The configuration of FIG. 6B requires that two separate boreholes be provided, but can allow for larger volumes of pressurized water to be provided to hydraulic drilling tool, and larger volumes of excavated slurry to be returned to drill rig for processing.

In another embodiment of the invention, the apparatus of the invention is substantially the same as that illustrated and described above, except that the drilling tool is pneumatic, such that the high pressure fluid used to disaggregate the material from the cavity walls is high pressure air. Referring to FIG. 7, drilling tool nozzle is outer channel and inner channel have the same meaning as the structures with the corresponding reference numerals in FIG. 2. In the embodiment of FIG. 7, outer channel provides high pressure air to nozzle to create a high pressure pneumatic jet that impacts wall of excavation cavity to disaggregate the material thereof. The direction of pneumatic jets can be varied, and in particular can be rotated to impinge upon different regions of the cavity wall, in the same manner as disclosed with respect to hydraulic jets and nozzles.

The disaggregated material will fall to the floor of cavity. Water will be present at this point of the cavity, either from naturally occurring groundwater, or added to the cavity as part of the mining process. The disaggregated material and the water will mix to form a slurry. In one embodiment the slurry can be returned to the surface through inner channel by means of a pump such as an eductor. In another embodiment, high pressure air conduit can direct high pressure air from outer channel to impel some of the slurry back through inner channel. The air space within cavity above slurry will be pressurized due to the use of high pressure pneumatic jet; this pressurization of the cavity will facilitate the movement of the slurry back through inner channel. In addition, inner channel can be provided with one or more air distributors such as in the form of annular manifolds having air outputs, as illustrated schematically in FIG. 7A, that further direct the flow of slurry back through inner channel. Those skilled in the art will be able to determine both the number of manifolds needed and distance intervals required between them, based on the needs of each installation.

In one embodiment, the invention can be practiced wherein the cutting tool comprises both hydraulic and pneumatic cutting jets.
In one embodiment of the invention, the means for returning the slurry back through inner channel 48 may comprise both a pump such as an eductor and a high pressure conduit to direct slurry back through inner channel 48. The foregoing description of the invention is intended by way of illustration and not by way of limitation. Other alternatives and equivalents will be recognized by those skilled in the art, and are intended to be encompassed by the claims herein.

What is claimed is:

1. A horizontal mining system for excavating a material from a seam of material to be mined, the system comprising
   a. a drill rig comprising means for boring a borehole that is substantially horizontal through at least a portion of the seam of material,
   b. a retractable casing, said casing adapted to be disposed within said substantially horizontal borehole,
   c. a high pressure drilling tool comprising at least one nozzle for emitting a high pressure jet, said high pressure drilling tool being operable to adjust the direction of the high pressure jet,
   d. a material return means adapted to be movably disposed within said casing,
   e. means for advancing and retracting said high pressure drilling tool and said pump means within said casing, and
   f. means for retracting said casing.

2. The horizontal mining system of claim 1 comprising a conduit for conveying the excavated material to the drill rig.

3. The horizontal mining system of claim 2 wherein said conduit for conveying excavated material is disposed within said casing.

4. The horizontal mining system of claim 2 wherein said conduit for conveying excavated material is in operative communication with said material return means.

5. The horizontal mining system of claim 4 wherein said material return means is adapted to direct excavated material through said conduit for conveying excavated material.

6. The horizontal mining system of claim 1 wherein said high pressure drilling tool is rotatable, thereby to adjust the direction of said high pressure jet.

7. The horizontal mining system of claim 1 wherein said high pressure drilling tool comprises at least one nozzle for emitting said high pressure jet.

8. The horizontal mining system of claim 7 wherein said nozzle is adjustable, thereby to adjust the direction of said high pressure jet.

9. The horizontal mining system of claim 2 comprising two casings, one casing for housing said2 said drilling tool and the second casing for housing said conduit for conveying the excavated material to the drill rig.

10. The horizontal mining system of claim 1 wherein said high pressure drilling tool is a hydraulic tool.

11. The horizontal mining system of claim 10 wherein said material return means comprises a pump.

12. The horizontal mining system of claim 1 wherein said high pressure drilling tool is pneumatic.

13. The horizontal drilling system of claim 12 wherein said material return means comprises a means for conveying high pressure air through said conduit for conveying excavated material to the drill rig.

14. A method for mining a material from an underground seam of material, the method comprising
   a. drilling a substantially horizontal borehole in the seam of material,
   b. disposing a retractable casing along the length of the borehole,
   c. providing a high pressure drilling tool at the end of said casing, the high pressure drilling tool comprising at least one nozzle for emitting a high pressure jet, said hydraulic drilling tool being operable to adjust the direction of the high pressure jet during drilling,
   d. drilling the seam of material with the high pressure jet, during which drilling the direction of the high pressure jet is adjusted from one orientation to another, thereby creating an excavation cavity, the slurry collecting in the excavation cavity, and
   e. removing the slurry from the excavation cavity back toward the origin of the borehole.

15. The method of claim 14 wherein including the further step of retracting the casing and the high pressure tool along said borehole to allow high pressure drilling of the seam of material to continue at a different location along the borehole, thereby expanding the excavation cavity.

16. The method of claim 15 comprising the further step of providing a barrier at a location within the excavation cavity to limit the space in the excavation cavity in which the slurry collects prior to removal.

17. The method of claim 16 wherein said barrier is provided by subsidence of the excavation cavity.

18. The method of claim 16 wherein said barrier is provided by depositing material from the casing at a desired location in the excavation cavity.

19. The method of claim 14 in which the direction of the high pressure jet is adjusted by rotating the high pressure drilling tool.

20. The method of claim 14 in which the drilling tool comprises at least one nozzle through which the high pressure jet is emitted, the direction of the high pressure jet being adjusted by adjustment of the nozzle.

21. The method of claim 20 in which the nozzle is rotatable, the direction of the high pressure jet being adjusted by rotation of the nozzle.

22. The method of claim 14 wherein said high pressure drilling tool is hydraulic.

23. The method of claim 14 wherein said high pressure drilling tool is pneumatic.

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