

Drilling through salt

In recent years, an increasing number of oil and gas projects involving drilling through salt have been presented by different exploration companies. It is important for underwriters, lawyers, regulators, financiers and engineers to have a clear understanding of the risks involved in order to assess their real exposure.

Most people in the oil production business believe the era of easy oil discovery is over, and indeed many of today's oil & gas reservoirs are to be found in increasingly difficult locations with complex geologies. These locations include large oil & gas reservoirs associated with salt structures: the impermeable nature of salt means that it can serve as a hydrocarbon trap.

The (Re)Insurance sector still views these projects as extremely risky, but our objective is to include these new prospects in our current portfolios as carefully as possible. SCOR Global P&C's Business Solutions division has already dealt with a few subsalt drilling projects.

Our task is to understand the risk exposure and, in conjunction with our clients - the Insureds - , determine adequate solutions. Communication, and working closely with our clients, are the keys to success.

This technical newsletter is a summary of a paper published by SCOR Global P&C at the request of the Joint Rig Committee of Lloyd's, an association representing the interests of insurers writing offshore energy risks in the London market.

➤ Risks associated with drilling through salt

Until 1980, it was common practice for explorationists not to seek hydrocarbons below salt, as they believed that quality reservoirs did not exist below salt layers. At that time, the imaging of salt bodies was unsatisfactory.

In recent years, companies have made major efforts to enhance the understanding of these salt bodies. Thus, in less than two decades, salt has morphed from foe to friend.

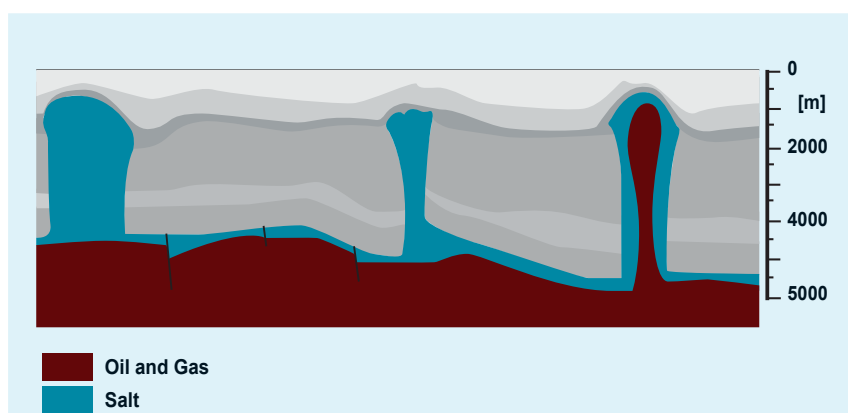
Drilling contractors are still looking for improvements in drilling performance, in order to lower the risks involved. Progress in this area is certain to continue and will result in significant new tools and techniques. For the time being, however, drilling through salt remains a relatively new practice, and is challenging and risky.

Salt structures and traps

Salt is one of the most effective agents in nature for trapping oil and gas: as a ductile material, it can move and deform surrounding sediments, creating traps. Salt is also impermeable to hydrocarbons and acts as a seal.

A salt accumulation is formed through the evaporation of seawater, and can reach thousands of feet in thickness. Over

time, the layer is covered with deposited sediment, becoming buried under an increasingly large overburden.

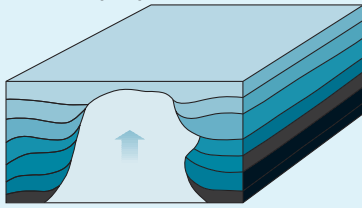


This drawing shows the geological profile through the Northwestern Basin of Germany, with some salt domes in blue and the oil and gas reservoirs in brown.

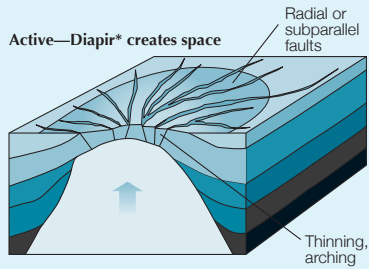
Source: Franz Kockel et al. (1996) - Geotektonischer Atlas von NVV - Deutschland Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover.

Process of flowing and rising salt

Passive - No space problem

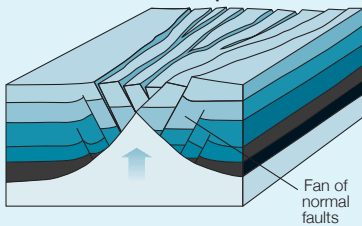


Active—Diapir* creates space



* Diapir is a type of intrusion in which a more mobile and ductily deformable material is forced into brittle overlying rock.

Reactive—Extension creates space



Flow of salt and Halokinesis

Salt is in many aspects unlike other sedimentary rocks: it is able to form at a geologically impressive sedimentation rate and does not compact or hardly compacts with depth. Most important, however, is its ability to deform plastically.

If the overlying sediments offer little resistance, the salt rises, creating characteristic domes, pillows and wedges that truncate upturned sedimentary layers. This process of flowing and rising salt – halokinesis – which may be observed in the Gulf of Mexico for example, is illustrated on the left.

Problems encountered when drilling through salt

As explained earlier, salt movement generates a wide variety of traps; therefore the industry has been repeatedly successful in discovering large hydrocarbon accumulations in these basins.

But salt diapirs have always been treated cautiously by operating companies because of their geological complexity, which creates an unusually high degree of uncertainty in terms of predicting lithology and pressure. This makes the planning and drilling of wells difficult and potentially expensive.

The real problem encountered when drilling through salt is linked to the properties of salt. Indeed the plastic flow under subsurface temperatures and pressures, along with low permeability (which make salt bodies effective hydrocarbon traps) present unique challenges for drilling operations.

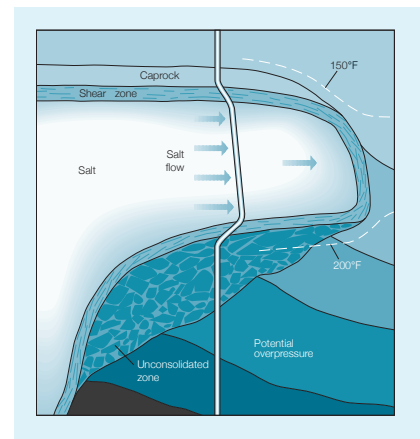
“Salt drilling is technically challenging” says Riaz Israel, Schlumberger senior drilling engineer, calling it “unforgiving” to drill through.

Adequate well design

Drilling across salt zones is subjected to tension, compression, burst and loads, which must be included in well design calculations.

It is also very important to propose solutions to prevent well collapse and to increase the strength of the protective pipe.

Wellbore displacement

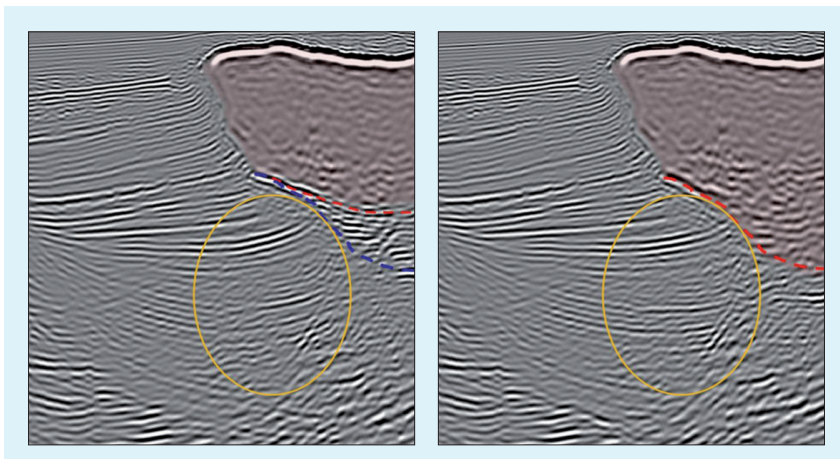


During the life of a well, salt movement can displace wellbore tubulars, possibly causing failure or restricted access, as illustrated above.

Challenges of subsalt imaging

But the main challenge is really to image through the salt structure, which is difficult due to the plastic properties of salt, and also to the three dimensional structure of

the salt dome. The top part of a salt structure almost always overshadows the traps, essentially putting them in a “shadow zone”, particularly beneath salt flanks.



The salt acts as a barrier and scatters the seismic waves used to build an image of the subsurface.

For example, an ambiguous positioning of the salt event can lead to different decisions concerning the well trajectory. The picture on the left, taken in the central Gulf of Mexico, illustrates the importance of imaging to proper well placement.

At present, the oil majors deploy a number of advanced techniques, which are available throughout the chain of geophysics expertise. These new technologies, along with their associated challenges, will be discussed in the following chapter.

➤ Technology and challenges involved in salt structure exploration

Industry seems to be taking a step back and reconsidering how to explore beneath complex salt basins. Advances in imaging and drilling will really change the way in which explorationists view salt bodies. Seen as impenetrable barriers, many structures are now proving to be rich reserves. And this new vision of subsalt is impacting Exploration & Production (E&P) decisions, from well planning and drilling to field delineation and development.

Seismic imaging principle

Seismic imaging is the first tool used to guide subsalt exploration and development, and is a three-step process:

- 1. Data Acquisition** - the gathering of seismic data in a geophysical survey.
- 2. Data Processing** - a mathematical step in which seismic data is transformed into a 2D or 3D image of the subsurface by means of highly complex algorithms and enormous computing power.
- 3. Seismic Interpretation** - the "translation" of the seismic image into geological terms by geologists and geophysicists.

All subsurface disciplines work in an integrated way (geologists, geomechanical engineers, petrophysicists, reservoir engineers, etc.) in order to build an adequate model mapping the complex geometries of salt bodies, but the role of the geophysicist is central to the pre-drill planning of these directional wells.

Challenges of subsalt imaging

There are different reasons for poor subsalt image quality and shadow zones: poor illumination, wrong velocity model, coherent noise interference, and imaging algorithm.

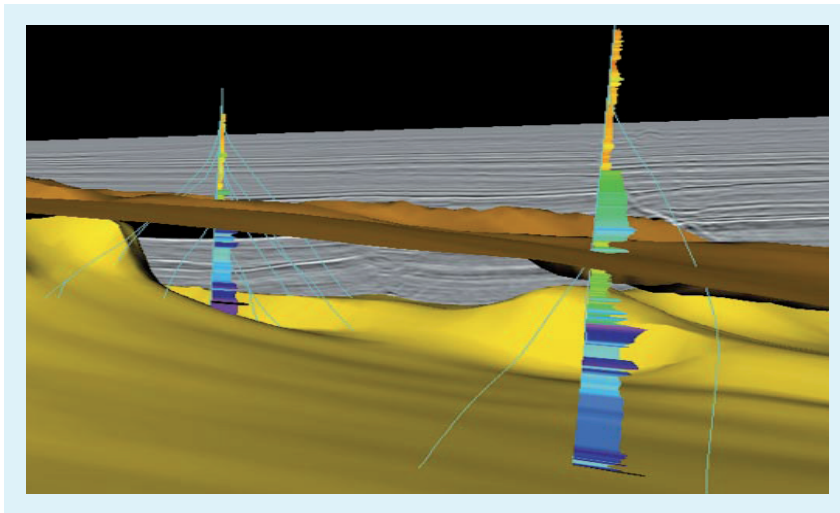
The reasons for poor subsalt imaging may include inappropriate acquisition parameters and a bad seismic survey, which is why the geophysical contractor must be chosen carefully.

If the salt causes distortion and scattering of the wavefield, the result is an image degradation that severely hinders the interpreter's ability to develop a complete and coherent understanding of the geology.

It is vital to resolve these problems in order to provide the best possible images of the subsurface, but this is challenging under considerable time constraints. Geologists also have a big role to play in subsalt imaging, which can be extremely sensitive to variations in salt interpretation. A very small error in salt geometry by the geologists can have a major impact on the outcome of the picture; the geological scenario has to fit the salt tectonics framework of the salt body.

The interaction between the various subsurface disciplines is well illustrated here: the top of salt feature in yellow has been interpreted on a seismic workstation, a panel of seismic data is shown as well as the well locations and deviated well trajectories.

Over the past five years, a great deal of effort has been focused on imaging beneath complex salt bodies, imaging subsalt structures under complex overburdens being the most difficult task in seismic exploration.



Innovative solutions to the proper imaging of salt bodies

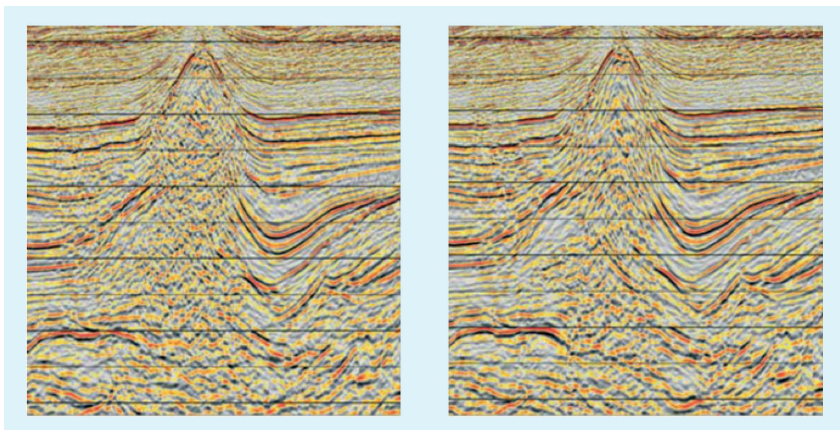
Due to the forces and movements illustrated in the seismic picture below, the stresses around and in salt structures can be high and troublesome to stabilize. Therefore, if borehole fluid pressure is lower

than salt strength, stress relaxation may significantly reduce openhole diameters. In some cases, relaxation causes borehole restrictions even before drilling and completion operations are finished.

To maintain the integrity of the boreholes, drilling fluid must minimize hole closure. In addition to this, drilling through salt is fast, but getting out of the salt and into the section below can be tricky due to pressure issues. Drillers have to be extremely cautious: drilling through salt sections requires that the particular properties of salt, its creep behavior and high solubility, be recognized and incorporated in the drilling plan.

Not very long ago, operators and contractors considered drilling through salt sections to be an extremely high-risk operation.

Nowadays, however, drilling through salt can be accomplished safely by applying knowledge of stresses and material behavior, using simple models that capture the critical aspects of borehole processes such as creep, heat flux, temperature sensitivity, and so on.

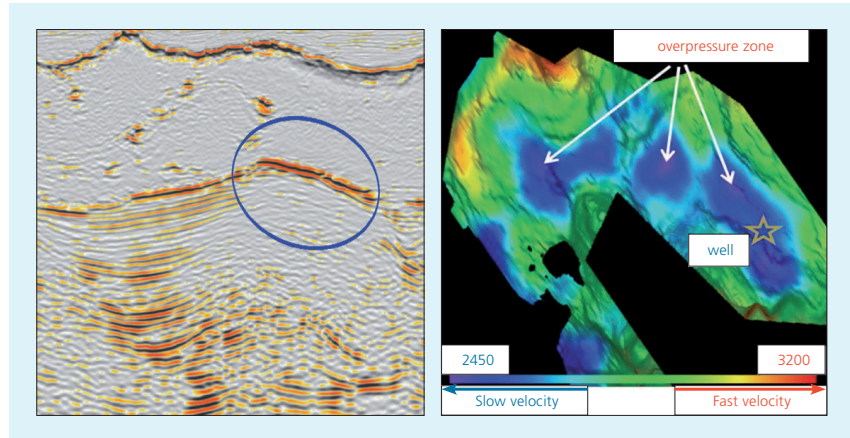


Subsalt overpressure

Subsalt overpressure may exist in some places, and extensive rubble or sheared zones are common underneath salt tongues or adjacent to diapirs.

Drilling into one of these is a common cause of a well blowout.

Thanks to improved subsalt images, it is nowadays possible to locate hazardous overpressure zones, which are indicated on the previous map. Conducting such studies should avoid most of problems of this nature during planning and drilling.

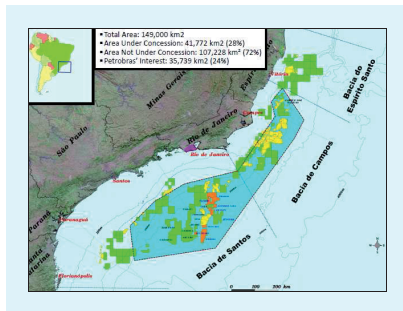


➤ Brazil: the major player in subsalt developments

When considering the risks linked to drilling through salt, the case study of Brazil is indispensable.

Indeed, in the past two years Brazil has discovered the largest oil deposits in the country's history and the world's most promising fields since the discoveries made in Kashagan, Kazakhstan in 2000. This has put Brazil well on its way to becoming a major producer in the future, but a number of technological and financial hurdles will have to be overcome first.

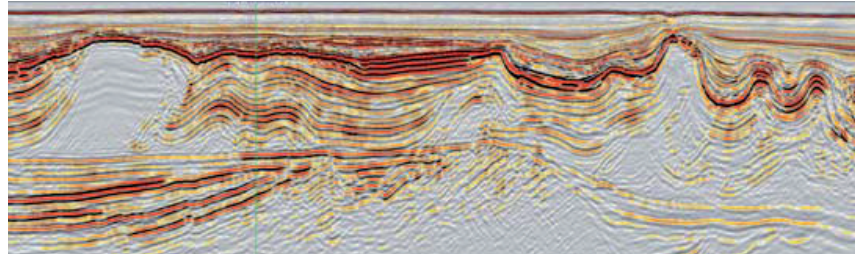
The finds are located in the Santos oil Basin, 300 km from the coast of Rio de Janeiro in south-eastern Brazil.



The pre-salt province, from the Santos sedimentary basin in the south, extending north through the Campos basin to reach the Espírito Santo basin, covers an area of approximately 149,000 km².

The first discovery – the giant Tupi field – was made in November 2007.

The Offshore Brazil Seismic image below reveals the subsalt structure around this Tupi discovery.

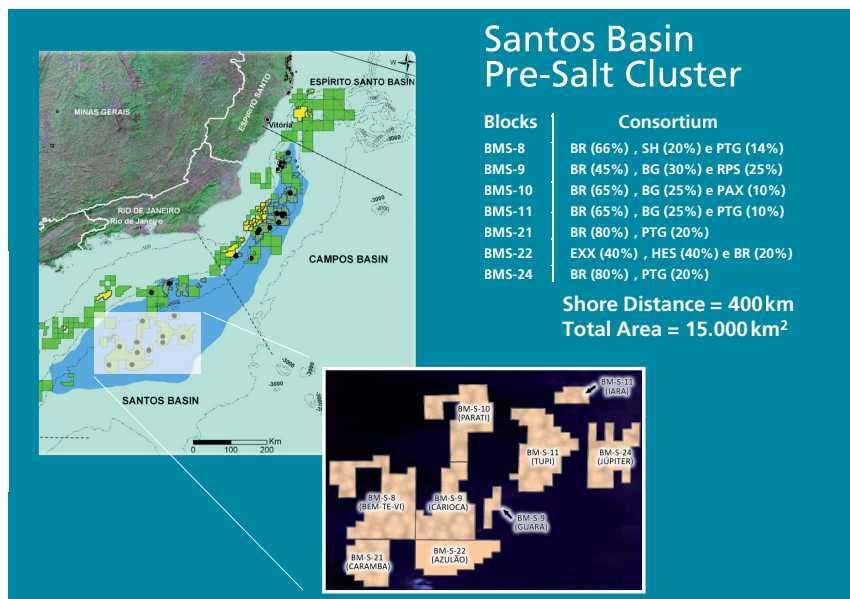


Potential reserves are estimated at 5-8bn barrels of oil equivalent (boe), which would make it the largest ever deep-water oilfield discovery. Partner company British Gas is more optimistic, estimating that the field could contain 12-13bn boe.

The Tupi discovery was followed by other large finds, including Sugar Loaf, to the south-west of Tupi, in December 2007, and the Jupiter natural-gas field, located east of Tupi, in January 2008. The three fields constitute the largest hydrocarbon discoveries in the cluster area of the Santos Basin.

The government estimates that reserves at Sugar Loaf could be even larger than those of Tupi, at around 33bn boe, and that the Jupiter field could have "similar dimensions" to Tupi. Other discoveries in the area include Parati, Bem te-vi, Carioca, Iara, Tupi Sul and Iati.

The President of the Agência Nacional de Petróleo (ANP, the industry regulatory agency) puts total potential reserves in the Santos Basin at 80bn boe. If the new discoveries are found to be commercially viable, Brazil could become one of the world's major oil-producing and exporting countries.



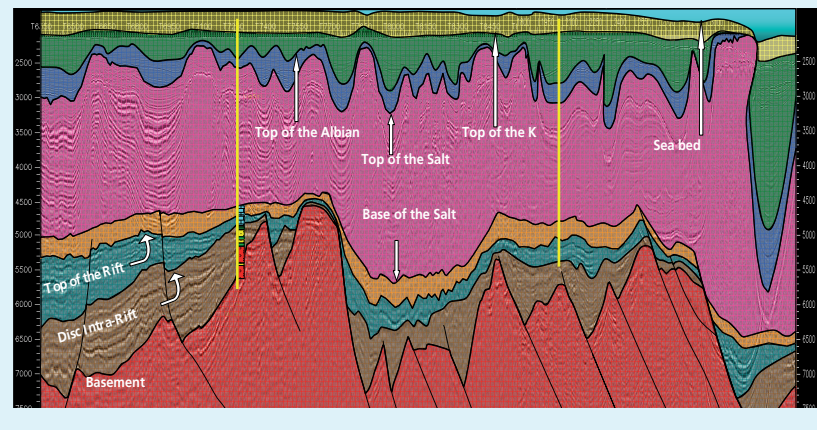
Tough conditions and high cost

The reserves are located in the so-called “pre-salt” area (below the thick salt layer and more than 4km below the sea bed, under a series of layers of rock and salt). Until now, Brazil’s reserves have been found in post-salt formations - above the salt layer.

The depth of the oil reservoirs is not the main challenge; more problems are posed by the depth and thickness of the salt formation. Unlike drilling through rock, which can be difficult owing to its thickness but once drilled remains stable, it is tough to maintain the dimensions of the hole after drilling through salt. Another challenge is the temperature shock of the oil as it travels up to the surface.

The technology needed and the subsequent development and maintenance of the reservoirs will be expensive. The development cost of each subsalt well is estimated at US\$100-150m, and Tupi alone could require as many as 200 wells. Developing the entire Tupi area could cost around US\$600bn over the life of the wells. Unexpected geological or operational issues – such as longer drilling times and increases in the rental costs of rigs – could further raise costs. The availability of deepwater rigs could also delay Brazil’s oil plans, as globally these are in short supply.

Seismic Line / Geological Section -Santos Basin



Conclusion

Brazil’s crude oil production could rise to more than 5 m barrels per day (mbpd). Future potential, however, is greater since the assumed future additions to reserves are conservative in comparison with the 100-150 billions bbls expected from the subsalt play. With discoveries being made above the salt and also onshore in this vast country, Brazil’s future crude oil production could be even greater.

Developing these fields will lead to a noticeable increase in the production of natural gas liquids and condensates. A very positive ‘oil’ production outlook for Brazil is, therefore, well-founded.

➤ Subsalt projects: current policies, forecasting, trends and uncertainties

Distribution of offshore salt sheets



The sedimentary basins of North Western Europe are classic areas of salt tectonics, especially the Dutch part of the Central European Basin, but a large part of the rest of the world’s hydrocarbon reserves are also associated with evaporitic deposits, for example the Caspian Sea, the Gulf of Mexico, offshore Brazil and the basins of the Middle East.

These may involve drilling through as much as 4900-8200 m of salt to depths of 16,400 to 29,500 feet. Successful and efficient sub-salt drilling will play an increasingly large role in terms of achieving many of the area’s deep-water drilling objectives.

To meet this challenge, the ability to directionally drill through salt and to understand and manage the issues this introduces will be a key factor for deep-water operators.

Many of the exploration successes over the last decade having been salt-related, insurers will be working increasingly on subsalt projects over the next few years.

As risk carriers, insurers and reinsurers are essential to the global economy and are important players in its evolution. This explains why they are actively involved in supporting these new projects.

Despite the fact that geophysicists have developed new methods to improve visualization through salt, knowledge of the existence of hydrocarbons below salt is a sufficient reason to start drilling. Indeed salt drilling is still a relatively new practice and presents challenges that are still not fully understood.

Therefore, underwriters need to ensure that studies have been carefully conducted, in order to avoid blow-outs and other catastrophes.

Technical knowledge and offshore underwriting must be closely linked, and open communication with the client is the key to a successful partnership.

As was the case for renewable energy and optical fibres in the 1980s and 1990s, drilling through salt, as a new industry, raises a number of challenges for insurers and reinsurers. These include:

- the reduction of capital costs and mini-mization of time before initial production;
- prototype and new technologies, fabrication and installation without adequate testing or quality control;
- lack of information concerning the detailed engineering or the geological environment;

- lack of expertise and experience of geophysical or drilling contractors and confrontational culture;
- cost savings or cuttings leading to minimal safety and equipment reliability.

Moreover, insurers and reinsurers are generally involved at a late stage in the projects, and have no impact at all on technical decisions or the decisions made by contractors. The transparency of the information available is not sufficient to

assess the quality of a project.

These “drilling through salt” projects are usually included in operational packages and it is sometimes difficult to isolate these specific risks. Underwriters have to be cautious and differentiate the types of risk involved.

However, the dispersion of these risky drilling projects among some traditional risks allows the (Re)Insurance industry to mutualize these risks on a portfolio basis.

➤ Drilling through salt: preparing for the underwriting challenges

In the decades ahead, the world will need to expand energy supplies in a safe, secure, affordable and environmentally responsible way. The scale of the challenge is huge and requires an integrated set of economic solutions.

For most of the Exploration and Production companies (E&P), the low hanging fruit has gone, meaning that we now have to investigate more complex areas in order to extract oil and gas.

In the never-ending global search for oil and gas, “pre-salt” hydrocarbon basins (oil and gas lying below more than 2000m-deep layers of salt) are becoming increasingly important, because such basins host massive reserves.

For example, as mentioned previously, worldwide attention has recently focused on the impressive volumes of oil and gas discovered at a depth of about 6 kilometers off the coast of Brazil.

Brazil’s crude oil production has grown by more than 1 mbpd over the last ten years and the new discoveries will lead to

even more impressive production growth. Brazil could soon be one of the major oil producers.

Frequent contacts with major clients confirm the technical evolution of exploration, and the trend of the offshore industry towards deeper waters.

From an insurance point of view, the purpose of this document is to explain the risks associated with “drilling through salt” projects, along with the challenges encountered by insurers and reinsurers when dealing with these.

It is essential for insurers and reinsurers to work closely with clients and to have a thorough understanding of the challenges presented by this offshore environment. This will help them to address some vital and very specific issues with the client before accepting any risks. These include:

- Obtaining all information relating to seismic surveys shot in the area, the role of seismic imaging being essential in the planning of these particular wells;

- The age of the various seismic surveys;
- The geophysical contractor that performed the seismic surveys;

- When the geological model was created, and whether or not it has been updated since then;

- Which drilling contractor has been hired, and whether or not they have all the required certifications for an operational driller;

- What contingency plan would be applied in case of a Blow-out, etc.

SCOR Global P&C’s offshore team, consisting of upstream engineers, has an excellent understanding of the technical challenges faced by operators. Thanks to this understanding and experience, SCOR Global P&C has been a major international offshore player since the early days of the SCOR Group.

Caroline Haquet

Underwriter Offshore & Shipbuilding
SCOR Global P&C

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