

Riserless Drilling: The Technique to Contain Shallow Hazards in Deepwater Exploration Wells

Pratap V. Nair

Retired Exploration Petroleum Geologist, Devidarshan, Kawdiar, Thiruvananthapuram - 695003, Kerala, India

Email: [vpratapnair\[at\]gmail.com](mailto:vpratapnair[at]gmail.com)

Abstract: Deepwater exploration often faces tight drilling margins from the mudline, with pelagic rocks and an overburden-parallel pore-pressure profile. Because seismic imaging cannot effectively resolve shallow-water overpressured sands, a precisely planned well is essential to reach the planned total depth. In deepwater drilling, the marine drilling riser transports fluids from the seafloor to the drill floor of the mobile offshore drilling unit. Typically, the first few thousand feet of drilling are performed riserless, meaning no riser is used to manage shallow-water overpressured sands and narrow drilling margins. During risered drilling, drill cuttings and mud are brought up to the drill floor, whereas in riserless drilling, these returns are released onto the seabed. The dual-gradient mud system mitigates shallow hazards and enables safe drilling to greater depths in deeper waters while keeping costs under control. This technology enables oil and gas exploration in deep waters.

Keywords: Deepwater, Narrow margin, Pore pressure, Challenges, Shallow water flow, Riserless, U tubing

1. Introduction

Almost three-fourths of Earth's area is oceanic, which has proved to be an oil and gas province, especially in deep waters. Globally, deepwater oil and gas reservoirs are predominantly located in passive margin basins. As a result, these basins largely mirror the geological features of deepwater reservoirs. Offshore exploration remains limited worldwide, with about 43% of undiscovered offshore oil and gas resources still untapped¹. Most new marine oil and gas reserves come from deepwater discoveries, and more lithologic reservoirs are being identified. These discoveries are primarily found in Mesozoic–Cenozoic resources worldwide.

Advancing technology is imperative for deepwater exploration and production. When executed with appropriate precision, this dual-gradient methodology balances subsurface pressure conditions to mitigate shallow hazards and enhance wellbore structural integrity, enabling the initial casing string to be set at substantially greater depths than with conventional drilling methods. Riserless drilling has become an increasingly critical component of deepwater operations. This significance is particularly pronounced in regions characterised by shallow gas deposits and shallow-water flow hazards. The technique, the primary focus of this paper, uses an open-ended circulating configuration in which the expendable weighted drilling fluid is released at the seafloor. This is commonly called the "pump and dump" procedure. The paper outlines the fundamental principles of riserless drilling methodology and provides a concise examination of the challenges inherent in conventional marine riser drilling systems used in deep-water environments. This matters because it addresses a key aspect of accessing deeper waters and greater depths with top-tier technology.

2. Deepwater Frontier

The offshore frontier represents India's most significant opportunity for major new discoveries. Offshore basins account for 51% of the aggregate basin area and 59% of the

total anticipated resource reserves. Deepwater regions, which cover 76% of the offshore territory, remain underexplored largely because of formidable technical challenges and the substantial fiscal requirements for subsea engineering.

India's future oil and gas prospects largely depend on offshore exploration. The country has deepwater and ultra-deepwater basins where water depths reach up to 3,000 meters. These basins, along the eastern and western coasts, are believed to contain over 5,600 MMTOE of hydrocarbons².

3. Exploration Results

Nelson et al. (2013)³ found that deepwater has become the main source of new oil and gas discoveries globally, representing over 50% of all conventional reserves, totalling 170 billion Boe. Additionally, six-year trend data from 2007 to 2012 indicate that offshore hydrocarbon discoveries are generally larger, especially in deepwater, where the average size reached 230 million Boe. This is roughly ten times the average onshore discovery size during the same period, at about 20 million Boe.

Recent discoveries in the Cauvery, Mahanadi, and Andaman basins have further supported this potential. With a vast coastline encompassing multiple offshore sedimentary tracts, the potential to discover super basins is immense.

4. Deepwater Geological Setting

Deepwater settings generally share common features. These include being shale-prone and experiencing less faulting and uplift. Evidence for additional mechanisms of overpressure generation, beyond disequilibrium compaction, is limited. These features shape the pressure regime. Deepwater environments are more susceptible to shale formation than shallow-water or shelf settings. Shales tend to be more pelagic and clay-rich (Figure 1).

Reservoirs are often isolated, although seismic imaging can reveal connected deep-sea fan systems (Figure 2). Deepwater

shales usually form from pelagic deposition and tend to have low permeability. As a result, overpressure begins at shallower depths compared to a more shelfal well with the same sedimentation rate⁵.

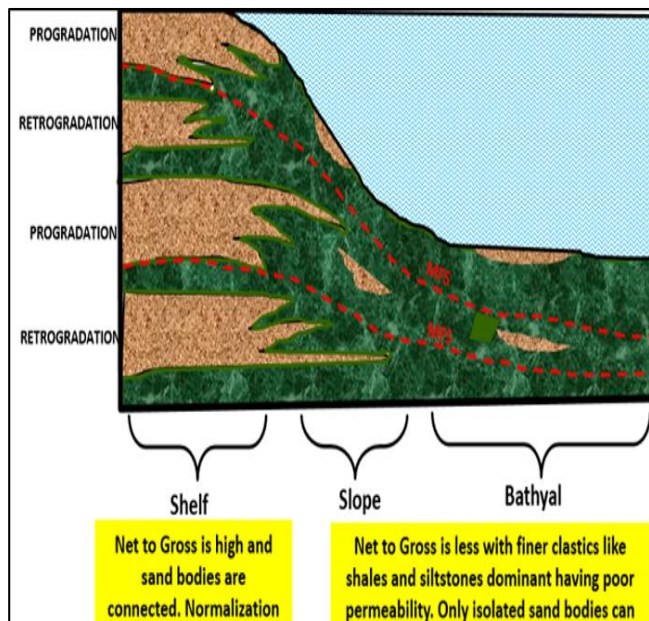


Figure 1: Depositional setup from continental shelf to Deepwater⁴

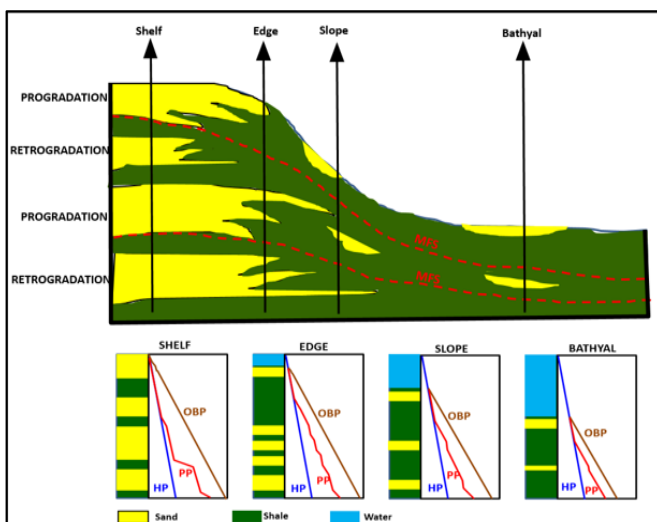


Figure 2: Illustration of the variation in subsurface pore pressure profiles with changing lithofacies along a cross-section extending from shelf to bathyal environments; MFS = maximum flooding surface⁴

From a geological perspective, depositional basins characterised by rapid subsidence and elevated sedimentation rates present optimal conditions for the occurrence of the SWF phenomenon. In environments susceptible to SWF, sand deposits are predominantly associated with Pleistocene-age sediments and are typically found within channel, slump, debris flow, and turbidite sand systems, as well as chaotic zones in the LST units.

The main cause of SWF sand eruptions is high water pressure in the sandy formation below the impermeable layer. Three main mechanisms contribute to SWF formation: compaction

disequilibrium, differential compaction, and structural overpressuring.

5. Challenges in Deepwater

For instance, deepwater pore-pressure regimes are likely to be overburden-parallel (Figure 3). These basic rules, derived from deepwater geology, enable more accurate well planning and constrain pressure interpretations derived from seismic velocity data. SWF poses a serious shallow hazard because the combination of overpressures and low formation fracture strength creates a narrow drilling margin (NMD). Excessive ECD could risk inducing fractures in the formation and allow overpressures to transmit to the seabed through the resulting fracture pathways (Figure 3).

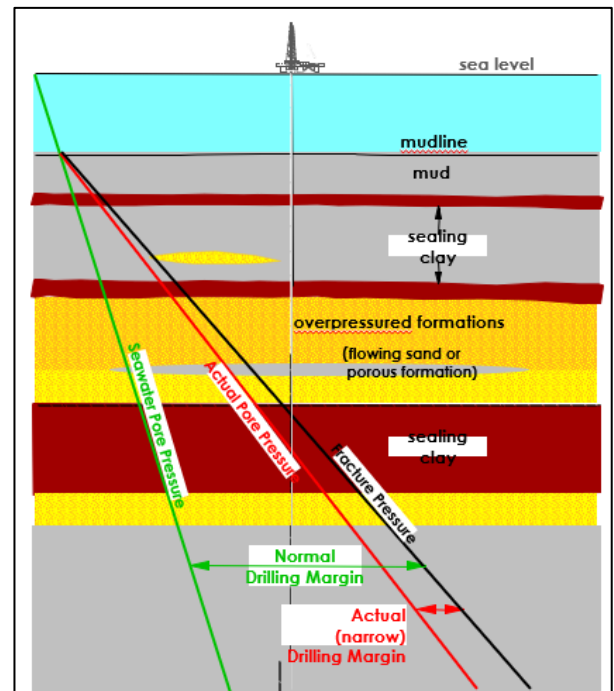


Figure 3: Typical Deepwater Pressure Profile⁵

Tectonic stresses are generally extensional, with some instances of transpressional activity, as seen in West Africa. Faulting occurrences are relatively rare, and uplift is minimal or absent. These deepwater shales typically originate from pelagic sedimentation, resulting in low permeability. Shallow subsurface formations in deepwater environments are characterised by low overburden pressure, poor cementation, and reduced fracture-pressure gradients within the geological structure. The optimal pressure window between formation pore pressure and formation fracture pressure is known as the drilling window. Pore pressure and fracture gradient estimates are critical in deepwater because well costs are high and pore-pressure-related problems are difficult to handle due to a narrow drilling window (Figure 4).

SWF can cause casing deformation, sand formation deterioration, compromised well structural integrity, and potentially catastrophic MODU damage, with subsequent well abandonment in a worst-case scenario.

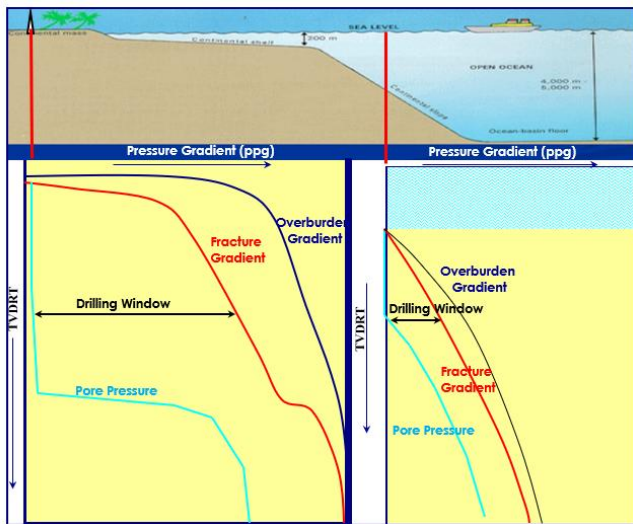


Figure 4: Narrow margin in deepwater between pore and fracture pressures

The occurrence of overpressure at shallower depths than in shelf environments with similar sedimentation rates increases the risk of shallow-water flows⁶. In regions like Green Canyon, Garden Banks, and Mississippi Canyon in the Gulf of Mexico, overpressure can occur just hundreds of feet below the seabed because sedimentation rates exceeded 2000 meters per million years during the Pleistocene⁷ (Figure 5). Data from the Nile Delta indicates that in deepwater zones, pore pressure profiles within thick shale layers tend to run parallel to the overburden, primarily due to disequilibrium compaction, causing pore pressure to mirror the overlying load⁷.



Figure 5: Shallow water flow in Gulf of Mexico^{8,9}

Shallow drilling hazards arise from water flow from overpressured shallow sands beneath the mudline in deepwater areas. Overpressure in these sands is mainly caused by high sedimentation rates and an impermeable mud or clay seal in condensed sections. When sand bodies are isolated within shale or mudstone, water cannot escape easily because surrounding low-permeability sediments restrict drainage. Moreover, rapid sedimentation from overlying layers applies significant pressure, causing these isolated, water-rich bodies to become overpressured.

Shallow water flows (SWF) are costly, and seismic imaging is limited by the small and highly variable acoustic-

impedance contrast between sands and shales. Shallow overpressures typically begin near the mudline and tend to grow linearly with depth BML. Often, sand overpressures are not in equilibrium with surrounding shales, so well design must account for these factors. Riserless drilling is the most effective approach, as it reduces the number of casings and helps prevent SWF from becoming a major obstacle (Figure 6).

Deepwater drilling operations face significant obstacles, including constrained pore-fracture pressure margins, wellbore structural instability, and ecological impacts from drilling effluent discharge.

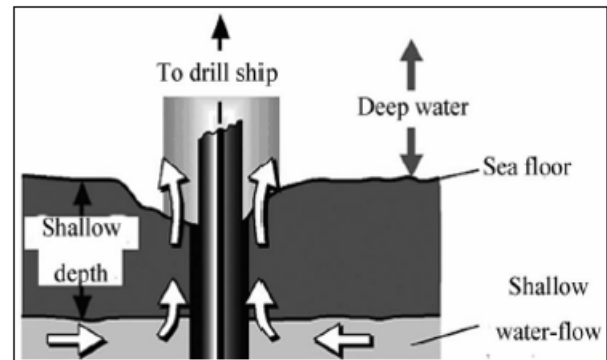


Figure 6: Shallow water flow just below the seafloor¹⁰

6. Risered vs. Riserless Drilling

Conventional drilling methods rely on hydrostatic pressure from a single-density drilling fluid column inside a marine riser assembly. Maintaining accurate and stable pressure in this crucial range was challenging, often leading to fluid influxes (kicks), fluid losses, or wellbore instability. Additionally, the "physical and economic limitations of standard riser systems" posed a significant hurdle.

In risered drilling, the annulus, which is the space between the drill pipe and the surrounding open hole, casing, or riser, remains consistently isolated from seawater. This condition facilitates circulation of a fluid with relatively uniform density, resulting in a single annular pressure-gradient profile.

Conversely, in riserless drilling, the system is exposed to seawater above the mudline, with returns directed to the seafloor. This configuration creates a natural dual gradient system, where a denser fluid composed of drilling mud, seawater, and cuttings occupies the annulus from the mudline to the bottom of the hole, while seawater is present above the mudline. Consequently, this arrangement produces a dual pressure-gradient profile: pressure increases along a hydrostatic gradient up to the mudline, and below the mudline, it increases along a steeper gradient influenced by the ambient mud weight (Figure 7).

In a risered drilling configuration, the pressure gradient within the wellbore is measured with respect to the drill floor. This increases pressure at the mudline, calculated as the product of mud density, seawater density, water depth, and a constant unit. The increased backpressure at the mudline consequently reduces the drilling distance required between casing points.

Conversely, riserless drilling allows exploration of shallower well sections without requiring an additional casing string.

Figures 8 and 9 illustrate a theoretical pore and fracture pressure profile for a deep-water well, along with the required mud weights to drill through the shallow interval.

In riserless mode (Figure 8), an additional casing string is required to manage the shallow pore-pressure ramp, as indicated by the red star. Conversely, this same interval can be drilled in riserless mode without supplementary casing, as shown in Figure 9.

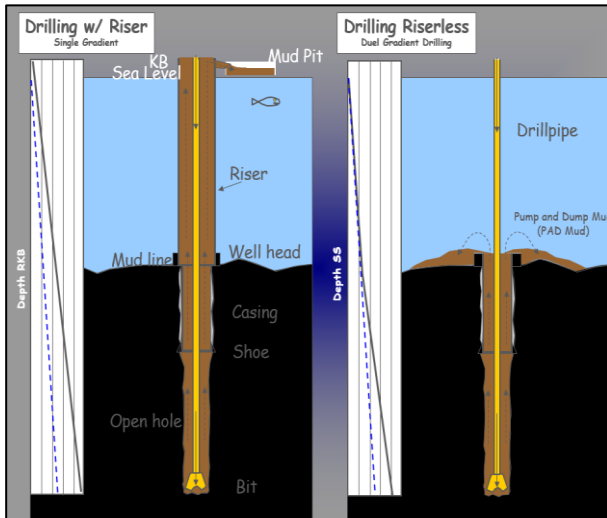


Figure 7: Schematic on drilling with riser and riserless

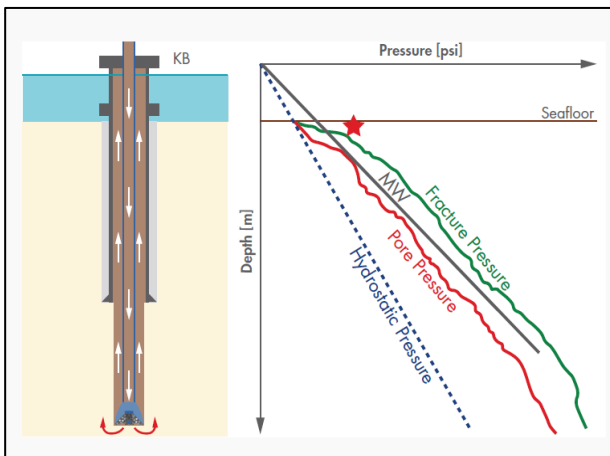


Figure 8: Schematic illustration of riserless drilling setup with PP-FG plot.

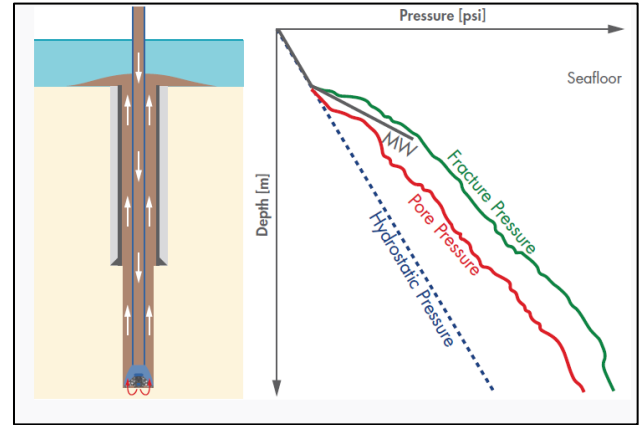


Figure 9: Schematic illustration of riserless drilling setup with PP-FG plot

7. U-tubing effect

The behaviour of one of the fluid columns can be used to describe what is happening on the other side of the fluid column if two fluid columns are connected at the bottom. In the oil field, this situation is commonly described as a “U-tube” in basic physics.

In the oil field, especially in the drilling business, a “U-tube” can be considered as a string of pipe (drill pipe and tubing) in a wellbore, and fluids are able to pass inside the string of pipe (drill pipe and tubing) and the annulus (area between the wellbore and the string of pipe). Figure 10 demonstrates the “U-tube” in the drilling parlance. Because of the pressure imbalance inside the drilling string and the well annulus, the U-tubing effect occurs¹¹.

In riserless drilling, as long as mud density and height of the column remain the same, pressure in both limbs of the U-tube will be equal and hence no U-tubing effect¹² (Figure 11).

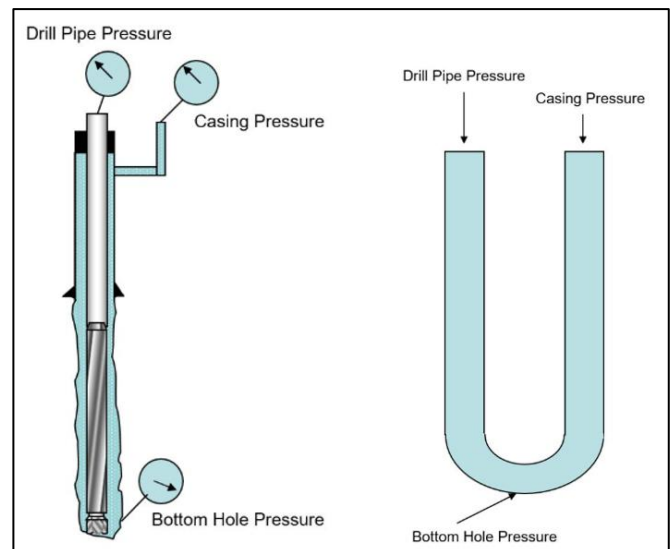
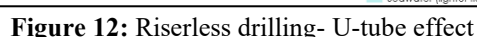


Figure 10: U-tube concept applied to drilling



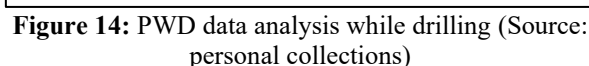
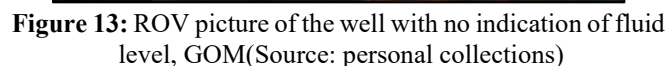
The equivalent fluid density in the drill string and column length is greater than the equivalent fluid density in the annulus; pressure is unequal in both limbs, causing flow due to the U-tubing effect (Figure 12). Because mud pressure in the drill string is greater than in the annulus, backflow into the drill string is averted during connections and pump-off. DGD in riserless drilling helps manage the narrow drilling margin and promotes wellbore stability.

Water flow observations are pore pressure measurements. If the well flows water, the pore pressure is at least ESD. If seawater is the drilling fluid, ESD is close to hydrostatic. Mud pumps are off at connection, and depths above the last no-flow connection can be associated with hydrostatic water pressure. If other logs such as resistivity or sonic are available, one can pick a compaction trend and calibrate it.



The basic tools deployed while drilling riserless sections include an APWD tool, which provides ECD at the bit along with other hydraulic data, MWD, and ROV runs on the seafloor during connections and whenever desired, in addition to continuous wellhead monitoring (Figures 13 and 14). ROV videos are tricky, and an expert must be involved. Never

interpret PWD data in isolation; always combine downhole data with surface drilling parameters and think in terms of drilling processes in real time. Frequently, high-resolution while-drilling seismic data is acquired, and a basic well log suite of gamma and resistivity in the large-diameter hole is also acquired (Figure 15). It provides an opportunity to establish a compaction trend. Integrating APWD data, subsurface geology (presence or absence of permeable lithology), and real-time pore pressure trends are strongly recommended when monitoring shallow water or gas sands flow events during riserless drilling.



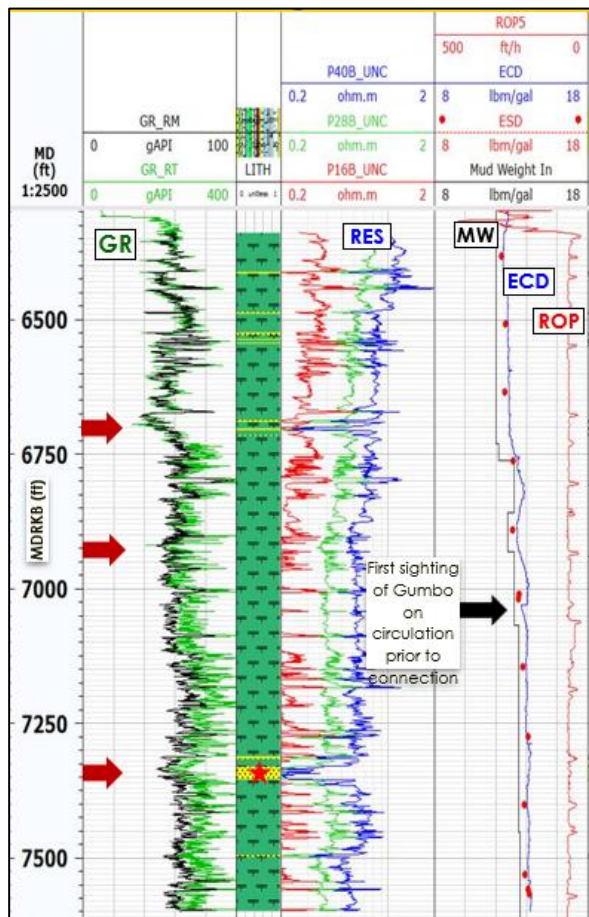


Figure 15: Real-time well and drilling logs (Source: personal collections)

Figure 16 shows a typical real-time pore pressure plot relative to the derrick floor and mud line, illustrating TVD normalisation. LWD, MWD, PWD, and ROV data were used in real time to generate the pore pressure plot. When riserless, ensure you understand whether equivalent mud weights were computed with respect to kb or ml. The overpressure plot is an alternative to normalising to TVD ml. This brings out small but meaningful variations in ECD, PP, etc., when riserless, especially in deep water.

11. TVD Normalisations

Instead of normalising the pressure values to TVD kb, subtract the seafloor pressure and compute equivalent mud weights normalised to TVD ml (Figure 17).

This highlights small but meaningful variations in ECD, pore pressure, etc., when riserless, especially in deepwater, which needs to be carefully monitored. Shallow overpressures typically initiate near the mudline and tend to increase linearly as depth below mudline (BML) increases. This is necessary for dual-gradient drilling, which enables us to manage the narrow drilling margin successfully.

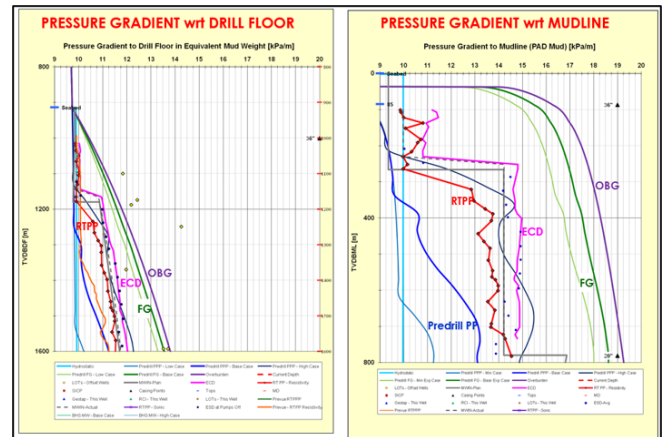


Figure 16: TVD ml normalisation in a deepwater well

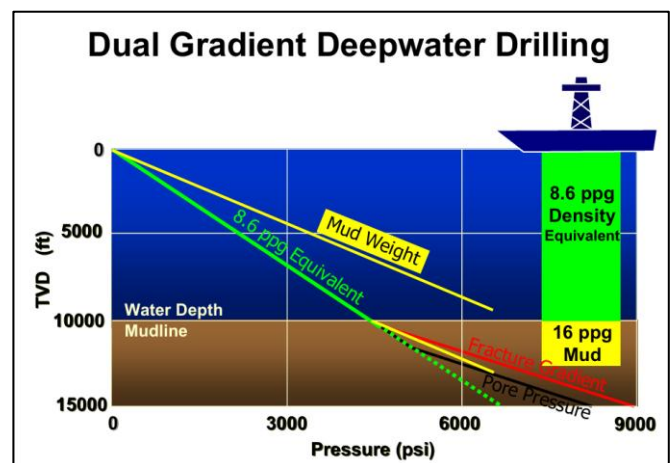


Figure 17: Dual water gradient drilling pressure profile¹³

12. Typical Operations in Riserless Drilling

As drilling extends into deeper waters, new technologies and methods are essential in the Gulf of Mexico. Riserless drilling systems like the DKD approach enable optimal placement of the surface casing shoe, improving deepwater well success in the region. In contrast, traditional seawater sweeps (SWS) and calcium chloride drilling typically result in shallower shoe placement and lower FIT results.

The traditional SWS drilling method involves drilling the surface hole and installing the surface casing, usually 20 or 22 inches in diameter (Figure 18). It is essential to keep kill fluid on standby. If pad fluid is required, it is stored nearby or mixed from the base kill fluid once TD is reached. At TD, circulate the pad mud, then lower and cement the surface pipe. The final depth of the seawater-drilled interval is set when the planned TD is reached, the hole begins to close on the string due to increased pore pressures, or hazardous flow or suspected problem zones are encountered.

Using seawater in the SWS method provides distinct benefits. It is readily available at the site and offers a budget-friendly solution. However, relying solely on SWS drilling can create challenges, especially with longer

drilling time and higher costs for deeper wells. SWS drilling remains the most cost-effective and practical approach for surface intervals, as long as managing shallow flows and

lower FITs is feasible. In more complex cases, advanced techniques like DKD may yield better outcomes.

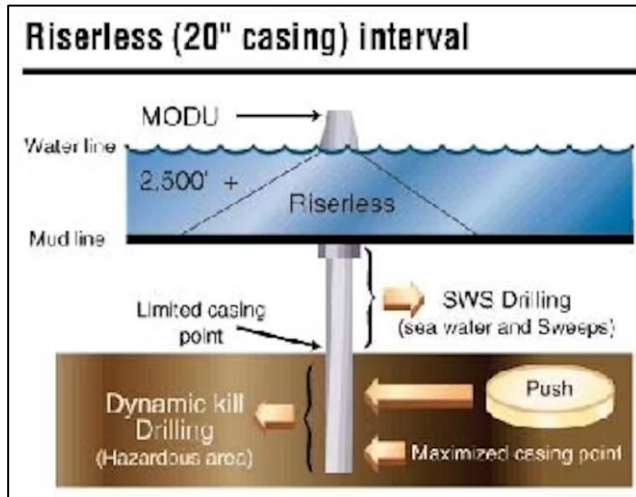


Figure 18: Schematic illustration of riserless drilling setup¹⁴

13. Pump and Dump Seabed Returns

Weighted mud serves as the drilling fluid and is discharged to the seafloor with the cuttings. This creates a natural dual-gradient system: seawater above the mudline and weighted mud below. It is acceptable for mud weight to exceed the fracture gradient (when the fracture gradient is computed relative to TVD kb). Pore-pressure analysis can help manage mud consumption, which is critical in logistically constrained situations. Advanced pumps can enable mud recovery in riserless drilling, though it's expensive (Figure 19). Seabed Returns Riserless Technique mud weight equivalent changes with increasing depth. EMW downhole increases without increasing EMW at the shoe¹⁴.

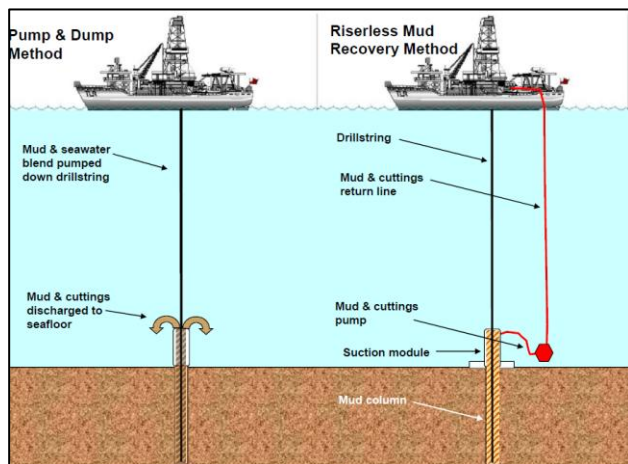


Figure 19: Riserless dual gradient drilling¹⁵

Riserless drilling enables hydrocarbon exploration in water depths previously considered impossible. Ultra-Deepwater Riserless Mud Circulation with Dual Gradient Drilling, known as the Riserless mud recovery method, has been developed to drill in ultra-deep water depths, say, up to 3657 m¹⁶. Dual-gradient riserless drilling improves cost-effectiveness and access to deeper depths in ultra-deep waters, reducing risk in deepwater exploration drilling. This is not the

focus of the paper, but it should be considered soon, given the ambitious Samudra Manthan scheme in vogue in our country.

Riserless drilling is anticipated to become the predominant methodology for deepwater drilling operations in the near future, owing to its distinctive operational attributes. Currently, scholarly investigations focus exclusively on either the seawater section or the formation section in isolation, rather than comprehensively analysing the entire drill string to examine the dynamic behaviour inherent in riserless drilling operations.

14. Kill mud

After drilling the riserless section, heavy mud is typically pumped to stop flow and maintain borehole stability. Keep in mind the dual-gradient system, which allows mud weight to be significantly higher than the expected fracture gradient. Using riserless drilling with weighted mud or DKD mud is crucial for safely and cost-effectively drilling deep-water wells in regions prone to shallow-water flow (SWF).

15. Concluding Remarks

Deepwater exploration drilling faces challenges in seismically detecting shallow water and overpressured gas sands near the mudline. Common manifestations of pore pressure include shallow water and gas sands that reduce the drilling margin. The narrow drilling margin, accentuated by reduced overburden due to the water column, challenges top-hole well construction. However, safe well design and execution can reduce costs by drilling the top-hole section riserless. Riserless drilling effectively provides a dual-gradient system that helps manage the narrow drilling margin. The benefits include the ability to regulate subsurface pressure conditions and set the initial casing string at greater depth.

Nomenclature

Boe = barrels of oil equivalent
MMTOE = million metric tonnes of oil equivalent
MFS = maximum flooding surface
SWF = shallow water flows
LST = lowstand systems tract
NMD = narrow margin drilling
BML = below mud line
APWD = annular pressure while drilling
ECD = equivalent circulating density
MWD = measurement while drilling
LWD = logging while drilling
ROV = remote operated vehicle
PWD = pressure while drilling
GOM = Gulf of Mexico
PP = pore pressure
FG = Fracture gradient
TD = total depth
TVD = true vertical depth
TVD ml = true vertical depth mud line
TVD kb = true vertical depth Kelly bush
MODU = mobile offshore drilling unit
DGD = Dual-gradient drilling
DKD = dynamic kill drilling
SWS = seawater and sweeps

FIT = formation integrity test
EMW = equivalent mud weight

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Author Profile



Pratap Vikraman Nair earned his B.Sc. Hons. and M.Sc. in Applied Geology from the Indian School of Mines in 1981 and 1983, both with full honours. He also holds a Doctorate in Petroleum Geology. From 1983 to 2007, he worked at ONGC Ltd., India's national oil company, serving as a petroleum geologist across most of the country's sedimentary basins. In 2007, he joined Royal Dutch Shell (RDS) and worked on assignments in the Netherlands, Nigeria, India, and Malaysia before retiring in 2021. As a Principal Technical Expert, he contributed to several frontier basin campaigns worldwide. Currently, he consults for Gujarat National Resources Ltd, Adani Welspun Ltd, and Oil India Ltd. In addition to Petroleum Geology, he specialised in the niche domains of Geomechanics, Geohazards, and Pore Pressure Prediction. He has authored 154 technical papers in renowned international journals and has received awards from ONGC Ltd and RDS for his technical achievements, including nomination for the National Mineral Award in India in 2000.