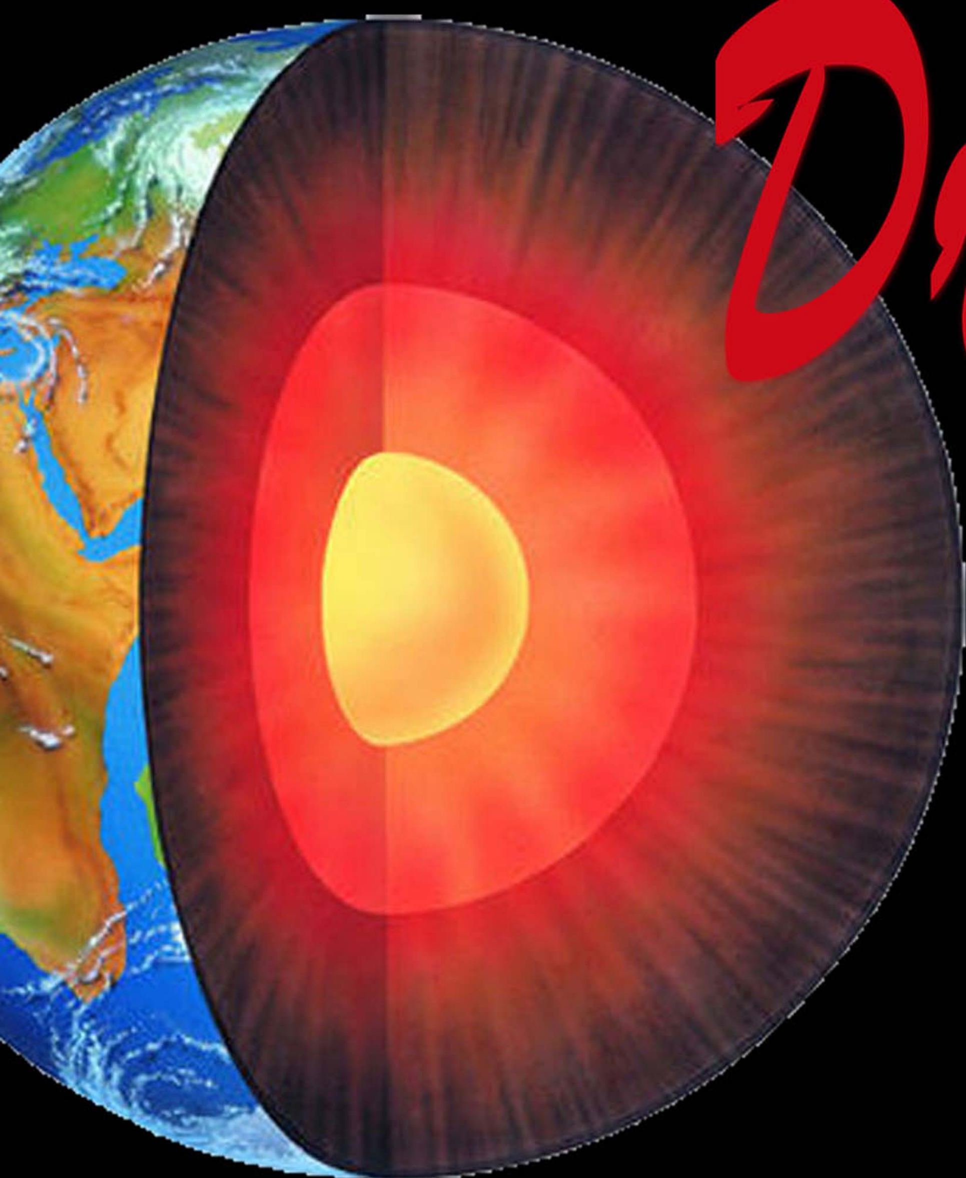


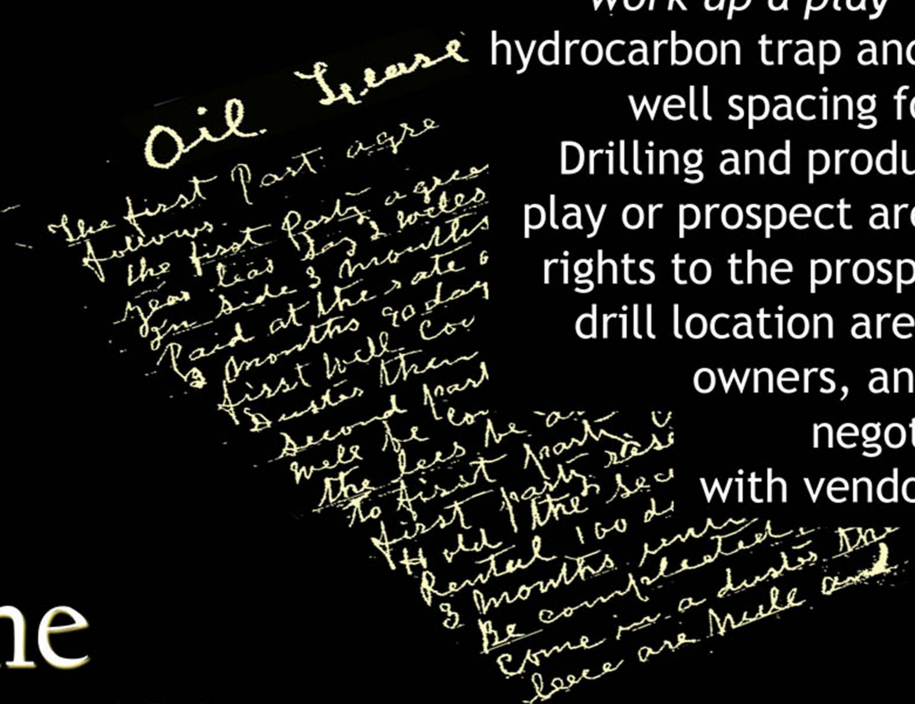
Drilling for Oil and Gas

Formula for success:
rise early, work hard, strike oil.

J. Paul Getty
Founder, Getty Oil Company

Step 1. Acquiring Rights and Access

Exploration geophysicists and geologists *"work up a play"* - identify a potential hydrocarbon trap and determine potential well spacing for field development. Drilling and production budgets for the play or prospect are calculated. Mineral rights to the prospect and access to the drill location are negotiated with land owners, and drilling services are negotiated and contracted with vendors. Required permits are obtained from regulatory agencies.



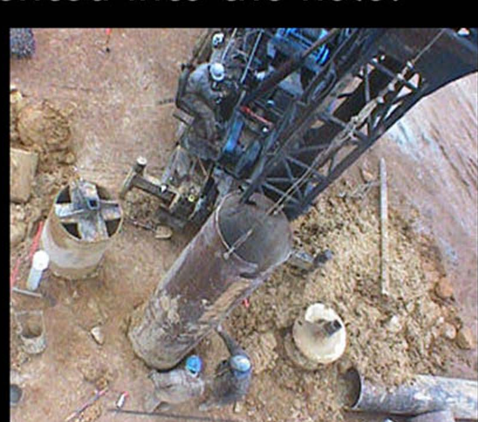
Step 2. Preparing the Site

After a well is *"staked"* (surveyed), the site is prepared for access, accomodations, and drilling rig equipment. But before the drilling rig is moved in, a pilot borehole is augered and a cement cellar is constructed to house blowout prevention equipment below the derrick floor. Proper site preparation ensures the security and safety of the drilling operations.

(photograph courtesy of www.geomatics.net)

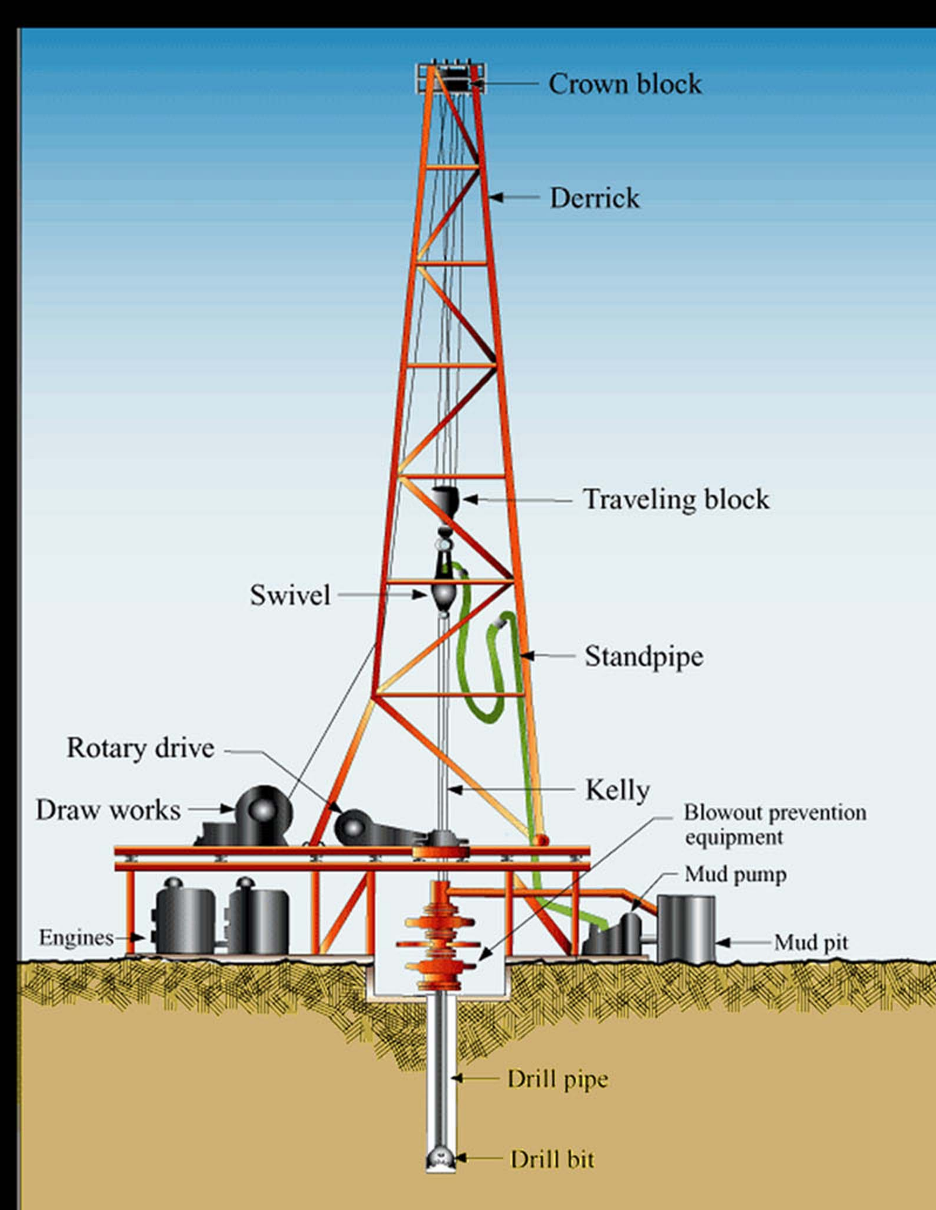
Step 3. Setting the Conductor Pipe

A large-diameter *conductor hole* 20 to 50 feet deep is augered and steel *conductor pipe* of 16 to 30 inch diameter is cemented into the hole. The conductor pipe prevents the hole from washing out around the drill rig floor, which could cause the drilling rig to collapse.



Setting conductor pipe in the conductor hole using a truck-mounted bucket auger rig.

(photograph courtesy of U.S. Department of Labor, www.osha.gov)



Step 4. Rigging Up

After the drilling rig is moved onto the wellsite, the derrick mast is raised, mud pumps are connected, and the engines, rotary drive, and associated machinery are set up. Before the well is *"spudded"* (the initiation of drilling), two operational boreholes are drilled: a *"rathole"* to hold the *"kelly"* (the steel bar used to transmit rotary motion to the drillstring) and a *"mousehole"* to hold a *"joint"* (drill pipe). Using these standby boreholes facilitates drillstring connections and provides temporary storage for the kelly during periods when the wellbore is standing open.

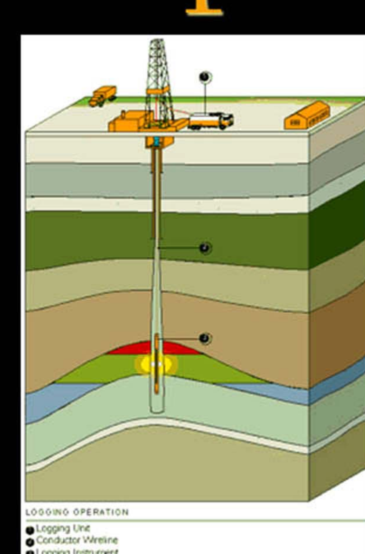
(modified from California Department of Conservation, www.consrv.ca.gov)

(photograph: National Energy Policy, 2001)

Step 5. Spudding and Drilling

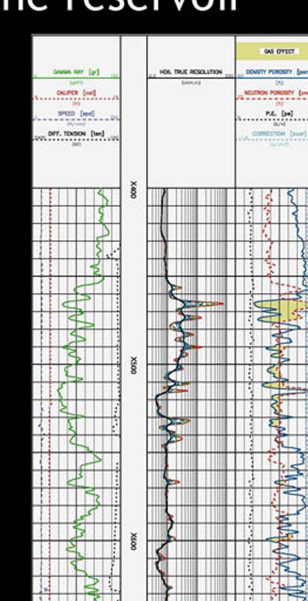
The driller lowers the *"drilling assembly" - the* kelly, drill pipe, drill collar (for added weight on the bit), and drill bit - to the bottom of the conductor hole and begins drilling. When the drillstring has bored down its full length, another joint is added to the top of the drillstring and drilling is resumed. Rotary drilling requires that drill *"cuttings"*, the loosened rock and mud from the digging action of the bit, be removed from the bottom of the wellbore up to the surface where the cuttings are disposed. Water- or oil-based slurry, referred to as *"drilling mud"*, is used to remove cuttings. Minerals and chemicals may be added to the drilling mud to help control downhole pressures and reduce caving potential. Besides removing drill cuttings and holding back subsurface pressures, the drilling mud also cools the bit. With a properly designed mud system, wells can be drilled to 30,000 feet where subsurface pressures reach over 10,000 psi and temperatures over 400 degrees F.

Step 6. Well Logging



(diagram courtesy of Baker Hughes Incorporated, www.bakerhughes.com)

After reaching the targeted *"TD"* (total depth), the wellbore is *"logged"* - a foot-by-foot downhole measurement of physical properties of the reservoir rock and its fluids. Properties measured include natural radiation of reservoir rock; how vibrational waves are transmitted through the reservoir rock; conductivity of reservoir fluids; and geometry of reservoir rock layers. Logging data provide descriptive and quantitative measurements that are used to answer two basic questions: Does the formation contain hydrocarbons? Will hydrocarbon recovery be profitable?



Example of high-definition induction log.
(courtesy of Baker Hughes Incorporated, www.bakerhughes.com)

Step 7. Completing the Well

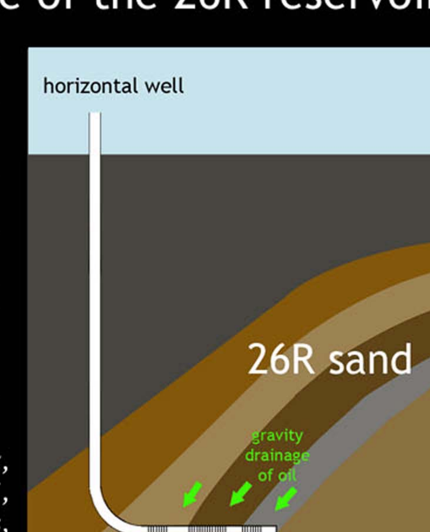
If the logging data confirm that the targeted formation is a *"pay"* zone - that is, economically producible hydrocarbons are present - then steel *"casing"* (pipes) are set inside the wellbore and cemented in place to hold back the formation and keep the hole from collapsing. The casing has *"perforations"* (slots or holes of engineered size and spacing) at the depth of the pay zone, enabling crude oil and natural gas to enter the wellbore and flow or be pumped to the surface.

(photograph courtesy of U.S. Department of Labor, www.osha.gov)

Naval Petroleum Reserve No. 1

Horizontal Drilling

Normally a horizontal well is placed parallel to the bedding of a horizontal oil zone. At Elk Hills, however, a unique horizontal application presented itself in the steeply dipping (up to 60 degrees) reservoir known as the 26R reservoir. In this case, the horizontal boreholes cut across the thick beds at the base of the 26R reservoir, 60 feet above the oil-water contact. The steep dips of the 26R induced a strong gravity drive downward into the long horizontal wells, which yielded an exceptionally high oil recovery rate of over 60 percent for the reservoir. Engineers estimated that more than 240 million barrels of oil would be recovered from this technique as opposed to 212 million barrels from conventional vertical wells.



(diagram modified from F.J. Gangle, K.L. Schultz, G.S. McJonnet, and N. Ezekwe, 1995, Society of Petroleum Engineers, Drilling & Completion)

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