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“Petroleum Provinces of the 21st Century”
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The Gulf of Mexico Deep water – a global perspective[1]

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Opportunities in the Deepwater, Gulf of Mexico, USA

Abstract

Conservative estimates of the expected ultimate recoverable reserves in the US Gulf of Mexico exceed 20 Billion Barrels Equivalent, and optimistically range well over 30 Billion Barrels Equivalent.
The US Gulf of Mexico covers an area of some 450,000 km2 with about half of this in water depths exceeding 500 m. Approximately 400 wells have been drilled in this province and fewer than 100 of these have penetrated more than 5,000 m. The opportunities in the Deepwater Gulf of Mexico result from the variety of geologic settings providing multiple play opportunities and a competitive lease situation.

Brown field exploration possibilities in the shallower, inboard reaches of the Deepwater Gulf provide several billion barrels in opportunities. Shell Oil is responsible for over half of industry's more than 7 billion barrels equivalent discovered to date. Recent discoveries and large lease rolls in 2000 and 2001 continue to make this an attractive play area. Industry has begun to probe major new play areas in ever more frontier areas of the Gulf. Recent lease acquisition has targeted play opportunities in the sub-salt environment, deep turtle structures, the Perdido fold belt and even some possibilities in the ultra-deep waters in front of the Sigsbee Escarpment. A major sector of the Eastern Gulf of Mexico moratorium area is expected to open for leasing in 2002, extending some of these major play areas.

Decreasing margins, price uncertainty, technical challenges and lower probabilities of success for the more frontier plays, require ever more diligent use of technology from imaging to infrastructure. Major efforts are underway in safety, environmental leadership, technical limit drilling, intervention and flow assurance, all key areas to success in the deepest waters of the Gulf of Mexico.

Introduction:

The role of the Gulf of Mexico as a major petroleum province for the next century has been a major focus at Shell, much as it has been at most of the leading oil and gas companies. The political stability of the United States, access to ready markets, and proximity to infrastructure and technology make the Gulf of Mexico a strategic focal point for portfolio development. The questions on many people’s minds are: Can the global drive to explore and develop in the Deep Water Gulf of Mexico be sustained at variable (especially low) oil prices? Is there enough potential in the Gulf left to warrant further exploration, and development activity. Should we rest easily on the assurances that OPEC restraint has caused a price rally, and return to business as usual?

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[1] Presented to the Second Wallace E. Pratt memorial Conference on Petroleum Provinces of the 21st Century, San Diego, California, January 12-15, 2000. Copyright © 2000 by AAPG
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Over 35 billion barrels oil equivalent have been found in present-day deep water (water depth 500 m or greater) environments world-wide. Most of this has been found on either side of the Atlantic, with between 7 and 8 Billion Barrel Equivalents discovered to date in the Gulf of Mexico (Figure 1.) The western coast of Africa has emerged as a major deep-water province and there are some exciting new prospective areas elsewhere around the world. Shell gross discovery volumes in the Gulf of Mexico exceed 4 Billion Barrels of Oil Equivalent, in a variety of trap settings (Figure 2.)

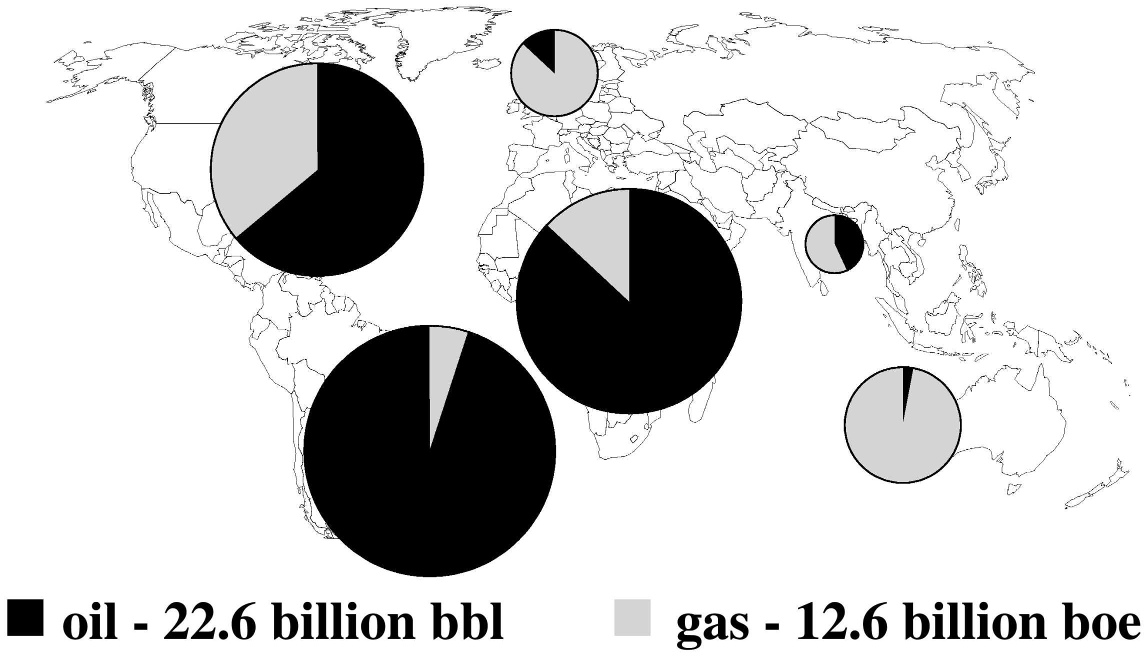

Fig. 1. Global Deepwater Discoveries

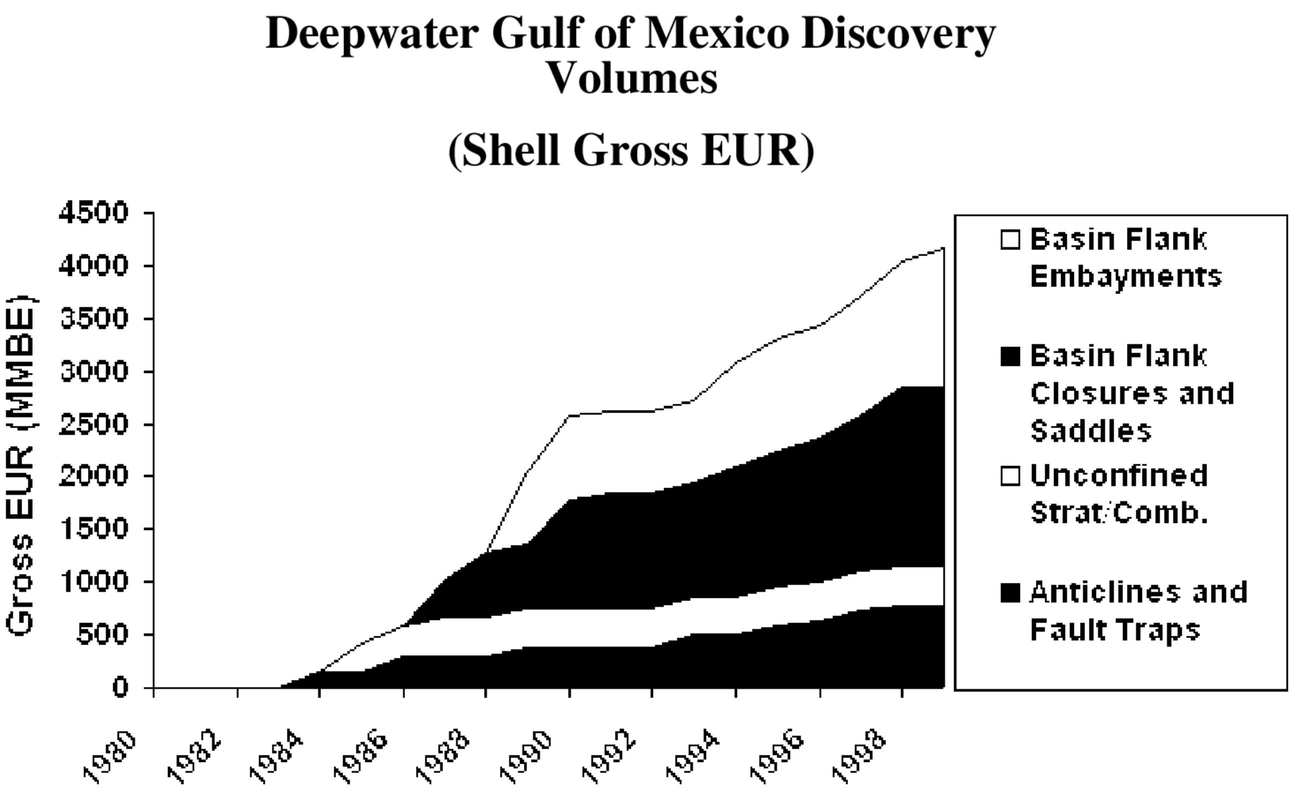

Figure 2. Cumulative volume of Shell gross volume discovered in the Deepwater Gulf of Mexico, by general prospect style. Includes 100% of the Estimated Ultimate Reserves of all Shell- partnered discoveries.

Some 70% of the discovered volumes in Deepwater have been found in turbidites, whereas only 10% of the volumes discovered between 200 and 500 meters of water depth can be attributed to turbidites (Figure 3.) In the Gulf of Mexico, over 90% of deepwater reserves are in turbidite environments. The variety of deep-water depositional systems has important implications for deep-water development plans and economics.

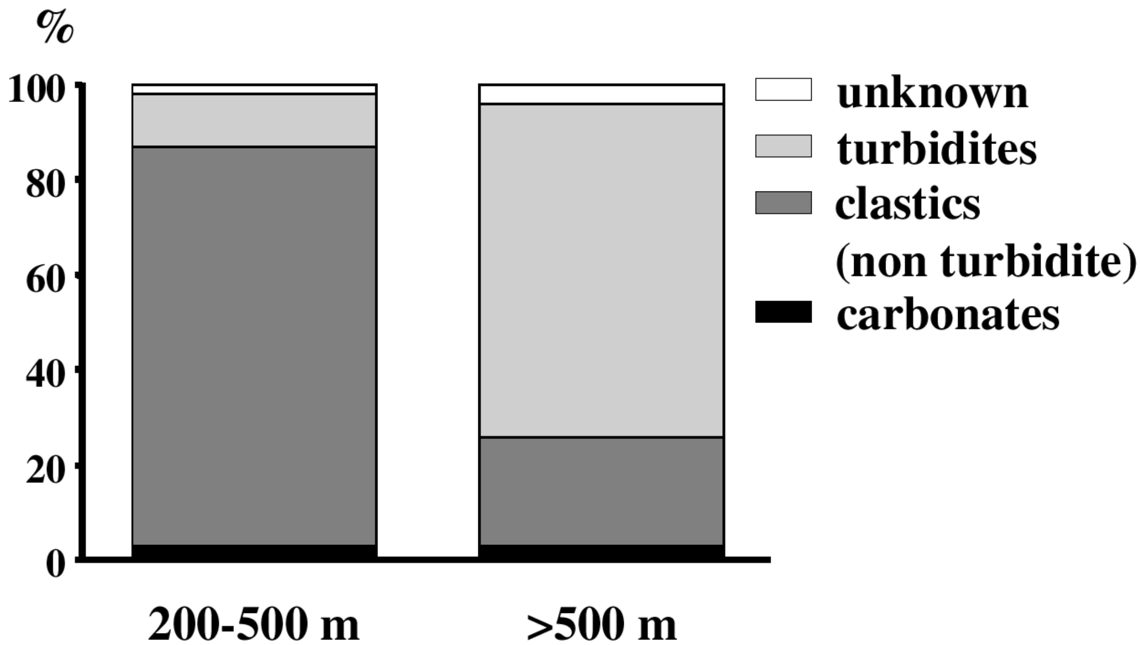

Figure 3. Word- wide Deepwater reservoir types

Only a fifth of the deep-water volumes discovered so far world-wide have been developed, largely by two companies: Shell in the Gulf of Mexico and Petrobras in the Campos basin (Figure 4.) An even smaller number of fields are actually on production (Figures 5 and 6.)

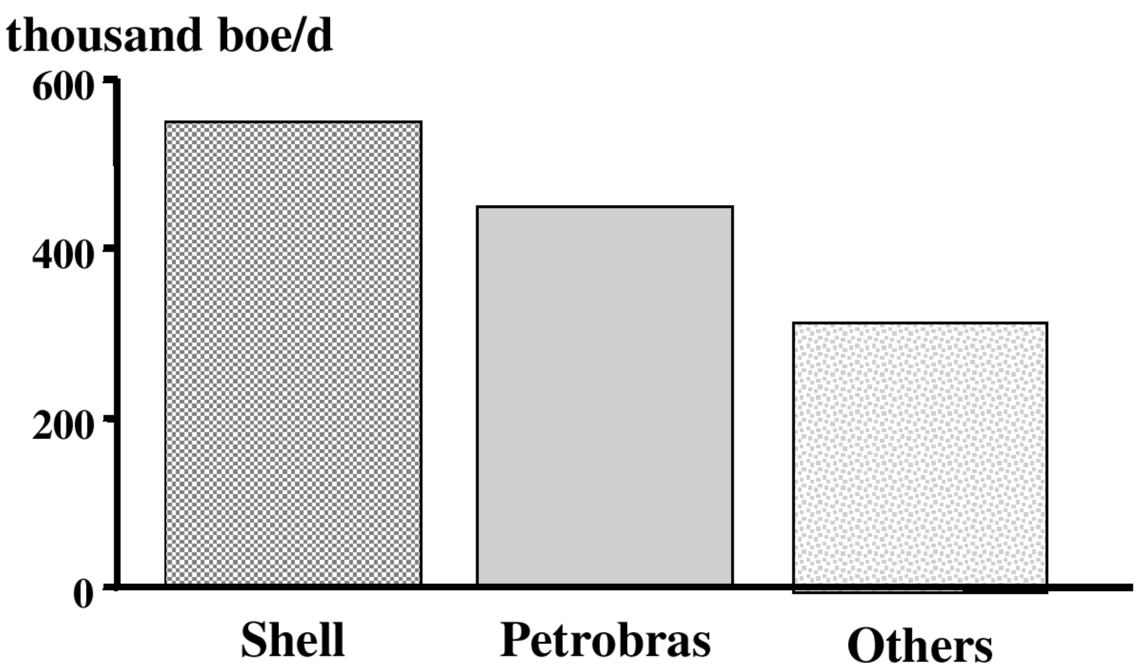

Figure 4. Deep- water operated production(> 500 m water depth)

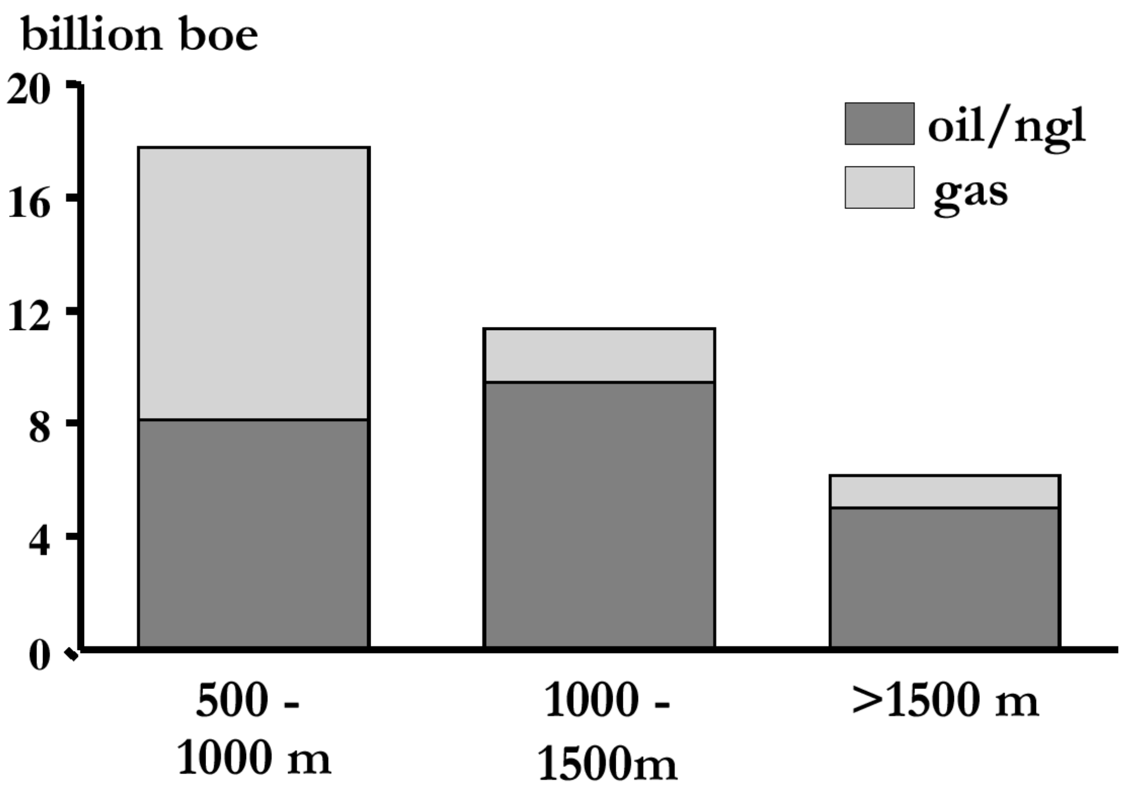

Figure 5. Global Deepwater Discoveries

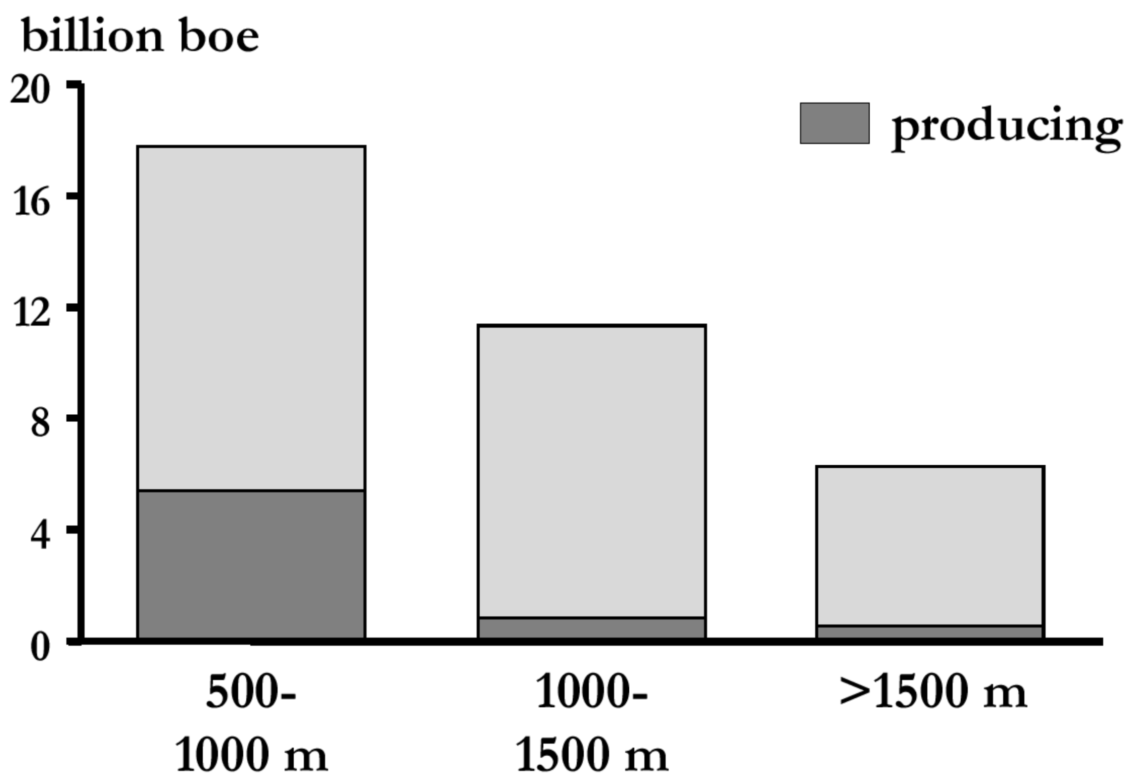

Figure 6. Global Deepwater Discoveries

The US Gulf of Mexico covers an area of some 450,000 km2 with about half of this in water depths exceeding 500 m. Approximately 400 wells have been drilled in this province and fewer than 100 of these have penetrated more than 5,000 m of section. The geographic extent of these deeper penetrations is limited to the eastern part of the Central Gulf. The remaining opportunities in the Deepwater Gulf of Mexico result from the variety of geologic settings providing multiple play opportunities and a competitive lease situation.

Many companies – large and small – are exploring in deep water Gulf of Mexico. Most of the prospective acreage up to 1,500 meters has been taken, often with very high signature bonuses and potentially onerous terms for periods of low oil prices. There is considerable interest emerging in water depths out to 3,500 meters. This reflects the continuing extension of industry's capabilities. We are currently developing fields in water depths exceeding 1,000 meters and exploring beyond 3,000 meters of water. Developing and producing beyond 3,000 meters is a realistic technical goal.   However, we shouldn't overstate the industry's experience in executing deep-water developments. The fields represented in Figure 7 vary greatly in size and complexity; the term 'in production' covers early production from very limited facilities, as well as full-scale development. Only four of these developments are in water depths over 1,000 meters. We can only speculate about the extent of the deep-water prize. But evidence is mounting that there are significant reserves remaining to be found.

<u>Shell's deep-water interests, experience and commitment.</u>

Shell has long pushed offshore limits. We are exploring in deep water around the globe, have deep-water production in the Gulf of Mexico and in the United Kingdom, and are developing the deep-water Malampaya gas field in the Philippines. In the Gulf of Mexico, Shell has made – or has interests in – 37 deep-water discoveries. Of these, 12 have already been brought onto production – delivering over 400,000 barrels equivalent of oil and gas a day. Four additional fields are under development (Figures 8 and 9.) Four Shell developments in the Gulf of Mexico– Auger, Mars, Ram-Powell and Ursa – use tension-leg platforms. A fifth, Brutus, is under construction. Subsea developments include Mensa in more than 1,600 meters of water, which is tied-back to a host platform over 100 kilometers away.

Shell's deep-water businesses around the world are producing annual revenues exceeding $2 billion at today's prices. The commitment to exploration and development in the Deepwater Gulf of Mexico requires a realistic assessment of knowledge, capability and asset strengths. The Offshore world in general and the Deepwater arena in particular, is an unforgiving environment – physically, technically, and economically. Commercial, environmental and social pressures require success in the areas of subsurface understanding, technical judgement, operating performance and economic discipline. The global petroleum and business environments can be as harsh as the physical environments offshore. Energy prices are constantly being driven down, reflecting abundant resources, relentless competitive pressures, and accelerating technological progress.

The marginal cost of non-OPEC oil developments dipped below $14 a barrel within the past year. This price volatility seems bound to continue. Cyclical, capital-intensive industries have a tendency to over-invest and supplies curtailed by recent low prices may be brought on quickly if prices remain high. Inelasticities in supply and demand encourage price volatility. Relatively small changes in production by major producers can result in major short-term price shifts. Historically, nominal oil prices tend to fluctuate between $10 and mid $20's per barrel (Figure 10.) These prices appear to represent world market boundary conditions imposed by supply, demand, taxes, industry investment profiles and the needs of some of the world's major resource holders (OPEC) to balance rate of production with income.   Overall, Shell scenarios suggest energy demand could rise by 60-80% by 2020. By then developing countries could consume over half the world's energy (Figures 11 and 12.) Expanding transportation in developing countries will spur oil consumption. Gas consumption will grow rapidly – possibly more than double – driven by the efficiency, lower cost, and cleanliness of gas-fired power. Energy markets will become increasingly competitive and complex. So what does this mean for the deep water Gulf of Mexico? It means that projects will have to compete for funds in the expectation that oil prices will remain volatile and the knowledge they face continuing downward pressures.

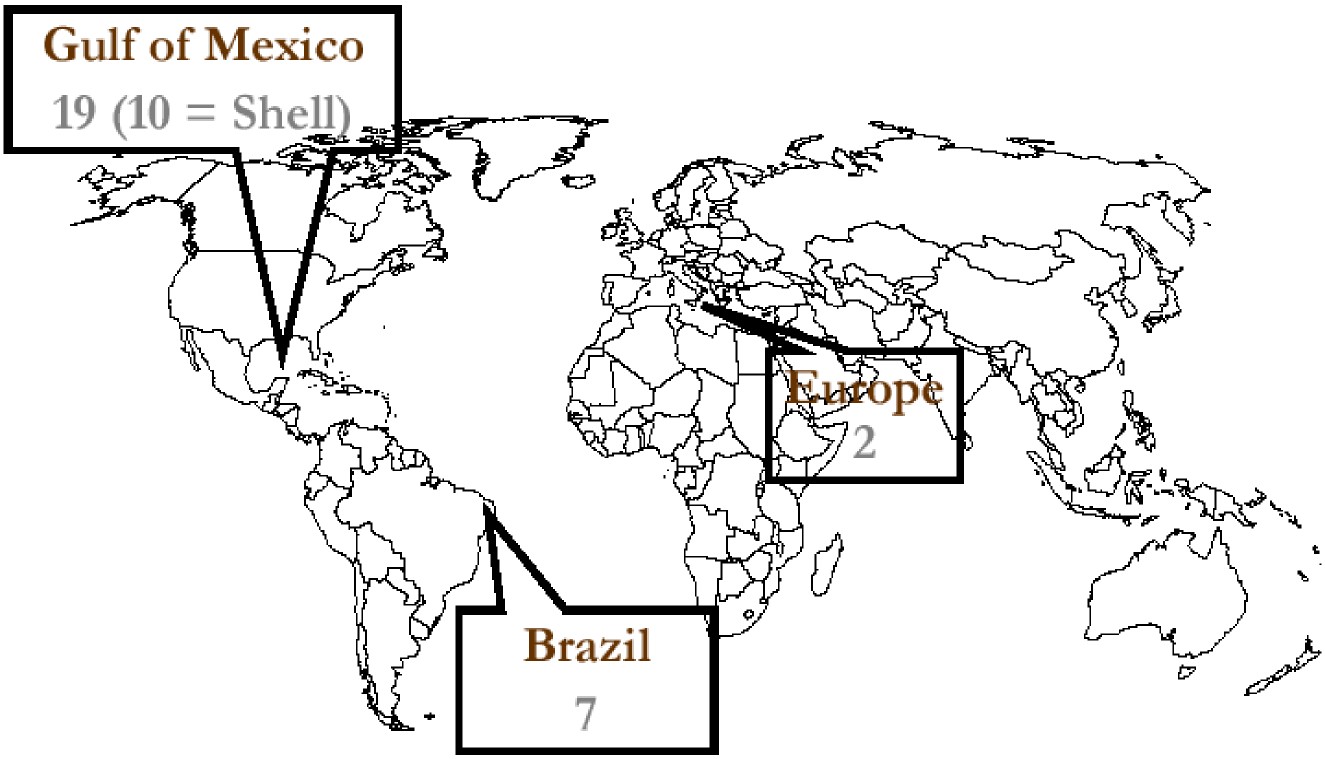

Figure 7. Deepwater development experience (fields in production)

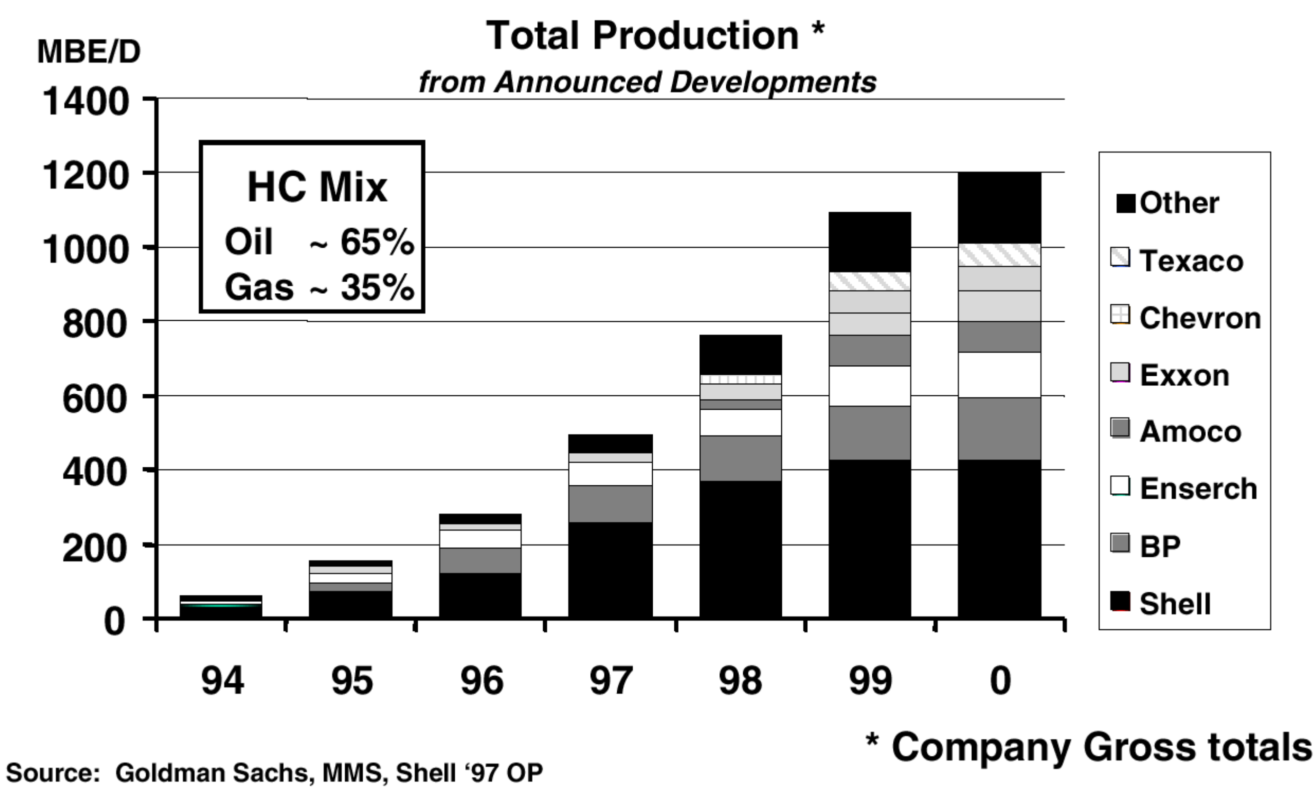

Figure 8. Deepwater GOM Production

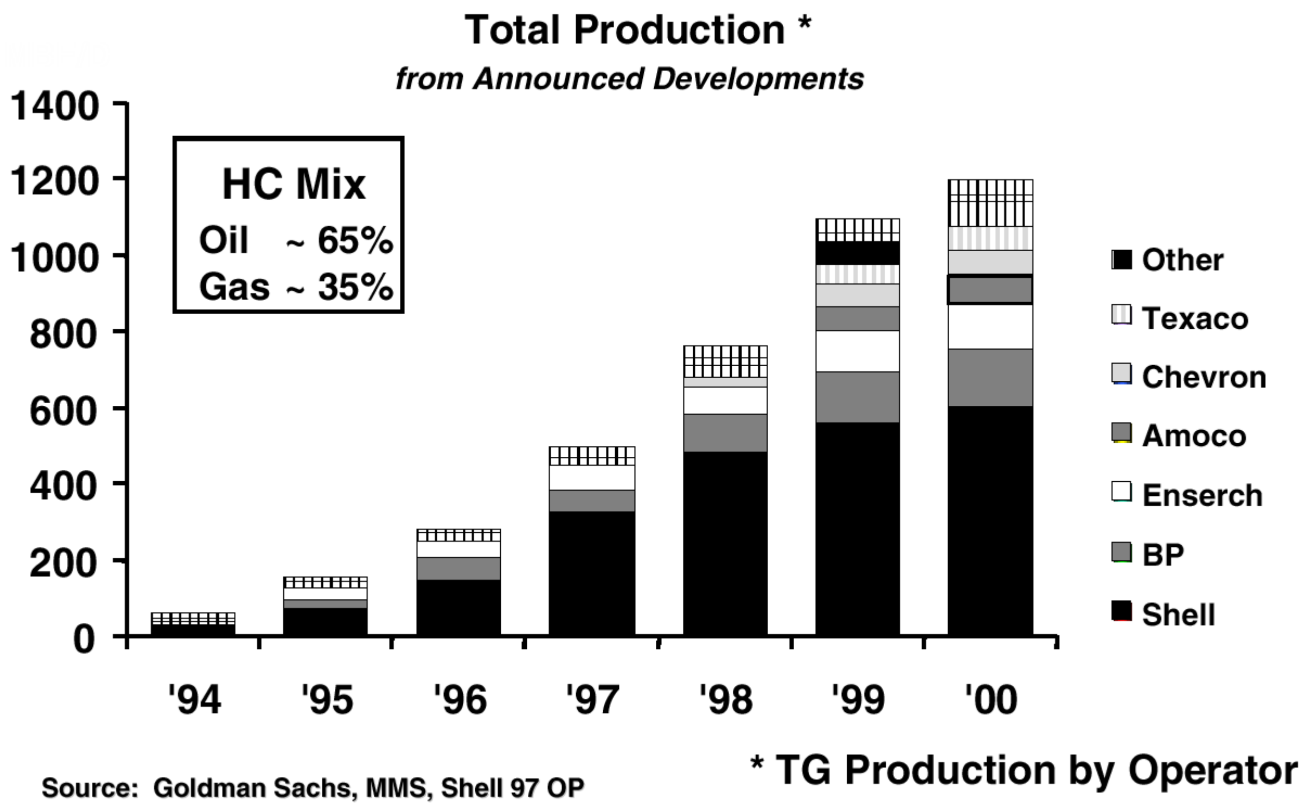

Figure 9. Deepwater GOM Production

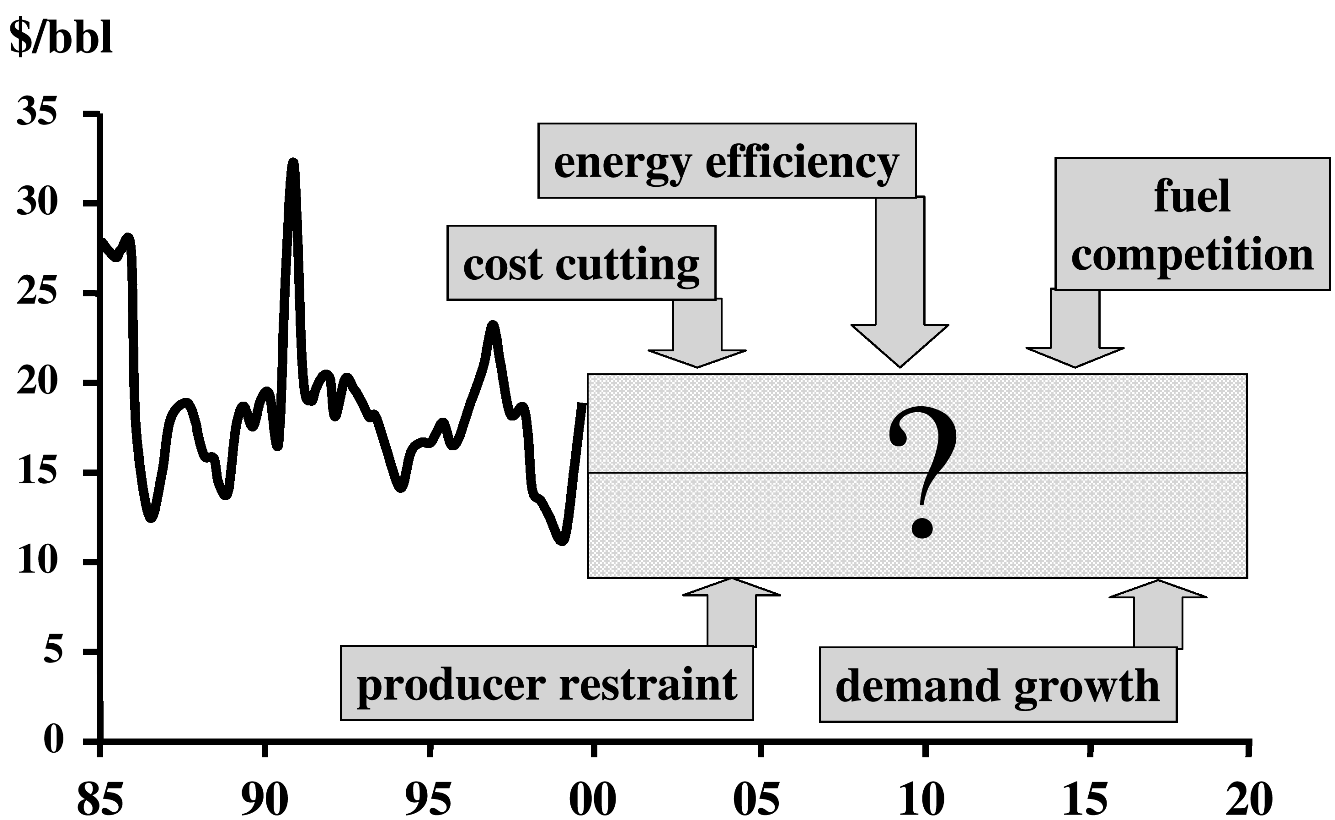

Figure 10. Uncertain future Brent crude 1985- 2020

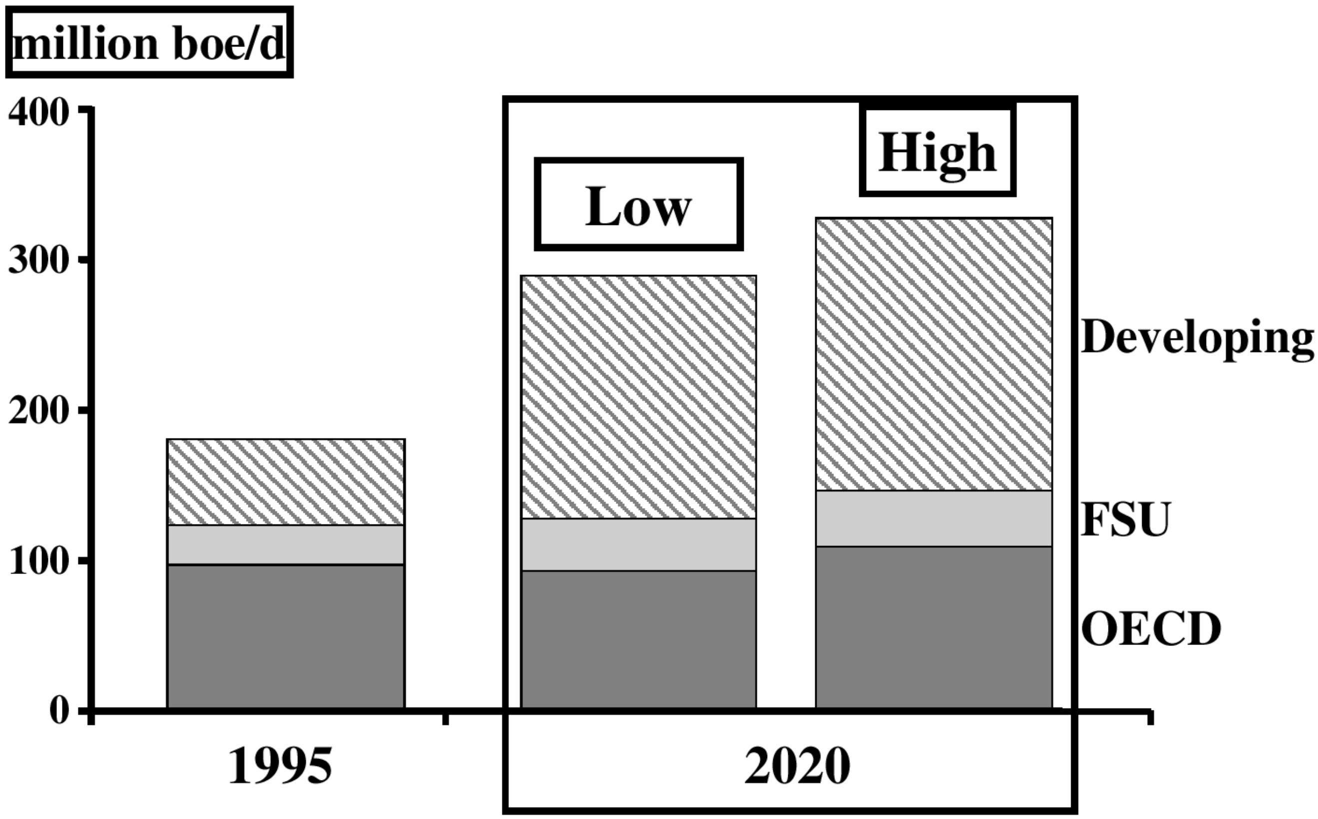

Figure 11. Shell scenarios - world energy demand 1995- 2020

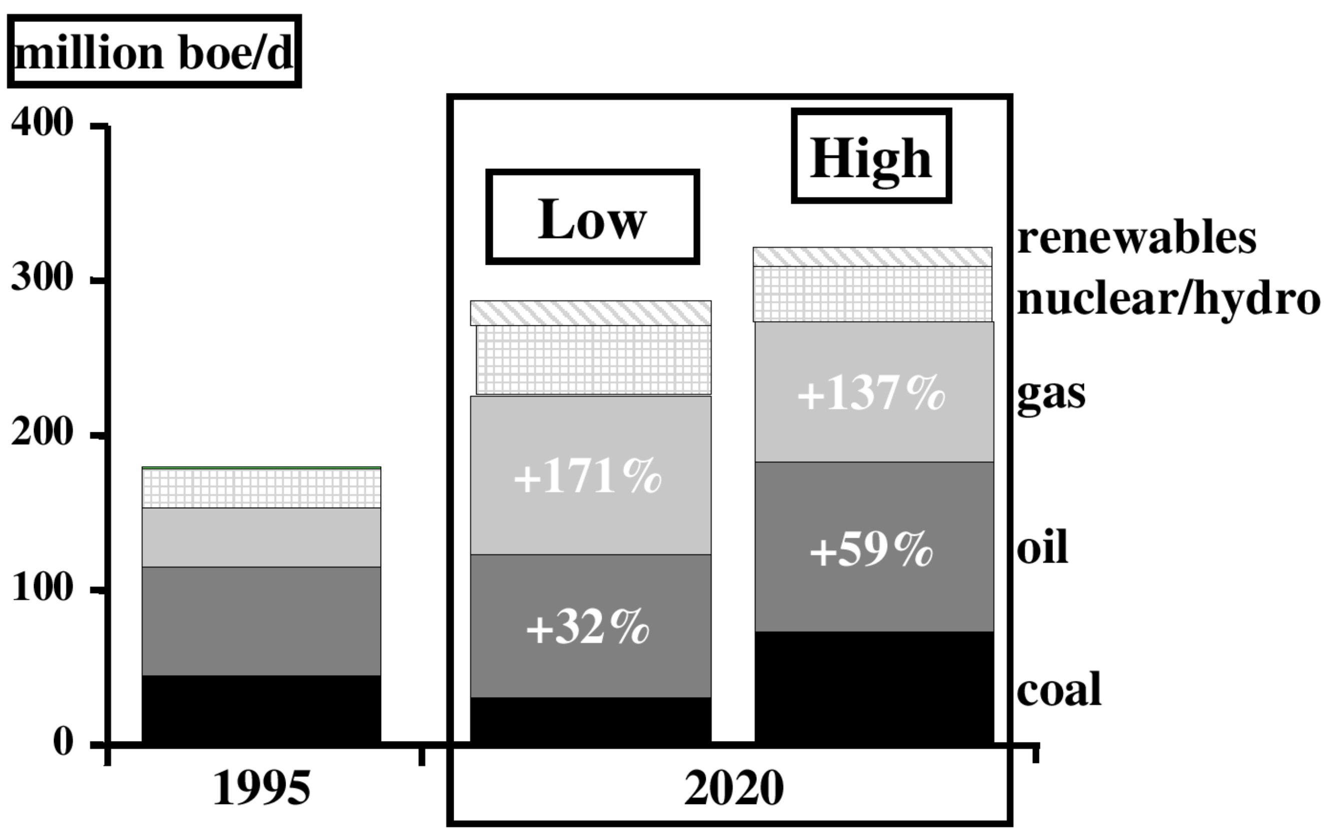

Figure 12. Shell scenarios - world energy supplies 1995- 2020

We must not be fearful of oil prices at the $10/barrel range, but we must be prepared for them and invest intelligently. The first imperative for meeting this challenge is learning from experience. This requires integrated organisations, a positive mindset, dedicated, committed staff, and the relentless, systematic pursuit of improvement.

In mid 1999, Shell brought the Ursa TLP into production. Ursa has a design capacity of over 220,000 barrels equivalent a day in nearly 1,200 metres of water. Compared with Auger, commissioned in 1994, the cost per barrel of throughput had been cut by nearly two-thirds. Achieving such dramatic cost reductions requires: quicker resolution of reservoir uncertainties, cheaper, more productive wells, flexible project management, effective supply chain management, leveraging existing infrastructure, and focusing on life-time costs.

A significant uncertainty facing many of us today involves the exploration performance of various deepwater reservoir facies. We are faced with a very fortunate setting in the Gulf of Mexico where sheet sands in confined basins such as those at Mars exhibit superb reservoir connectivity, aerial extent, and homogeneity. Individual wells can produce in excess of 30,000 to nearly 40,000 barrels a day. By contrast, most of the reservoirs discovered in the past five years in West Africa – from Nigeria through Angola – are in channelized facies. Although field sizes appear to be quite large, these reservoirs have less aerial extent – and often less homogeneity and connectivity. Industry has limited experience in developing channelized turbidite reservoirs, and this presents a significant uncertainty for development planning. Reducing this uncertainty will require careful 3D interpretation, analog studies from both shallow subsurface and outcrop examples, and interdisciplinary teamwork between reservoir engineers and geologists. In Shell, we have developed proprietary software to seismically image reservoirs, invert them into a geologic model, and, at present we have been successful in predicting reservoir sweet spots and internal discontinuities ahead of the bit. Simultaneously, we are enhancing our ability to image beneath salt, opening whole new play opportunities in the Gulf alone. The subsurface challenge is not just to resolve reservoir uncertainties as quickly as possible – with limited information from high-cost deep-water wells. It is to apply this understanding in evaluating and planning development. This depends on seamless communication. Done wrong, unit development costs for even giant fields can turn a healthy prospect into an economic failure.

Improvements in life cycle costs are dependent in real ways on reducing implementation time across a range of disciplines. Shell has been able to reduce exploration and appraisal times in the Gulf of Mexico as well as shortening construction times (Figure 13.) However, the need for speed must always be balanced by proper planning within this rather unforgiving environment. How that balance is struck will be affected by the economic conditions. Wells and subsea facilities account for 70% of typical deep-water costs. Deep-water wells offer particular challenges, including managing shallow water flow, coping with high loads and extreme conditions, and delivering wells capable of handling high production rates.

In Ursa, the first pre-drilled wells were destroyed by shallow water flow – requiring the platform location to be moved and development modified. The relocation was costly, and the solution to the problem was in developing an integrated approach of geology, geophysics and engineering. Geologic models took advantage of high resolution seismic data and integrated this information into sophisticated reservoir modelling and simulation programs. New drilling methods and proprietary project management systems, allowed us to reposition the template, drill the new wells and come in on time and overall, close to budget. We can now use this information in basins world-wide and predict shallow water flow problems and correct for them in advance.

Some new wells at Ursa reach five kilometres out and down surpassing the limit of industry extended reach experience (Figure 14.) One of the Ursa wells recently produced over 39 thousand barrels a day of oil which represents an industry record. Designing-while-building Ursa's deck and hull helped cut four months from the schedule and added flexibility to deal with changing reservoir understanding. This approach depends on understanding key parameters and constraints. It also requires effective supply chain management through strategic relationships which align goals and provide a productive risk-reward balance. The initial plan was to integrate hull, tendons and modules on location. When the original platform location was lost, integration was switched to Curaçao with less than one year's notice. Such challenges are inherent in deep-water projects. The flexibility to cope with them, while still reducing time and costs, requires knowledge of every aspect of deep-water development. Shell designed its TLPs as hubs for surrounding accumulations. Current developments include Macaroni tied back to the Auger TLP, and Angus tied back to Bullwinkle. Macaroni came on-stream in August 1999. And Angus has been brought into production and is expected to ramp up some 50,000 barrels a day of oil and gas by January 2000. Europa and King will be commissioned in 2000, both tied back to Mars.

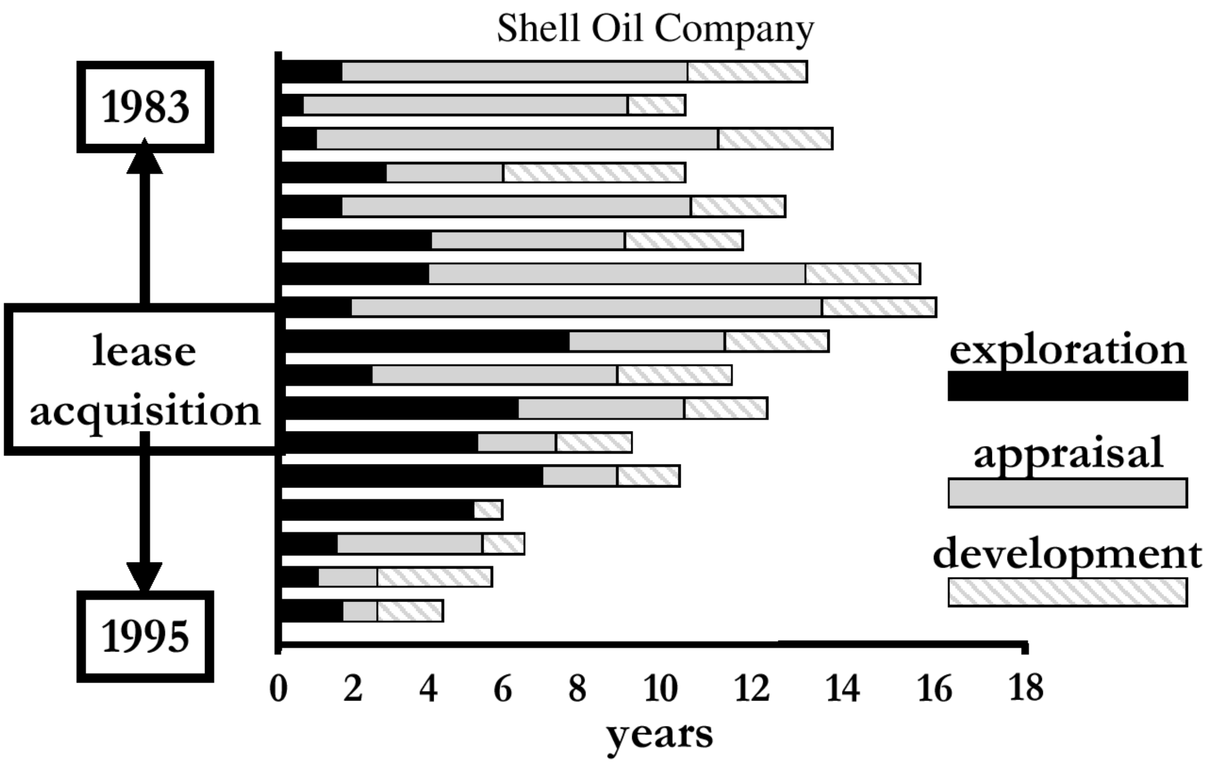

Figure 13. GoM Cycle Times

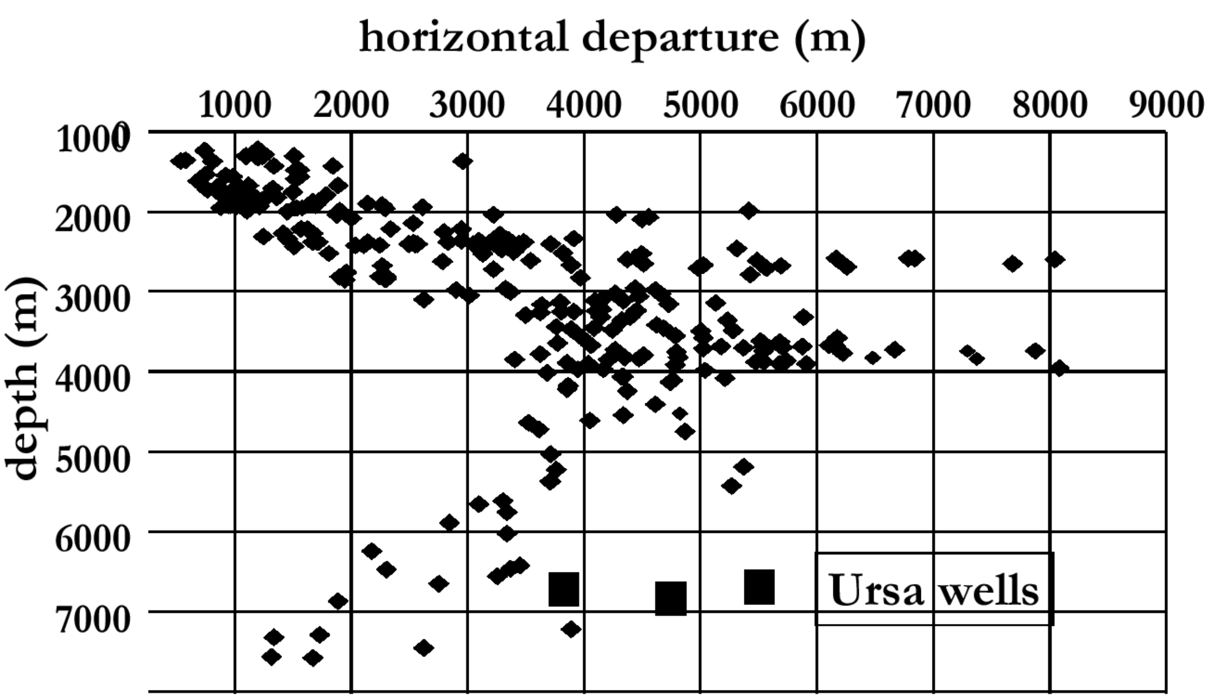

Figure 14. Industry extended reach experience

Focusing on life cycle costs reflects the obvious, though often neglected understanding that it is useless to reduce development costs merely to spend more later. This is particularly true in deep water where the costs of well intervention are very high and the penalties severe. Shutting in a 30,000 barrel a day well has significant impact on the bottom line. We have found it is imperative to understand not only reservoir quality and architecture, but also to understand the geochemistry of the fluids in order to deal effectively with waxes, asphaltenes and other flow inhibitors. By understanding these factors in advance, we can plan for remediation and treatment facilities, before intervention becomes necessary. Proprietary laboratory techniques now allow us to accurately measure wax content and detect other substances from very small samples.

Extending deep water expertise around the world depends on disseminating learning gained in leading areas. Organisational barriers to effective exchange must be challenged. However, these may reflect decentralised structures which deliver other benefits. One of the most productive ways of transferring knowledge is to move people around, enabling them to apply and develop their experience in new settings. But we also work very hard to build continuing communications among our world-wide deep-water community.

One example of the successful exchange of experience is Shell's 'Drilling The Limit' and 'Realize the Limit' approaches. These seek to understand and achieve the technical limits of all phases of well design and execution – time, cost, information, production, reserves and then to challenge the technological possibilities (Figure 15.) Shell Malaysia recently made the Kamunsu East gas discovery in 750 metres of water. The 3,000 metre well was drilled, cored and logged in just 34 days – and cost $7 million less than expected. A technical limit approach kept non-productive time to 5%. In the Gulf of Mexico, the Boris exploration well was completed in 22 days against a planned 37, at less than half the $14.5 million budget.

The development of the major Bonga discovery in 1,000 metres of water in Nigeria depends on harnessing wider experience. It is being planned by a global team based physically in Nigeria, Holland, Houston, and New Orleans. The intention is to develop the field using an FPSO and sub-sea wells. One key area for cost saving is optimising the sub-sea layout – balancing flow line length against well deviation and retaining flexibility to cope with reservoir uncertainty. Reliability is essential, in remote areas with limited availability of rigs, repair vessels and spares. No less challenging is the ultra-deep water of the Gulf of Mexico. Extreme distances from shore involve complex logistics. Even such routine issues as supply delivery and staff changes will require innovative solutions.

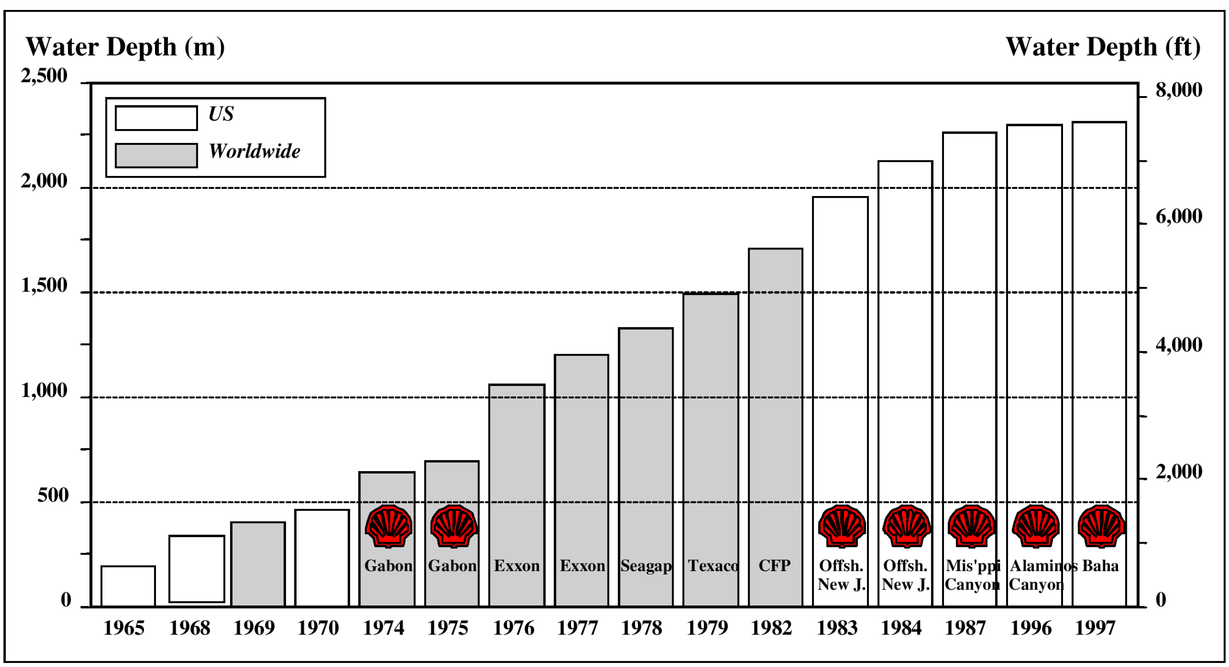

Figure 15. Capabilities - Well Delivery A Recognized Leader in Industry

Another imperative for the deep water is continued technological advance. Gas disposal is one of the technology challenges facing deep water. Along with other companies, we are pursuing the possibilities for floating LNG and gas-to-liquids plants. Other challenges involve deep-water drilling, remote intervention, extending sub-sea flow lines and assuring flow, and developing ultra-deep platform concepts. One of the main issues for deep water drilling is the weight of the fluid column acting on unstable formations. Another is how to extend drilling reach while retaining casing dimensions which allow high productivity. The long-reach wells on Ursa had to be able to fit 5½ inch completion tubing. Riserless drilling systems address both of these issues.

An example of the rapid technology development in this area is the Shell Sub-sea Pumping System, which should be on the market within a year. The SSPS allows drilling fluids to be pumped from the sea floor, rather than the deck of the drill ship, and is the key enabler for riserless drilling, extending casing reach, and maintaining larger overall borehole dimensions. Another approach is expandable tubulars – where pipe diameter is expanded in situ. This technology was developed by Shell and is being marketed through two joint-ventures – Enventure with Halliburton and e2tech with Baker Hughes.

Finally we should never forget the essential role of continued development of subsurface interpretation and modelling tools which are at the heart of deep-water progress. Maintaining the pace of technology development in an uncertain business environment is essential for all serious deep-water players. There are some important challenges arising for industry: preventing accidents and raising environmental standards, ensuring licence terms that encourage long-term investment, attracting, training and retaining talented staff.

The physical and technical challenges of deep water place a particular responsibility on this industry to maintain safety and environmental standards. Before we start deep-water operations we must be sure we have done everything possible to prevent failures, and are prepared to deal with them if they occur. We should have properly assessed the environmental impact of our plans, in consultation with all stakeholders. Remoteness cannot be an excuse for lower waste management standards, especially for such things as drilling mud and produced water. In the case of gas, this industry has an obligation to avoid routine gas flaring everywhere. We need to work together as an industry to raise safety and environmental standards. A lapse by one company adversely affects us all.

We all recognize the need to plan for the development of smaller accumulations from the outset, about the complexities of dealing with gas, and about the importance of maintaining high standards. These require a long-term perspective. Favourable economic terms encourage continuous improvement in the technology applied, thereby reducing costs and increasing recovery. Changes in the structure of lease bonus minimum bids, rental rates and royalties that adversely impact development and prodcution companies, can limit the industry's collective ability to pursue the most challenging sectors of the Gulf of Mexico.

Deep-water developments are technically challenging. We shouldn't overestimate the industry's experience in executing them. They require substantial investment of money and expertise. These investments must be made in the expectation that oil prices will be volatile, and may tend to fall. Investors must look for a potential reward – if they perform well – commensurate with the risks they bear. There will be increasing competition for investment funds and investors will rank opportunities in terms of that risk-reward balance.

What can we look forward to in deep water? I don't have a crystal ball but here are some thoughts.

The maturity of the exploration effort in the Gulf of Mexico suggests there will be smaller fields discovered which will need to be developed as satellites. The industry's capabilities will increase – as we learn from experience, disseminate knowledge, and develop our technologies. But we will reach into deeper water, explore in harsher conditions, look for deeper, sub-salt environments and deal with variable quality gas and oil. Demands for higher safety and environmental standards will increase.

In terms of the business outlook, we can hope that oil prices remain high, but market forces require constant vigilance. Like all energy businesses, the future of Deepwater exploration and production will be increasingly competitive. Success will depend on our ability to continue learning and improving everywhere. More than anything else this depends on the people – their skills, their attitude, their ability to work and learn together quickly.