United States Patent [19]

Grable

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[54] **RECOVERY OF SUB-SURFACE METALS**

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[73] Assignees: **Wasteland Reclamation Corp.,** Long Beach; **Bill C. Laney,** Torrance; **William W. Haefliger,** San Marino, all of, Calif. ; part interest to each

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[21] Appl. No.: **380,362**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 338,151, March 5, 1973, Pat. No. 3,790,213.

[52] **U.S. Cl.** **299/8,** 175/58, 175/103, 175/107, 175/308

[51] **Int. Cl.** **E21c 45/00**

[58] **Field of Search** 299/41, 18, 8; 175/308, 175/58, 59, 60

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Primary Examiner—Ernest R. Purser

Attorney, Agent, or Firm—William W. Haefliger

[57] **ABSTRACT**

A method of recovering segregatable particles in an underground formation includes the steps:

a. progressively rotatably cutting into the underground formation both generally vertically and laterally to produce an underground swath, and to loosen said particles,

b. delivering liquid in a pressurized stream to said swath to displace the loosened particles in the delivered water, and

c. locally collecting the displaced particles in a collection zone in said swath, during said cutting, for subsequent retrieval at the surface.

24 Claims, 13 Drawing Figures

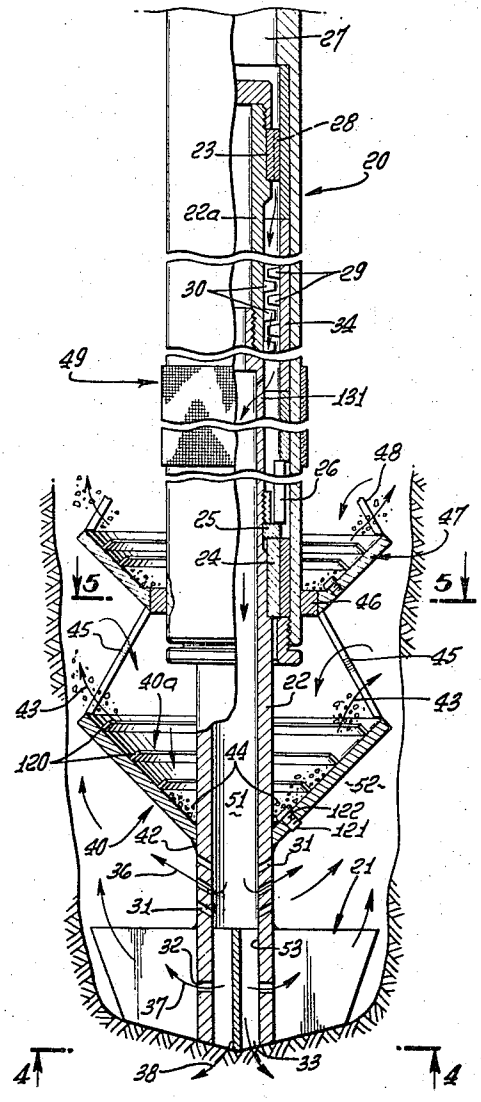


FIG. 1.

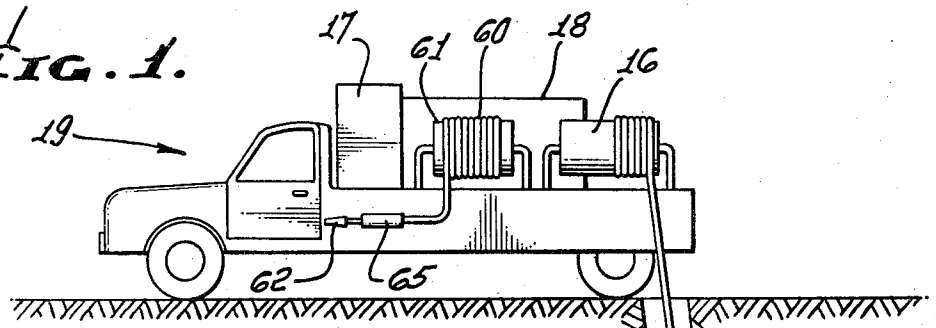


FIG. 6.

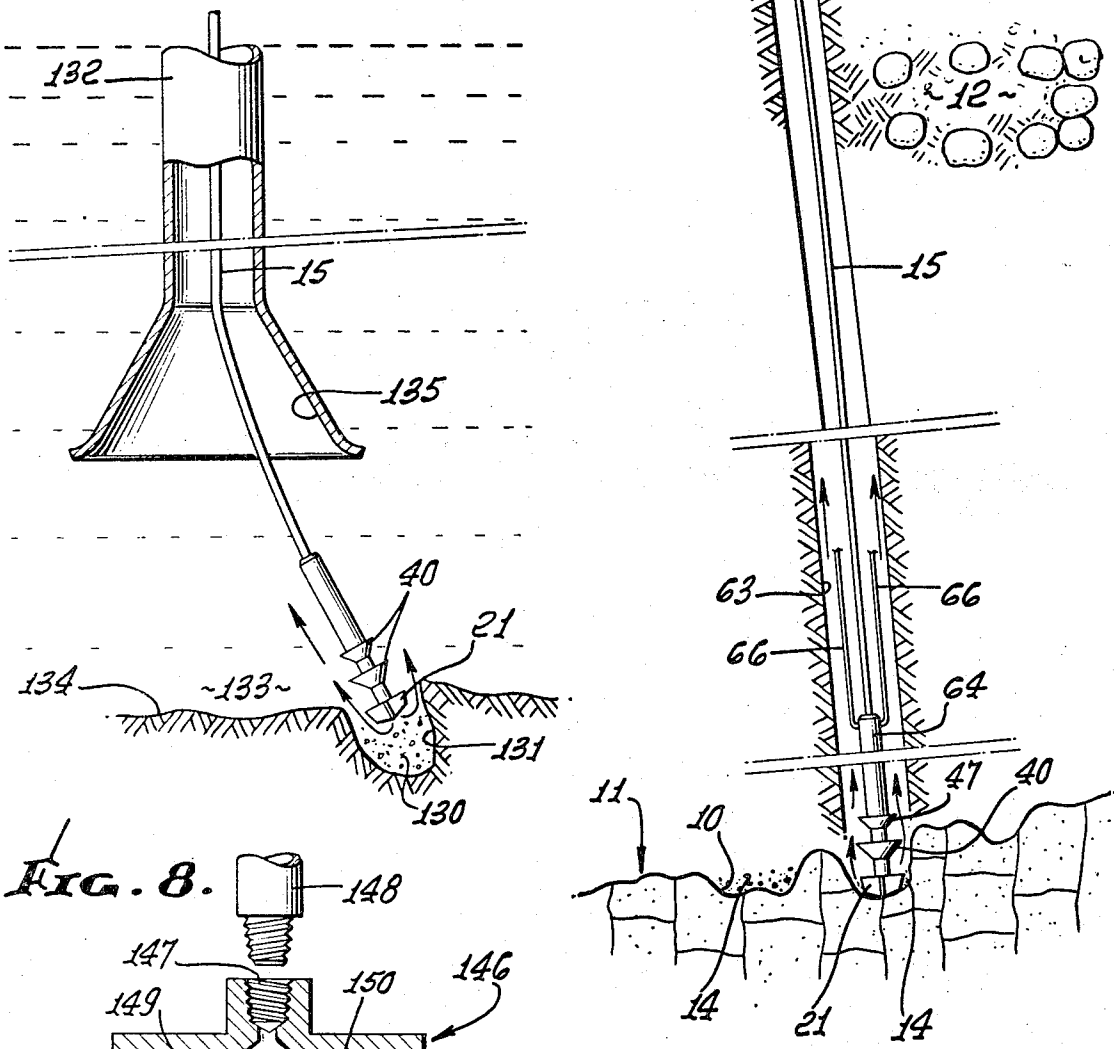


FIG. 8.

FIG. 3.

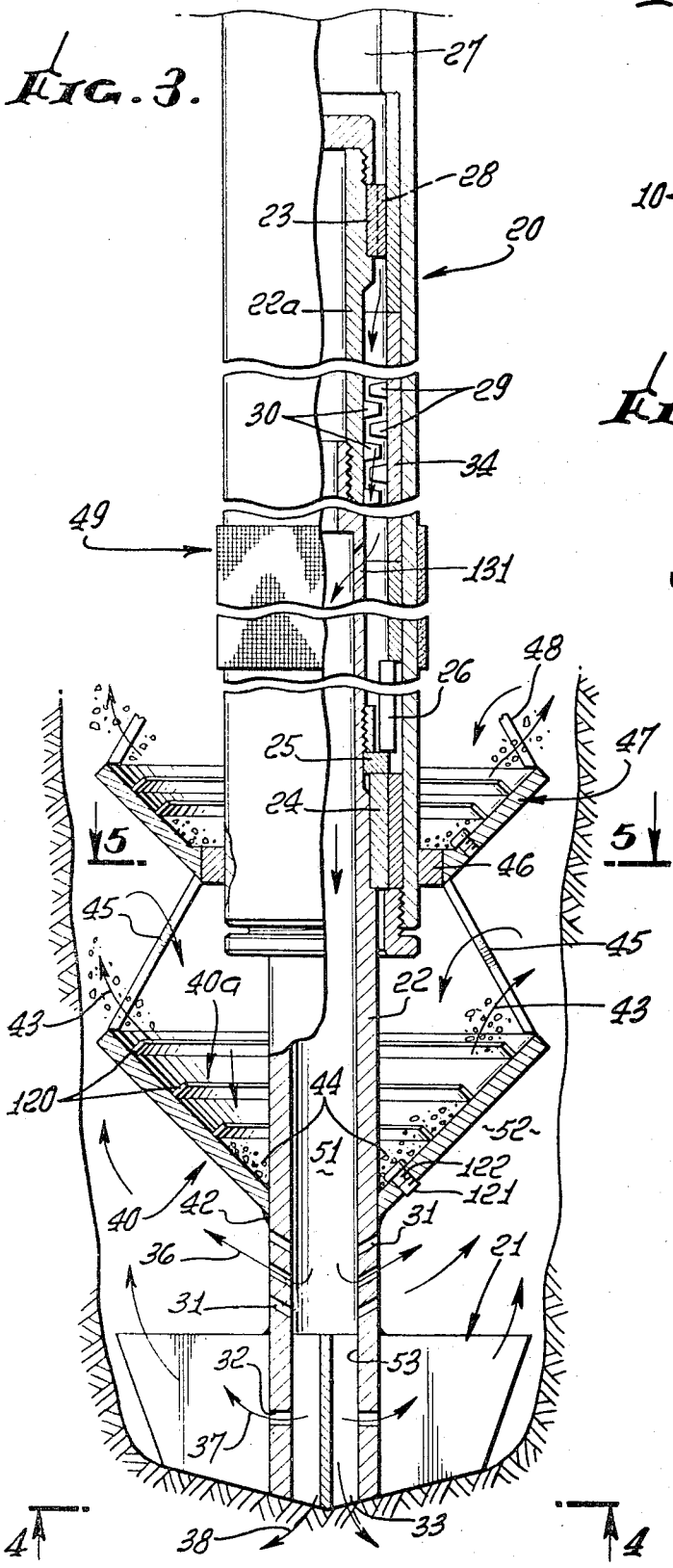


FIG. 2.

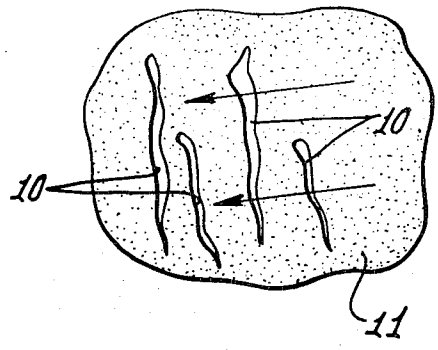


FIG. 4.

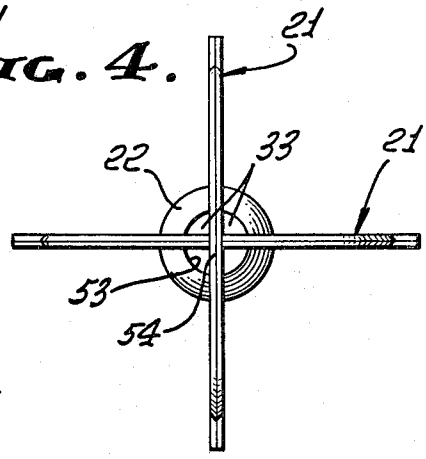


FIG. 5.

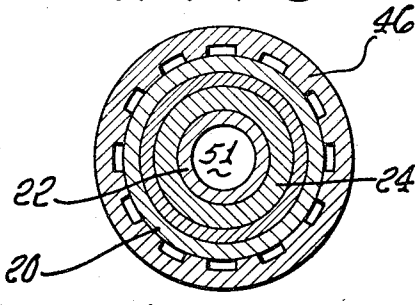


FIG. 7.

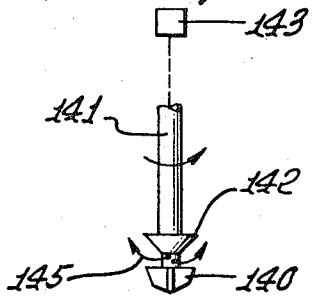


FIG. 9.

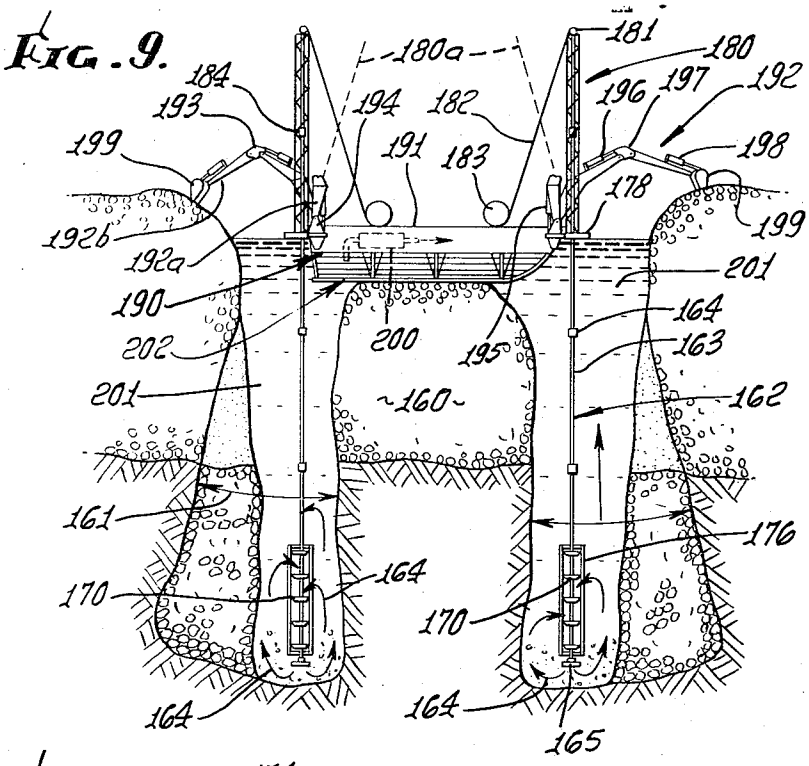


FIG. 10.

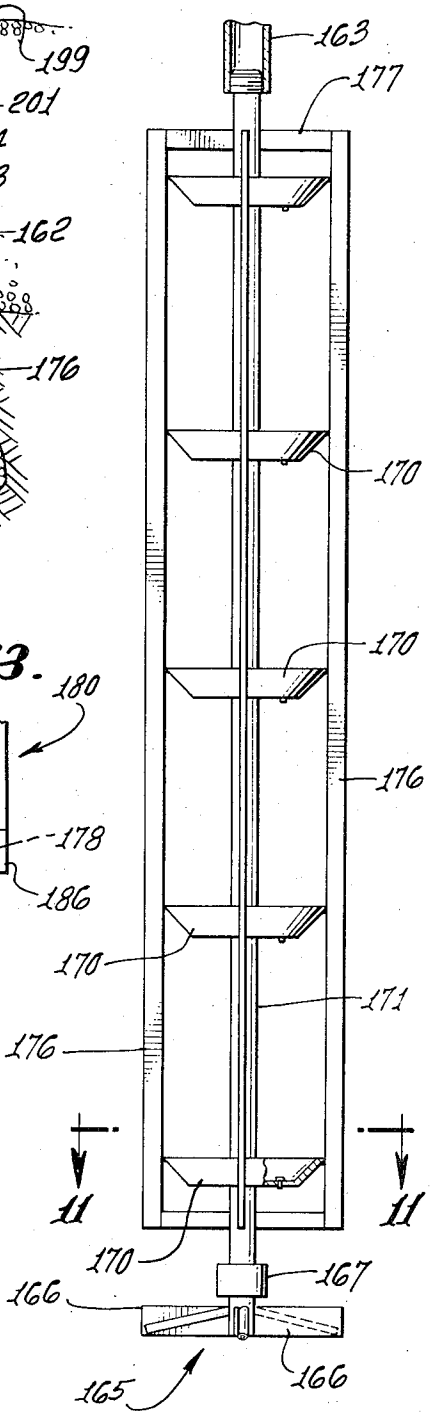


FIG. 11.

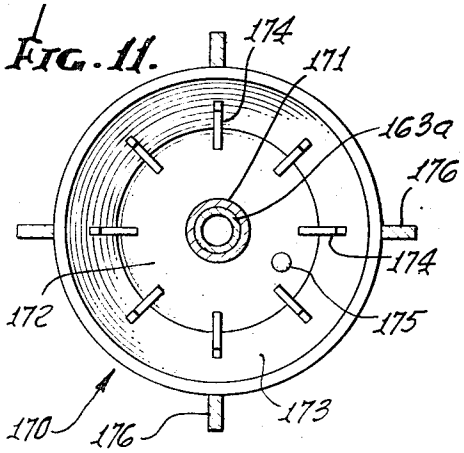


FIG. 13.

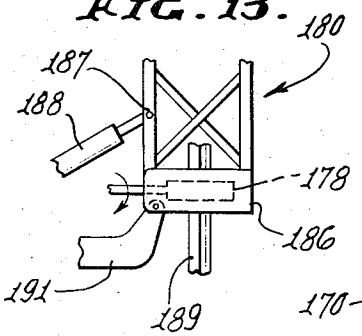
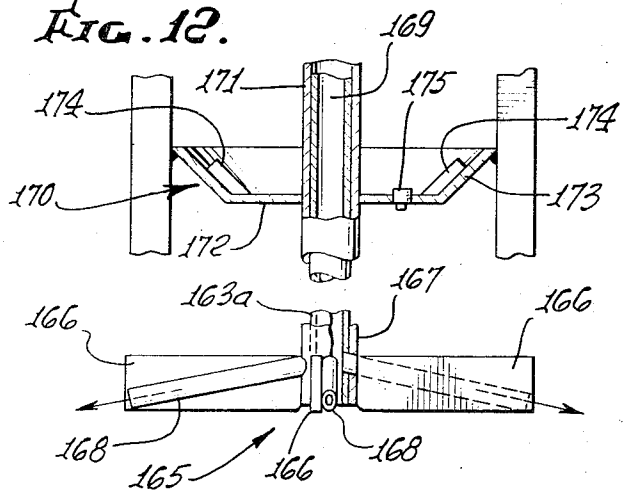


FIG. 12.



RECOVERY OF SUB-SURFACE METALS

BACKGROUND OF THE INVENTION

This application is a continuation-in-part of my co-pending application Ser. No. 338,151 entitled "Sub-Surface Particle Recovery," filed Mar. 5, 1973 now U.S. Pat. No. 3790213.

This invention relates generally to the recovery of metallic particles at sub-surface localities, and more particularly concerns methods and apparatus for effecting such recovery without removal of the overburden and without mining activity carried out by humans at underground levels.

Mining operations over large areas of the world have involved stripping the overburden off bedrock underlying streams where gold and/or other precious metal particles were concentrated. Typically, intermixed soil and rocks were re-deposited over the bedrock after dredging of the gold bearing layers; however, the bucket type dredging equipment that was conventionally employed could not reach much of the gold or metal particles, as for example larger particles that were trapped in cracks and crevices in the bedrock. Where ore recovery beneath the sea was conducted, ocean floor "sweeping operations" to recover loose particles and grannules did not contemplate recovery of inaccessible or trapped materials. No way was known, to my knowledge to accomplish recovery of such trapped precious metal particles, or other weight segregatable particles, in the simple manner as now afforded by the present invention. As to the latter, the invention is especially useful in that particle recovery may now be carried out beneath undisturbed land, without requiring stripping of the overburden off the bedrock.

SUMMARY OF THE INVENTION

It is a major object of the invention to provide solutions to the above problems, which will enable precious and other metal or heavy particle recovery at remote sub-surface locations, i.e., beneath the land or water body surface level.

Basically, and in its method aspects, the invention contemplates employment of metallic tubing extending downwardly into an underground formation together with cutting means and particle collector means caused by the tubing. The steps of the method include rotating the cutting means, as for example by rotating the tubing, and bodily displacing the tubing to effect cutting of the formation both generally vertically and laterally to form a swath or swaths, delivering liquid such as water in a pressurized stream via the tubing to the swath to displace the loosened particles in the delivered water, and locally collecting the displaced particles in the collector means for subsequent upward retrieval. As will be seen, the tubing and cutting means may be bodily displaced both vertically and laterally during rotation of the cutting means, such lateral displacement effected by tilting of a surface support for the tubing, or by advancement of a carrier vehicle at the surface, and lateral cutting may be effected by operation of a rotary reamer carrier by the tubing near the collector means.

In its apparatus aspects, the invention concerns the provision of first means for progressively rotatably cutting into the underground formation both generally vertically as well as laterally to produce the swath and loosen the underground particles, such means including tubing as described; and collector means carried by the tubing for collecting the particles in the underground swath, for subsequent retrieval. The first means may include rotary cutter and rotary reamer elements as described, to be rotated by the tubing, and rotary table and tiltable mast structure may be employed to rotate and tilt the tubing. Additionally a carrier vehicle may be employed to carry the rotary table and mast structure, that vehicle being capable of floating, and being movable over rough terrain as by articulated legs to be described.

These and other objects and advantages of the invention, as well as the details of an illustrative embodiment, will be more fully understood from the following description and drawings, in which:

DRAWING DESCRIPTION

FIG. **1** is an elevational showing of apparatus in use;

FIG. **2** is a plan view showing crevices in underground bedrock;

FIG. **3** is a vertical section showing details of one form of collector, cutter and drive apparatus;

FIG. **4** is a section on lines **4—4** of FIG. **3**;

FIG. **5** is a section on lines **5—5** of FIG. **3**;

FIG. **6** is an elevation showing recovery of metal particles on the ocean floor;

FIG. **7** is a vertical elevation showing other apparatus;

FIG. **8** is a modified form of the apparatus;

FIG. **9** is an elevation showing further modified apparatus;

FIG. **10** is an enlarged elevation showing details of the reaming, cutting and collector structure of FIG. **10**;

FIG. **11** is a section on lines **11—11** of FIG. **10**;

FIG. **12** is an enlarged sectional elevation; and

FIG. **13** is an elevation showing mast tilting apparatus.

DETAILED DESCRIPTION

Referring first to FIGS. **1** and **2**, the invention makes possible the recovery of metal particles, as for example gold and other precious metals, from sub-surface localities such as cracks and crevices **10** in bedrock **11**, all without removal of the overburden **12**. Such cracks or crevices typically exist under present or past streams, and may contain larger gold particles including nuggets which dredging buckets cannot or could not retrieve. The bedrock may lie between 50 and 150 feet below the surface **13**; however, the invention is applicable to other areas, where bedrock may be much deeper.

Means is provided, as for example tubing **15**, to deliver water in a pressurized stream to an underground locality, as at **10**, for displacing metallic particles **14** at that locality in the delivered water; and, a collector is carried by such means at a position to collect the displaced particles, and to be upwardly retrievable in response to upward displacement of the tubing. The latter may be flexible so as to be wound on a drum **16** at the surface, the drum being rotatable to extend the tubing and to retract same wherein desired. A source of pressurized water is indicated at **17** and may include a suitable pump the outlet of which is connected at **18** with the tubing. These elements may be suitably car-

ried, as for example by a vehicle **19.** During operation over a body of water, a floating vessel may be employed, the tubing then extending downwardly in the water to the floor where the pressurized water stream is delivered for displacing metal particles to be collected.

Referring to FIGS. **3–5,** the lower extent of the water delivery means may include a metallic housing **20** supporting a rotary cutter **21.** The cutter is carried by a tubular shaft **22** projecting below the housing and supported therein for rotation as by suitable bearing sleeves **23** and **24.** Axial loading is transmitted between the shaft and housing as by thrust bearing elements **25** and **26.** Pressurized water flows downwardly from the tubing into the housing passage **27,** then downwardly through ports **28** in the bearing sleeve **23,** then downwardly past stator vanes **29** and rotor vanes **30** to enter the shaft via ports **131,** and then downwardly toward the cutter to exit from the shaft as at ports **31, 32** and **33.**

The stator vanes **29** carried by a sleeve section **34** associated with the housing direct the water into the rotor vane carried by the shaft upper section **22*a***, and at an impingement angle causing the rotor vanes and the shaft to rotate at a relatively high velocity, for example between 700 and 1,500 RPM to develop between 60 and 200 horsepower delivered to the cutter or bit.

The lower portion of the shaft with ports **31–33** may be considered as a nozzle, from which water exits as indicated by arrows **36–38** to displace particles loosened by the cutter, or adjacent the nozzle, as to entrain them to flow upwardly about the collector indicated at **40.** Such particles may typically include earth and rock material as well as metallic particles such as gold and other precious or valuable metals displaced in and from the cracks and crevices previously mentioned. The collector is shown as supported directly above the cutter, and has frusto-conical shape tapering downwardly toward the cutter, whereby the upward streams of water and entrained particles flow outwardly and upwardly about the collector at increased velocity, and then inwardly toward the housing above the collector at reduced velocity. As a consequence, the particulate material settles into the collector interior at **40*a***; however, since the cutter is operatively connected with the rapidly rotating structure (as at connection **42** to the shaft **22**), the lighter material including earth and small rock particles are centrifugally thrown outwardly as indicated by arrows **43,** leaving the heavier metallic particles, including gold, retained at **44** within the collector, the angularity of the collector being such as to achieve this result. Spider arms **45** connect the collector with a suitable guide ring **46** centering on the cylindrical housing **20** as shown. Additional collectors of progressively reduced outer diameters may be provided in vertical series, one of these being indicated at **47** attached to ring **46** to be rotated by collector **40.** Spider arms **48** connect the collector **47** with another guide ring, not shown, centering on housing **20.** All the collectors operate in the same manner, recovering heavy metallic particles from the rising water streams. If desired, concentric or spiral riffles may be incorporated in the collectors as at **120,** to aid retention of metal particles.

A metallic particle adsorbing medium **49** may be carried by the housing portion of the tubing to extend above the collector or collectors for adsorbing or catching very small lightweight metal particles remaining in the water streams rising above the collectors and adjacent the housing. Such material may for example consist of natural wool or similar material forming small interstices in which particles become trapped.

Referring again to ports **31,** they may be directed upwardly as shown to pass pressurized water in jets from the interior **51** of the shaft to the region **52** directly below the collector **40.** Ports **32** may be directed radially to jet water between the four, or other suitable number, blades of the cutter; and ports **33** may be directed downwardly to deliver water under pressure to the formation for hydraulically displacing same. Merely as illustrative, ports **33** may be formed between the bore **53** of the shaft and the inner extents **54** of the cutters as best seen in FIG. **4.**

Referring back to FIG. **1,** means may be provided for hydraulically drilling a guide passage in the formation **12** to initially receive and guide the cutter and collector downwardly toward the metal particle retrieval locality, as for example is exemplified by the crevice **10.** Such means may include a conduit **60** on a reel **61,** and having a terminal nozzle **62** to which water under pressure is delivered (as from unit **17**) to hydraulically bore into the formation. The thus formed guide passage is indicated at **63.** Weight, such as drill collars, may be added or connected to the tubing **15** and to the conduit **60,** as at **64** and **65** respectively, to urge and direct the cutter **21** and nozzle **62** downwardly. Further, guide wires may be connected to such weights as indicated at **66** and may be manipulated at the surface to direct the angularity from vertical of the downward progress and the lateral bodily displacement of the cutter at the locality **10** as by directional force exertion on the tubing. For example, the crevices over an extended region of the bedrock may successively penetrated and traversed by the cutter, through controlled manipulation of the guide lines.

At regular intervals, the collector or collectors may be upwardly retrieved as by upward withdrawal of the tubing **15,** to remove collected metal particles. Water flowing back upwardly to the surface may be allowed to percolate into the soil, or may be collected and reused.

Referring again to FIG. **3,** threaded plugs **121** are shown connected into the collectors to close threaded bores **122,** proximate the lowermost interiors of the collectors. Such plugs may be removed after upward recovery of the apparatus to the surface, to enable connection of water lines to the bores for flushing out the segregated metal particles.

FIG. **6** shows an application to recovery of metal particles **130** trapped in an ocean (or other water body) floor crevice **131.** A metallic tubular guide **132** may be employed to downwardly pass the apparatus (including rotary cutter **21** and collectors **40** on flexible tubing **15**) to a selected zone **133** proximate the ocean floor **134.** A downwardly opening bell **135** guides the apparatus into the tube **132** upon upward retrieval, and it allows lateral movement or travel of the apparatus at the ocean floor for cutting into the trapped particles **130** lengthwise of the crevice.

The invention also contemplates that the tubing **15** may be rigid, as may take the form of a string of metal drill pipe or tubing as used in oil well operations. FIG. **7** shows a cutter or bit **140** at the lower end of a rigid tube **141,** with a conical collector **142** also carried by the tube. The latter may be rotated by suitable means

143, as for example a power swivel (which may operate at a subsurface level) or a rotary table at the surface. Hydraulic fluid may be supplied to the tube to exit near the bit and under the collector, as shown by arrows 145. The means 143 may alternatively comprise an electric motor near the bit and collector location, for rotating these elements, as via suitable structure represented at 141.

In FIG. 8, a bit 146 is attachable at 147 to a rotary tube 148 which may be turbine driven, as described above. Ducts 149 and 150 in the bit conduct hydraulic fluid to the exterior to entrain cuttings and elevate them to a collector carried by tube 148, but not shown. A projection such as a hardened ball 151 eccentrically carried by one of the four blades of the bit, at the underside thereof, is engageable with the uneven bedrock surface 152 to cause the turbine driven bit to vibrate and jump up and down while rotating at high speeds. This motion causes a faster settling of the gold in the collectors or pans.

Referring to FIGS. 9–12, means is shown for progressively rotatably cutting into the underground formation 160 both generally vertically and laterally to produce an underground swath or swaths 161, and to loosen segregatable particles (as for example noble metal particles such as gold, silver, etc.). Such means includes pipe or tubing 162, which may comprise drill pipe stands 163 connected by joints 164, to deliver water in a pressurized stream to the swath or swaths in order to upwardly displace the loosened particles as for example in flow paths indicated by arrows 164. The cutting means may comprise rotary cutters 165 as are better seen in FIGS. 10 and 12, and which have blades 166 extending radially from a hub 167 on the lower end of the rotating pipe sub 163*a*. Water is delivered to the tips of the blades via conduits 168 suitably attached to the back sides of the blades and communicating with the pipe interior 169.

A vertically spaced series of collectors 170 is located directly above the cutter 165, and connected with the pipe sub 163*a* via sleeve 171. The collector trays may have flat bottom plates 172, upwardly and outwardly inclined annular walls 173, and radially extending shallow baffles 174. The latter drive the contents of the collectors at the same angular velocity as the collector to assure centrifugal displacement and outward discharge over walls 173 of all but the segregatable heavy particles, such as gold. Flush plugs are indicated at 175 to be removable for removing the collected particles after collector retrieval at the surface.

The means to cut the underground formation also includes a rotary reamer carried by the pipe sub 163*a*, as via sleeve 171, to extend sidewardly of the collectors. As shown, the reamer may include a series of circularly spaced, vertically extending blades 176 joined at their opposite ends to the sleeve 171 via web members 177.

The means to rotate the reamer, cutter and collectors may include a rotary table at the surface, as indicated at 178, for rotating the pipe or tubing 162 in the same manner that oil well drill pipe is rotated as it is progressively lowered. Accordingly, up and down movement of the pipe together with the reamer, cutter and collectors is enabled at the same that these elements are rotated. In this regard, the top pipe stand is connected to a kelly projecting in a mast 180 at the surface, and elevator means is carried by the mast to elevate and lower the pipe via the kelly. Such elevator means may comprise a pulley 181 at the top of the mast to support cable 182 extending from draw works 183 over the pully and downwardly in the mast to a swivel 184 supporting the kelly. In addition, structure is provided to tilt the mast, as for example between the solid line position and the broken line position 180*a*, so that the reamer may progressively cut the underground swath 161 referred to, while it is rotated as well as elevated and lowered. Such tilt support and actuating structure is schematically shown in FIG. 13, wherein the rotary table 178 is seated on a base 186 to be tiltable about pivot 187 and an actuator 188 controls tilting of the base. The kelly appears at 189. This representation is schematic only, and other mechanisms may be employed for tilting the masts either directly or indirectly. For lateral tilting, the legs 192 (to be described) may be operated to rock the vehicle.

Multiple combinations as described may be provided, FIG. 9 showing two such units including tiltable masts 180 on a carrier vehicle. Four such masts and associated tubing etc., may be respectively located at the four corners of the vehicle 190. The latter includes a floatable hull 191 there also being articulated, terrain engaging legs 192 carried by the hull to advance it over rugged terrain such as swamps, hills, shallow lakes, etc. The legs may be located at opposite ends of the vehicle, i.e., one at each corner, to have retracted raised positions and various extended i.e., "walking" positions as shown in which the legs are extended to grip the terrain in order to relatively raise, lower, advance and retract (linearly and/or rotatably) the carrier over rough as well as smooth terrain, as described in my copending application Ser. No. 323,769. The legs may include booms or links 192*a* and 192*b* pivotally interconnected at pivot locations 193, and the backhoe booms or links 192*a* may be pivotally supported at 194 on the carrier. Fluid pressure responsive actuators 195 are connected between leg support structure on the vehicle and links 192*a* to extend and retract the latter; fluid pressure responsive actuators 196 are pivotally connected between links 192*a* and supports 197 for the inner ends of booms or links 192*b* to pivotally extend and retract the latter relative to links 192*a*, and fluid pressure responsive actuators 198 are pivotally connected between links 192*b* and the claws or backhoes 199 (which are pivotally connected to the outer ends of legs 192*b*) in order to pivot the claws as required. Suitable controls are located at each end of the vehicle for operating the legs. Accordingly, the carrier vehicle may be moved (i.e., "walked") over very rough, rocky terrain and set down whereever desired in order to "puddle in," float, or rest on the terrain as via a sled 202 under the hull.

The vehicle hull 191 may be designed to carry suitable pumping equipment indicated at 200, legs 192 and controls as well as other equipment. Also, the hull is sized to floatably support such equipment during the "puddling in" process, the legs being long enough to be lowered and operated to enable walking of the vehicle out of a shallow puddle formed during particle recovery. Also, the dug-in legs may resist vehicle movement, as may be desired. Water standing in the swaths as at 201 may be pumped at 200 for re-supply to the pipes 163.

In operation, the cutting means such as cutter 165 is rotated and the tubing bodily displaced to effect cutting

of the formation **160** both generally vertically and laterally to form an underground swath or swaths; water is delivered in a pressurized stream to the swath to displace the loosened particles in the delivered water, and the displaced particles are collected in a collection zone or zones (as for example collectors **170**) in the swath, during cutting of the latter, for subsequent retrieval. Further, the cutting means is advantageously rotated by rotating the tubing as it is subjected to generally vertical and lateral bodily displacement, the tubing being suspended as by a carrier vehicle for tilting, lifting and lowering as previously described. In addition, the carrier vehicle may be advanced during such cutting, as by operation of articulated legs as described.

I claim:

1. In the method of recovering segregatable particles in an underground formation, the steps that include

a. progressively rotatably cutting into the underground formation both up and down and laterally to produce an underground swath, and to loosen said particles, said lateral cutting being carried out during up and down cutting,

b. delivering liquid in a pressurized stream to said swath to displace the loosened particles in the delivered water, and

c. locally collecting the displaced particles in a collection zone in said swath, during said cutting, for subsequent retrieval at the surface.

2. The method of claim **1** wherein said particles are metallic.

3. The method of claim **2** wherein said particles are selected from the group that includes the noble metals.

4. The method of claim **3** wherein said rotating of the cutting means and bodily displacement of the tubing are effected to cut the formation both directly beneath and at the side of the collector means.

5. In the method of recovering segregatable particles in an underground formation, and employing metallic tubing extending downwardly into the formation and cutting means and collector means carried by said tubing, the steps that include

a. rotating the cutting means and bodily displacing the tubing up and down and also laterally to effect cutting of the formation both up and down and laterally to form an underground swath, and to loosen the particles,

b. delivering water in a pressurized stream via the tubing to said swath to displace the loosened particles in the delivered water, and

c. locally collecting the displaced particles in the collector means, for subsequent retrieval.

6. The method of claim **5** wherein the tubing and cutting means are bodily displaced both up and down and generally laterally during rotation of the cutting means.

7. The method of claim **6** wherein the cutting means and collector means are rotated by rotating the tubing and at a rotary speed to effect centrifugal throw-out of non metallic particles from the collector means.

8. The method of claim **7** including the step of suspending the rotating tubing for lateral tilting to effect said lateral cutting of the formation by said cutting means.

9. The method of claim **7** including the step of simultaneously suspending the rotating tubing for said generally vertical displacement while the tubing remains tilted.

10. The method of claim **9** including the step of providing a carrier vehicle at the surface and from which the tubing is suspended as aforesaid.

11. The method of claim **10** including the step of advancing the carrier vehicle during said cutting of the formation.

12. The method of claim **11** wherein said vehicle has articulated support legs, and wherein said advancement of the vehicle is carried out by operating said legs.

13. In apparatus for recovering segregatable particles in an underground formation, the combination comprising

a. first means for progressively rotatably cutting into the underground formation both up and down and laterally to produce an underground swath and to loosen said particles, said means including tubing to deliver water in a pressurized stream to said swath to displace the loosened particles in the delivered water, and

b. collector means carried by said tubing for collecting the displaced particles in said swath during said cutting, for subsequent retrieval.

14. The combination of claim **13** wherein said first means includes a rotary cutter carried by the tubing to extend below the level of said collector means, and a rotary reamer carried by the tubing to extend sidwardly of said collector means.

15. The combination of claim **14** wherein said reamer includes a series of blades extending generally parallel to said tubing in radially outwardly spaced relation thereto, and circularly spaced thereabout.

16. The combination of claim **15** wherein said collector means includes a series of collector trays spaced lengthwise of the tubing and located radially inwardly of said blades.

17. The combination of claim **13** wherein said first means includes a rotary table at the surface for rotating the tubing.

18. The combination of claim **13** wherein said first means includes a mast at the surface, and elevator means carried by the mast to elevate and lower the tubing.

19. The combination of claim **18** wherein said first means includes structure for tilting the mast.

20. The combination of claim **18** including a carrier vehicle supporting said mast.

21. The combination of claim **18** including a rotary table at the surface for rotating the tubing during said elevation and lowering thereof.

22. The combination of claim **21** including a carrier vehicle supporting the mast and rotary table.

23. The combination of claim **22** including additional combinations supported by said vehicle, said combinations including at least one additional mast on the vehicle, at least one additional rotary table on the vehicle for rotating at least one additional tubing string, at least one additional elevator on the additional mast to elevate and lower the additional tubing string, means to tilt said additional mast, and formation cutting means and particle collector means on the additional tubing.

24. The combination of claim **23** including articulated, terrain engaging legs on the vehicle and means to operate the legs to advance the vehicle.

* * * * *