OVERVIEW OF FRACTURED ROCK DRILLING METHODS IN EPA REGION 10

Advantages, Disadvantages, and Other Considerations

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Geologic Issues in the Pacific Northwest that Impact Selection of Drilling Method

Common Drilling Techniques in Fractured Rock

Percussion

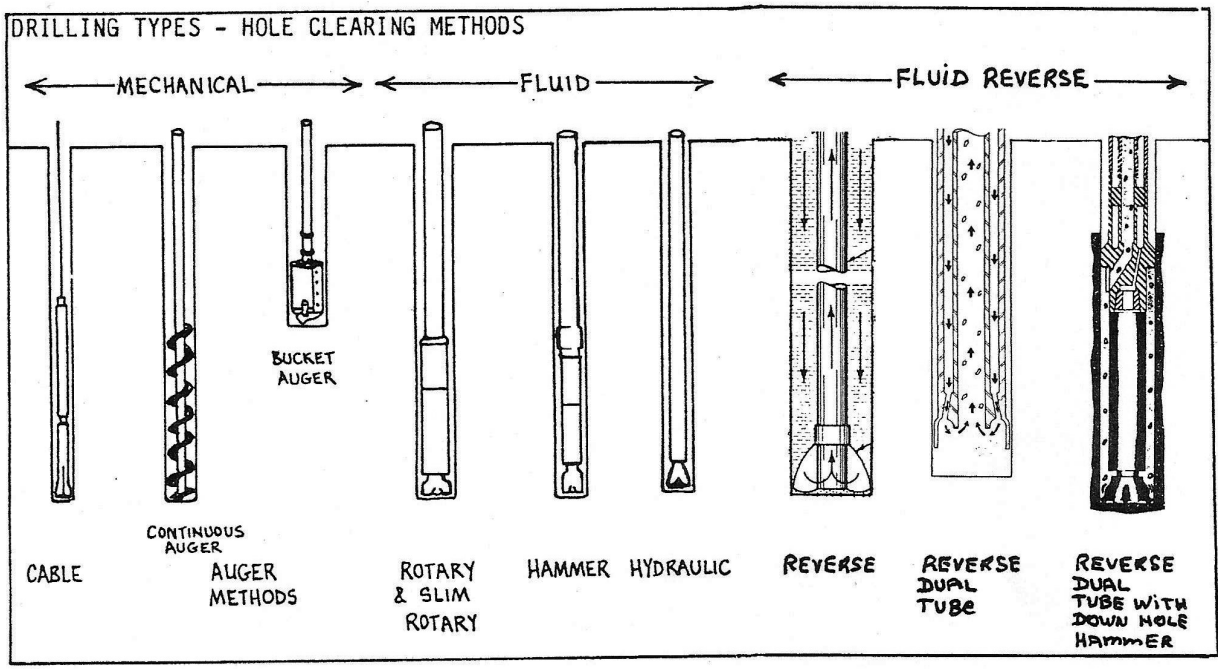
- Cable tool drilling

Rotary

- Air rotary drilling
  - conventional circulation
  - reverse circulation
- Dual-wall rotary drilling
- Coring
- Mud rotary drilling

Combination (Rotary + Percussion)

- Downhole hammers
- Rotary-Sonic



hammer bit

tri-cone bit

Percussion - Cable Tool Drilling

Advantages:

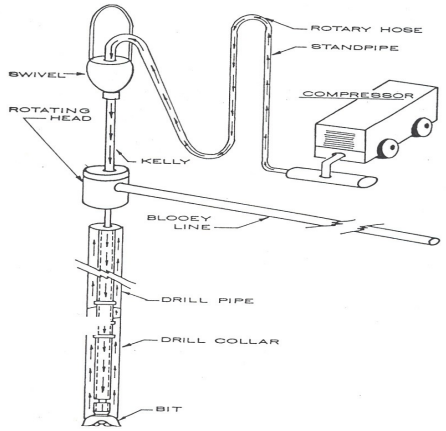
- Drills nearly “everything” (soft or hard)
- Can provide good formation samples
- Info on water-bearing zones available during drilling
- Can typically drill a wide range of borehole diameters
- Reliable equipment
- Can be relatively less expensive than other drilling methods

Disadvantages:

- Drilling in “hard rock” is very slow
- Need to drive steel casing in unconsolidated sediments to keep borehole open
- Installation of continuous grout seal can be difficult

Air Rotary Drilling

Conventional Circulation



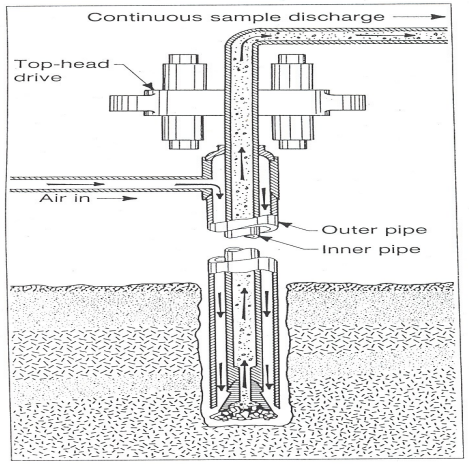
Advantages:

- Good in hard rock
- Speed of advance
- Ease of well completion
- Less expensive

Disadvantages:

- Hole stability
- Loss of circulation (LOC)
- Sampling issues

Reverse Circulation



Advantages:

- Good in hard and soft rock
- Good sample recovery
- Hole stability control

Disadvantages:

- Well completion issues
- Availability
- More expensive

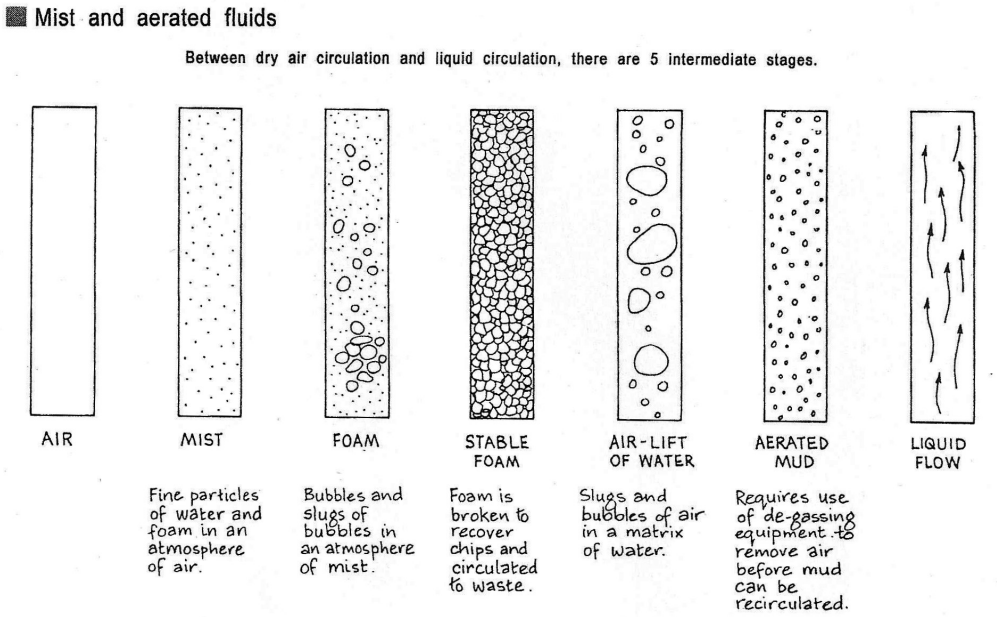
Air Rotary Drilling (cont.)

Types of Drilling Fluids Commonly Employed:

- Air
- Water (+Air)
- "Foam"
- "Mud"

Functions of Drilling Fluids:

- Cool and lubricate bit
- Lift cuttings to surface
- Help stabilize borehole
- Control LOC



***** IMPORTANT FACTOR - TYPE OF BIT USED *****

Tri-Cone vs. Hammer

City of Warden Well No. 9

Drilled Air Rotary Using Conventional Circulation With An Air-Hammer Bit

- Drilled 505 feet below ground surface (bgs) into the Columbia River Basalt
- 20 inch-diameter borehole
- SWL: 53 feet bgs
- Air-lift yield: 6,000 gpm

City of Warden Well No. 9

Example of "Cuttings" From Warden No. 9

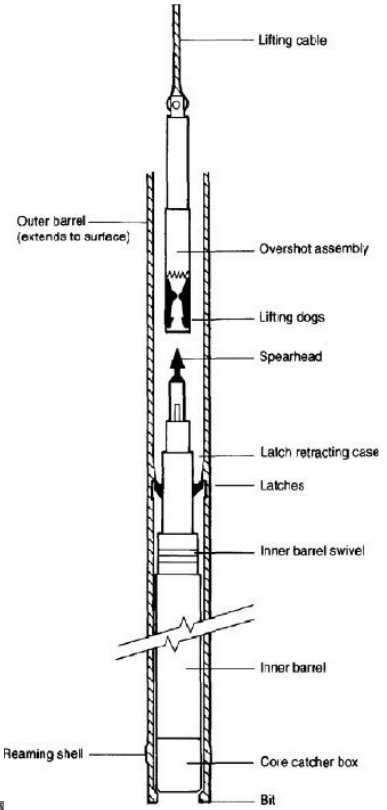
Wireline-Core Rotary Drilling

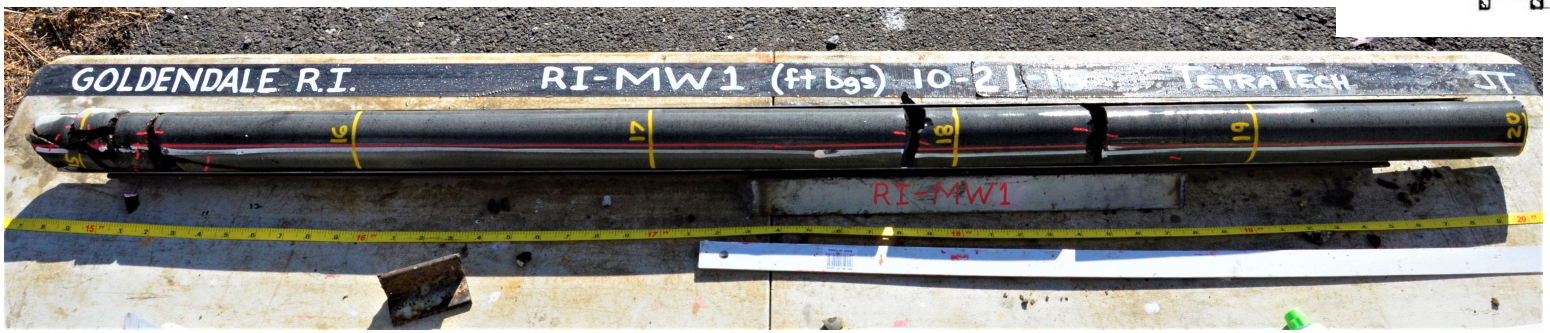
Advantages:

- Good in hard, fractured rock
- Continuous core
- Limited drilling fluids needed
- Limited cuttings discharged
- Relatively fast drilling

Disadvantages:

- Relatively small-diameter borehole
- Borehole stability control
- More expensive





Downhole Hammers Combination (Rotary + Percussion)

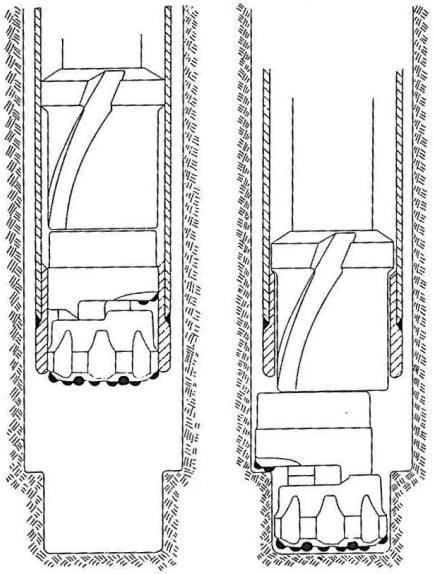
Advantages (Dual-Wall Systems):

- Casing advances with hammer bit
- High penetration rates in hard rock
- Good cuttings recovery/control
- Control borehole stability
- Minimize LOC
- Ease of well completion

Disadvantages:

- Maximum depth limitations
- Hammer bit can be “flooded out”
- Relatively expensive

Eccentric reamer hammer bits



Eccentric reamer dual-wall system “Odex/Tubex/Sim-cas”

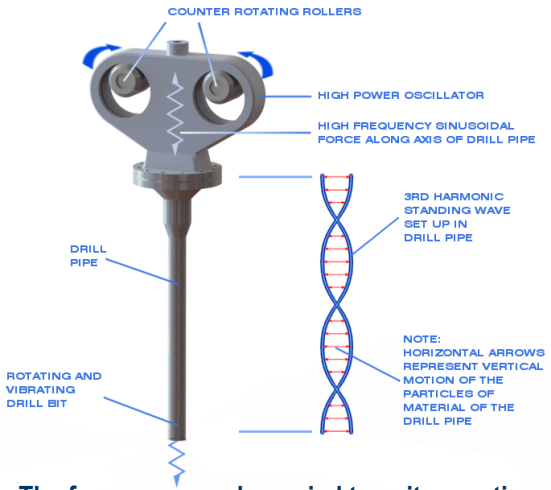
Rotary-Sonic Drilling Method

Advantages:

- Good in hard and soft rock
- Continuous core
- Limited drilling fluids needed
- Very limited cuttings discharged
- Relatively fast drilling

Disadvantages:

- Limited availability in some areas
- More expensive



The frequency can be varied to suit operation conditions and is generally between 50 and 160 hertz (cycles per second).

Sonic drill rig looks like a conventional air rotary drill rig, but the big difference is in the drill head, which contains mechanisms necessary for standard rotary motion plus an oscillator which causes a high frequency force to be transmitted along the drill string. The drill bit is physically vibrating up and down in addition to being pushed down and rotated.

QUESTIONS