Petroleum Agency SA
EXPLORE SOUTH AFRICA

PETROLEUM EXPLORATION IN SOUTH AFRICA
INFORMATION AND OPPORTUNITIES
Explore South Africa!

- Petroleum Agency SA encourages investment in the oil and gas sector by assessing South Africa's oil and gas resources, and presenting these opportunities for exploration to oil and gas exploration and production companies.
- Compliance with all applicable legislation in place to protect the environment is very important, and rights cannot be granted without an approved Environmental Management Plan.
- Explorers must prove financial and technical ability to meet their commitments in safeguarding and rehabilitation of the environment.
- Preparation of Environmental Management Plans requires public consultation and a clear demonstration that valid concerns will be addressed.

Petroleum Agency SA, based in Bellville, Cape Town, is responsible for the promotion and regulation of exploration and exploitation of oil and gas (petroleum) resources within the Republic (onshore and offshore) on behalf of government in terms of the Mineral and Petroleum Resources Development Act

Contact us to find out about:
- Onshore or offshore exploration opportunities for oil and gas in South Africa.
- Permits and rights for reconnaissance, exploration or production
- Availability of oil and gas related geotechnical data

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Upstream activity in South Africa at an all-time high

Petroleum Agency SA is responsible for promoting and regulating oil and gas exploration in South Africa, archiving all data related to oil and gas exploration, and developing the local upstream industry for the benefit of all South Africans.

One of the Agency’s roles is to counsel government on issues related to oil and gas, and we have recently played a leadership role in the Task Team process investigating shale gas exploration and the controversial technique of hydraulic fracturing.

South Africa is on the brink of major developments in the upstream industry and the next few years will be key in determining South Africa’s future energy profile. There is currently unprecedented interest and a record level of activity in petroleum exploration.

In the Orange Basin, PetroSA have been joined by Cairn India, and are looking at both oil and gas potential. Sunbird Energy and partners have a production license for the development of the Ibhubezi Gas Field and intend to pursue the option of Independent Power Production. Thombo Petroleum have completed acquiring seismic over their acreage with partners Afren.

Other operations in Western Cape waters include exploration of the deep water and ultra-deep water by BHP Billiton and Shell South Africa Upstream, PetroSA together with Anadarko and exploration by Sungu Sungu Petroleum.

Petroleum Agency SA is very pleased to have attracted exploration companies of such high calibre, who have a record of successful exploration. We are of the opinion that there is great potential for both gas and oil reserves in this basin.

The south coast has seen on-going exploration in Block 9 from PetroSA, where they have concentrated on finding further assets close to existing infrastructure and on development of the F-O gas field.

Other upcoming activity off the south coast includes exploration of the deep water by Canadian Natural Resources and exploration of the northern Pletmos, Algoa and Gamtoos basins by Bayfield Energy and NewAge. We are also currently processing an application from Total for an exploration right to the south.

Off our east coast, Impact Oil and Gas have taken on ExxonMobil as partners.

Onshore, the major interest remains in unconventional resources. These are of three types, namely: Coal bed methane, biogenic gas and shale gas.

Coal bed methane exploration is concentrated around the coal bearing basins in the north eastern parts of the country. Operators have already carried out successful drilling in terms of their work programs.

To the south the first onshore production right, applied for by the Australian based Molopo Energy, has been granted. Molopo has a gas sales agreement with Novo Energy for compressed natural gas for use in vehicles. This small project will mark the first economic production of gas onshore.

Many will be aware of the EIA’s estimate of 370 Tcf of gas as a shale gas resource figure for the Karoo. Our own estimate of the resource is far smaller; yet still represents a very important resource. At the time of writing, the Minister has yet to lift the moratorium through a notice in the Government Gazette, and it is this announcement that will guide and inform the process in future.

The above summary presents some of the very exciting developments underway, and also a little of what we expect in South Africa’s upstream industry over the next few years. Petroleum Agency SA welcomes our new operators to our country and wishes them all success in their endeavours. It is our hope that indigenous oil and gas may soon play a significant role in our country’s energy supply.
PETROLEUM AGENCY SA regulates and monitors the activities of exploration and production activities and is the custodian of the national exploration and production database for petroleum.

OUR VISION
A vibrant sustainable and responsible upstream industry in South Africa.

OUR MISSION
To promote, facilitate and regulate exploration and sustainable development of oil and gas in South Africa.

OUR STRATEGY
To increase exploration & production activities in SA
To regulate the exploration & production environment
To acquire, archive & enhance all petroleum exploration & production data
To ensure a viable and sustainable Agency

VALUES STATEMENT
Petroleum Agency SA aspires to be a world class organisation, committed to:
Professional Excellence
Integrity
Direct, Open Consultative Communication
Transparency
Respect
Teamwork
Active Regard for the natural environment
Corporate Social Responsibility
Empowering, vibrant workplace
We are proud to be South African

ROLES
Petroleum Agency SA
Promotion of open acreage
Data management
Reconnaissance surveys
Contract negotiations
Evaluation of work programmes
Evaluation of development programmes
Monitoring of operations
Recommendations for granting of rights
Issuing of permits
Administration of Upstream Training Trust

Department of Mineral Resources
Policy and regulations
Liaison with other State Departments
Health and safety
Approval of Exploration and Production Rights

PERMITS AND RIGHTS
Reconnaissance Permit:
The right to collect new data, eg. a non-exclusive seismic survey

Technical Co-operation Permit:
12 month study of data in the national archive with option to apply for an exploration right

Exploration Right:
Multiphase programme of exploration work with acreage relinquishment at end of each phase

Production Right:
The right to produce oil and gas

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Introduction to Petroleum Agency SA

Petroleum Agency SA has three main roles: to promote oil and gas exploration and production in South Africa, to regulate the oil and gas exploration and production industry in our country and to archive all geo-technical data produced through oil and gas exploration. These roles apply to both conventional and unconventional resources.

The Agency must also advise government on issues regarding oil and gas exploration and production, and carry out special projects at the request of the Minister.

The Agency encourages investment in the oil and gas sector by assessing South Africa’s oil and gas resources, and presenting these opportunities for exploration to oil and gas exploration and production companies. Our team of geoscientists study existing data to identify prospective resources. These are then presented to investors at local and international conferences and exhibitions, through direct presentations to exploration companies and through advertisements. Part of our role is to ensure that explorers understand the regulatory regime of our country and to advise government in the formulation of regulations that are in line with international norms.

Compliance with all applicable legislation in place to protect the environment is very important to us, and rights cannot be granted unless we are satisfied with the environmental management plan. Explorers must also prove financial and technical ability to meet their commitments in safe-guarding and rehabilitation of the environment. The Environmental Management Programme process requires public consultation and a clear demonstration that valid concerns will be addressed, and must satisfy both provincial and national authorities.

The Agency is involved in CSR initiatives both indirectly through its operators, as well as directly through its own programmes. Production right holders must put a social and labour plan in place that involves previously marginalised sectors of the population in the benefits flowing from development. These plans are approved and monitored by the Agency. The Agency also administers the Upstream Training Trust for the development of specialist skills in the natural sciences, engineering and technology. The Agency has its own CSR programme that includes development of skills through internships, while staff is regularly involved in social outreach events such as house-building with Habitat for Humanity. Petroleum Agency SA invites all parties interested in becoming involved in South Africa’s upstream industry to contact us directly.

Corporate Social Responsibility at Petroleum Agency SA is the demonstration of the values of our organisation. The initiative of Petroleum Agency SA’s corporate social responsibility is to improve the quality of life of historically disadvantaged South Africans through skills development and educational programmes with an emphasis on youth.

As an organisation, we are deeply committed to conducting business in a socially responsible way. It is important that we contribute in establishing a foundation of skills required for our industry as well as our country. In order to achieve this Petroleum Agency SA focuses on the educational projects that promote Maths, Science and Technology e.g.

Career/Science Exhibitions targeting educators and learners.

Career presentations at Tertiary level on the petroleum industry.

3-year Internship programme within the organisation that provides an opportunity for training to South African graduates.

A 3 year contribution to the University of Fort Hare for a Geological Chair.

Petroleum Agency SA as a corporate citizen has an interest in the lives of the South African community at large. Other programmes chosen to invest in have been:

Provision of skills/education on Disaster Management to unemployed youth in disadvantaged communities, Crisis Relief & Prevention Programme in the form of hampers distributed amongst families in times of crisis. Through a partnership with Habitat for Humanity, the Agency donated funds and employees participated in building houses at Emfuleni in the Western Cape.

Human Resources is responsible for the overall human resources function for the Agency, general administration which includes office management and general house keeping, and overseeing the Upstream Training Trust which mainly provides bursaries to students at tertiary institutions.
Finance Department

The finance department of Petroleum Agency takes responsibility for organizing the financial and accounting affairs including the preparation and presentation of appropriate accounts, and the provision of financial information for management.

Finance is also responsible for IT by providing the operating parameters for individuals and supporting use of the IT systems, networks and architecture. This includes responsibility for conventional IT security and data assurance.

The IT Department ensures suitable infrastructure by providing the operating network, circuitry and all equipment needed to make the IT system work in accordance with an established operating standard and system size.

Functionality is catered for by providing the capacity for operating applications, storing and securing the electronic information the organization owns, and providing direct operating assistance in software use and data management to all functional areas in the organisation.

The Procurement Section establishes and manages Preferred Supplier agreements for the provision of indirect goods and services to the Petroleum Agency SA. The Procurement Section fully supports Affirmative Procurement initiatives by building partnerships with BEE vendors and ensuring that potential BEE suppliers are identified and that a comprehensive database of BEE suppliers is created and maintained. These agreements deliver increased value for the company's expenditure through volume discounts with suppliers, improved levels of service, and consolidated management information.

Procurement also manages all Requests for Tenders (RFT) for Indirect goods and services to the Agency and ensures that BEE vendors are provided with advice and support in the tender process (obtaining and evaluating quotes, and managing suppliers). We are responsible for the development of policies and procedures relating to the procurement service, strategic and operational and use of Preferred Vendors across the company.

The overall aim is to seek best value for money on all goods, services and works bought by the company, to continuously improve the procurement process to ensure best value from contracts awarded and to minimise the administration involved in making purchases. The unit also strives to ensure that all procurement is open, transparent and accountable by complying with Procurement Policy and with procurement best practice.

Information Services

The continental shelf of the Republic of South Africa covers some 200 000 km² and the country has a coastline of approximately 3 000 km in length. Petroleum Agency SA is responsible for the archiving and management of the national exploration database and has catalogued all of the data and reports resulting from the drilling of some 300 boreholes and the acquisition of 227 00 line km of 2-D and 9700 km of 3-D seismic data. All hydrocarbon exploration data belongs to the state. Licensees that carry out exploration activities are required to supply all new and reprocessed data on relinquishment to the Agency for incorporation into the National Database.

A new block naming system has been in use since 1994. For convenience of reference to existing data, the old (1965) licence blocks are also used since borehole and seismic line designations refer to them. The latest degree licence block system definitions are also defined as an overlay on our maps.

Although data catalogues can be generated for any offshore geographical defined area, including listings of all the data available that is relevant to the assessment of each area, the data is conveniently organised into geological basins and features below:

- Summary of wells by basin
- Summary of seismic by basin
- Generalised location maps

A Data Room has been established at Petroleum Agency SA in Cape Town where interested parties may view all data available including a viewing set consisting of selected reports, seismic data and associated results.

Bookings for the Data Room should be made by contacting our offices.
Regulation Division

The purpose of the Regulation Division is to regulate the exploration and production of oil and gas in South Africa in a sustainable manner. The Division is divided into 3 departments: Licensing & Legal Compliance; Technical Compliance and Environmental Compliance.

The Licensing & Legal Compliance Department ensures compliance by the holders of rights and permits and the Agency with the terms and conditions of rights and permits, and evaluates and monitors compliance with the social and labour plan. The Technical Compliance Department assesses the technical ability of the applicant and ensures compliance by the holders and the Agency with the terms and conditions of the right and the permit in terms of the MPRDA.

The Environmental Compliance Department manages, enforces, monitors and evaluates implementation of environmental requirements by holders with environmental legislation and terms and conditions of the right or permit under the MPRDA.

Rights and Permits in Terms of the MPRDA

There are two types of permit and two types of right which may be issued or granted under the MPRDA:

**Technical Cooperation Permit**
A Technical Cooperation Permit (TCP) is a permit issued to applicant in terms of section 77(1) of MPRDA which allows the applicant to carry out desktop studies, acquire existing seismic and other data from other sources including the Agency but does not include any prospecting or exploration activities.

**Reconnaissance Permit**
A Reconnaissance Permit is issued to the applicant in terms of section 75(1) of MPRDA to carry out any operation for or in connection with the search for a mineral or petroleum by geological, geophysical or photogeological surveys and includes any remote sensing techniques, but does not include and prospecting or exploration operation. This permit accommodates those wishing to acquire speculative surveys.

**Exploration Right**
An Exploration Right is granted to the applicant in terms of section 80 of MPRDA to enable reprocessing of existing seismic data, acquisition and processing of new seismic data or any other related activity to define a trap to be tested by drilling, logging and testing, including extended well testing of a well with the intention of locating discovery.

**Production Right**
A Production Right is granted to the applicant in terms of section 84 of MPRDA to enable the applicant to conduct any operation, activity or matter that relates to the exploration, appraisal, development and production of petroleum.

Petroleum Geology Resources

The Promotion Division is responsible for attracting oil and gas exploration investment to South Africa and for quantifying South Africa's oil and gas resources.

We comprise a small group of earth scientists, drafting and support staff, who work with exploration data to identify and advertise new opportunities for investment and to reduce the risk for prospective operators. We advertise these opportunities through displays at international oil and gas conventions and exhibitions, country and company visits, advertisements and our data room at our office in Cape Town. There are two departments in the division, viz. The Frontier Geology Department and The Resource Evaluation Department.

Frontier Geology is responsible for evaluating and attempting to quantify the potential of the offshore beyond the reach of current exploration technology, as well as that of the onshore Karoo Basin where little exploration has taken place to date and existing data is very old, so that the basin's potential is still poorly understood. Frontier Geology is concerned with the conventional as well as future sources of hydrocarbon resource such as gas hydrates offshore and coal bed methane and shale gas onshore.

The Resource Evaluation Department is responsible for evaluating and quantifying the potential of the offshore areas around South Africa that can be exploited through current exploration and production technology.

This department is tasked with the identification of exploration opportunities in the area and for facilitating the entry of new explorers into the South African upstream industry. A major responsibility is the upkeep of a quantified and risked inventory of exploration opportunities.
South African Oil & Gas Fiscal Terms

The key provisions are:
An annual exploration fee, royalty and income tax, state participation, BEE participation in production and an annual contribution to the Upstream Training Trust.

Annual Exploration Fee:
Onshore rights - starts at R1/hectare with a minimum of R 1000 and escalates in 50c/hectare increments each year.
Offshore right - starts at R 200 000/ sq degree pro rata with a minimum of R 50 000 and escalates annually in line with the South African Consumer Price Index (CPI).

Royalty
Royalty is payable in terms of the Mineral and Petroleum Resources Royalty Act. The rate is variable based on profitability with a minimum rate of 0.5% and a maximum of 5% per annum.

Income Tax is payable
Income tax is payable in terms of the Income Tax Act, Schedule 10 of which contains additional provisions applicable only to the upstream petroleum sector, and will not exceed 28%. All expenditure and losses incurred will be allowed as deductions. In addition, a further 100% of all capital expenditure incurred for exploration and 50% in production is allowed as a deduction for the purposes of calculating income tax liability. This amounts to 200% of capital expenditure for exploration and 150% for production. All allowable costs (both operational and capital) may be immediately expensed for income tax purposes.

Guarantees
Both the Income Tax Act and the Royalty Act make provision for the Minister of Finance to enter into a contract guaranteeing that for the duration of the right (including any production right flowing from an exploration right, but excluding renewal of a production right) the terms of the Tenth Schedule and Royalty Act will be no more stringent than at date of signature.

Customs Duties and Exchange Control
The Customs and Excise Act makes provision for the full rebate of customs duties on imported goods and equipment for use in the upstream sector. Oil and gas companies are also exempt from the normal restrictions on operating Customer Foreign Currency Accounts.

State Participation and BEE Participation Interest
State participation of 10% at the production stage, carried through exploration, will be through PetroSA. A further 10% interest will be made available on commercial terms for participation by BEE companies (Black Economic Empowerment companies). This may be taken up by PetroSA in the absence of any BEE participants.

Annual Upstream Training Trust Donation
Onshore rights:-
R1/ hectare with a minimum of R 1 000.
Offshore rights:-
R 200 000/ sq degree pro rata with a minimum of R 50 000.
ABOUT SOUTH AFRICA

In any economic analysis, South Africa stands out as the most developed nation in Africa as well as one of the richest. For example, whereas South Africa comprises only 4% of the area (Figure 1) and has 6% of the population of Africa, it consumes more than 50% of the continent’s electrical power. The economy is based on free market principles and the country is one of the world’s major trading nations.

Population and GDP
South Africa’s population is estimated at >50 million. Estimates of per capita purchasing power parity Gross Domestic Product (2011) range from US$10,700 to US$12,067 (IMF, WB, CIA, Dowling). Total GDP in 2011 was around 555 000 million USD, around 25th in the IMF ranking. The most important contributors to the GDP were services (65.5%), industry (31.3%) and agriculture (3.2%).

Energy
South Africa’s energy interests are administered by the Department of Energy. The South African Agency for Promotion of Petroleum Exploration and Exploitation (Petroleum Agency SA) is a subsidiary of CEF (Pty) Ltd, a government owned company concerned with the search for energy solutions for South Africa and SADC countries. Petroleum Agency SA is responsible for promoting, licensing, monitoring and data archiving of South Africa’s petroleum exploration and production industry and is the designated agency in terms of the Mineral and Petroleum Resources Development Act (2002).

PetroSA is South Africa’s national oil company and is separate from Petroleum Agency SA. It is also a subsidiary of CEF (Pty) Ltd., and owns, operates and manages the South African Government’s commercial assets in the petroleum industry, including exploration and production off the southern coast of South Africa, participation in international upstream petroleum ventures and production and marketing of synthetic fuels from their GTL plant at Mossel Bay.

The national electricity utility, Eskom, has a total installed capacity of approximately 44 000 MW. Eskom is aiming to almost double this capacity by 2026. Not only does Eskom supply all South Africa’s needs but it also exports power to neighbouring countries. Coal provides the source for 90% of Eskom’s capacity. The remainder comes from nuclear and hydro-electric power stations and gas turbines. Electricity sales have increased significantly in recent years: utilisation is almost at peak capacity and demand is expected to continue to increase strongly.

The primary energy resource in South Africa is coal. Due to very large coal deposits, which can be exploited at extremely favourable costs, a large coal-mining industry has developed. South Africa has proven reserves of 30 billion tonnes - the seventh largest in the world. It is also the world’s sixth largest coal producer and the second largest exporter of steam coal. Annual production exceeds 250 million tonnes.

Most of the coal consumed locally is utilised not as a final energy product but as feedstock, primarily for electricity and synthetic fuel production; coal supplies about 77% of the total primary energy market in South Africa. There is currently active interest in exploring for Coal Bed Methane in parts of the Karoo Basin.

South Africa also has 14% of the western world’s uranium resources. These resources are scattered with most of the current production as a by-product of gold mining. Whereas South Africa’s coal and uranium reserves are clearly sufficient for many years to come it is certain that energy demand will also increase rapidly. It is government’s stated objective to diversify the energy mix and environmental pressures suggest that at least part of this demand be met by a ‘clean’ source such as natural gas.
Oil imports, local oil production, & consumption

South Africa imports approximately 66% of its crude oil requirements (Figure 3), mainly from Saudi Arabia, Iran, Nigeria and Angola. Current domestic consumption is approximately 575,000 bbl/d. The balance between imports and consumption is made up mainly by the production of liquid fuels from coal using Sasol's synthol process with minor contributions from domestic oil and gas fields (Oribi and Oryx oil, E-CE and F-A gas to liquids). Sasol's synfuel production capacity is around 160,000 bbl/d (crude oil equivalent) and products include petrol, diesel, paraffin and LPG. A modified form of the Fischer-Tropsch process has been used since 1992 by PetroSA at its Mossel Bay GTL plant to convert gas and condensate to liquid fuels. The maximum capacity of this plant is 36,000 bbl/d, which is equivalent to about 6.25% of the country's requirements.

Natural Gas

Domestic natural gas has been produced from the F-A and E-M gas fields and satellites since 1992 and is utilized for GTL feedstock, as discussed above. Natural gas has been imported from the Pande and Temane fields in Mozambique since 2004, and is distributed to approximately 550 industrial and commercial customers in Gauteng, the Free State, Mpumalanga and KwaZulu-Natal. Current imports equate to the energy equivalent of about 52,000 bbl/d.

Refining

South Africa has refining capacity of 662,000 bbl/d (including coal to liquids and gas to liquids capability). In Africa, this is second only to Egypt. Crude oil refineries are Sapref and Enref in Durban, Chevref in Cape Town and Natref in Sasolburg. Plans are currently on the table for a new refinery with the capacity for 400,000 bbl/d to be built in the Eastern Cape and operated by PetroSA.

Transport

In addition to well developed air and rail links, South Africa has 750,000 km of roads and over 9 million registered vehicles. South Africa thus represents an important world market for petroleum products and this market is currently expanding rapidly. Since over 60% of current demand is met by imported crude there is a ready local market for any indigenous hydrocarbons that are discovered in South Africa. South Africa has six major ports, namely Saldanha, Cape Town, Port Elizabeth, East London, Durban and Richards Bay (Figure 2). Smaller facilities exist at Mossel Bay and Port Nolloth, and a new deep water harbour is under construction at Coega near Port Elizabeth.
THE OFFSHORE ENVIRONMENT

South Africa is a large country. Its land area is more than 1.1 million sq km and its coastline has a total length of nearly 3000 km. The west coast, from the Orange River to Cape Point, is almost 900 km long and the remainder, from Cape Point to the Mozambique border, is more than 2000 km long.

The continental shelf is 20-160 km wide off the west coast, 50-200 km wide off the south coast, but rarely more than 30 km wide on the east coast, except along the Durban Basin. Similarly the continental slope is fairly wide on the west and south coasts but narrow to the east (Figure 4).

The coastline is swept by two major ocean currents:

- The Agulhas Current is a warm southwesterly flowing current that skirts the east and south coasts as far as Cape Point. It reaches its maximum strength close to the shelf break and over the continental slope.
- The Benguela Current, on the other hand, is cold and flows northwards from the Antarctic up the west coast of Africa as far as Angola.

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Figure 4. Structural elements and sedimentary basins of South Africa.
REGIONAL GEOLOGICAL SETTING

Stratigraphic nomenclature
Soekor (now PetroSA), the state oil company founded in 1965, developed a stratigraphic nomenclature for the sedimentary successions encountered offshore. During early stages of exploration, various structural elements such as basins, sub-basins, structural highs and major faults were identified and named.

Current stratigraphic nomenclature reflects a committed sequence stratigraphic approach based on the seismic recognition of multiple unconformities within the drift successions. Sequences initially defined by significant unconformities, as recognised on seismic sections, were assigned numbers (1 to 22) (Brown et al., 1995). Third and higher order sequences, composite sequences and sequence sets recognised subsequently were designated by letters (A, B, C etc.). Unconformities are designated by the sequence overlying them (e.g. 1A, 4B etc) and by their nature (Type 1 = t1 etc.), as illustrated in the chronostratigraphic charts of the Orange Basin and Bredasdorp Basin (Figure 6).

Structural elements
South Africa’s offshore basins can be divided into three distinct tectonostratigraphic zones. The western offshore comprises a broad passive margin basin related to the opening of the South Atlantic in the Early Cretaceous. This is known as the Orange Basin which is the largest offshore basin (Figures 4 and 5).

The eastern offshore is a narrow passive margin that was formed as a result of the breakup of Africa, Madagascar and Antarctica in the Jurassic.

Very limited deposition has occurred here and only the Durban and Zululand Basins contain an appreciable sedimentary section. The southern offshore region, known as the Outeniqua Basin, shows a history of strong strike slip movement during the Late Jurassic - Early Cretaceous breakup and separation of Gondwana. The Outeniqua Basin consists of a series of en echelon sub-basins (the Bredasdorp, Pletmos, Gamtoos and Algoa basins) each of which comprises a complex of rift half-graben overlain by variable thicknesses of drift sediments. The deepwater extensions of these basins (excluding the Algoa Basin) merge into the Southern Outeniqua Basin.

Upper Palaeozoic
Subduction on the southwest margin of Gondwana in the Late Carboniferous - Early Permian led to the transformation of an old passive margin into a foreland basin (the Great Karoo Basin), Figure 7. Further convergence in the Permo-Triassic led to the development of the Cape Fold Belt which extends from Australia through Antarctica and South Africa to South America.

Figure 5. Comparative size of South Africa’s major basins.
Slope fans and prograding wedges not generally shown due to space constraints.

Figure 6. Generalised chronostratigraphy of the Orange and Bredasdorp basins, with ages subject to revision by International Commission on Stratigraphy (2012).
Mesozoic and Tertiary

Following erosion and peneplanation there was a phase of widespread volcanism in the Early to Middle Jurassic in southern Africa, the Falklands and Antarctica. This provides the first evidence of the impending breakup of Gondwana (Figure 8).

At this time the Falkland Islands lay off the south or southeast coast of South Africa (Figure 9). Breakup started on the eastern margin of Africa with Madagascar and Antarctica beginning to move away in the Middle Jurassic. This initiated the formation of the Durban and Zululand basins.

During the Early to Mid-Cretaceous a complex series of microplates including the Falkland Plateau gradually moved west southwestwards past the southern coast of Africa creating important dextral shearing of the South African margin. This created the Outeniqua sub-basins as a series of oblique rift half-grabens which may be regarded as failed rifts, oldest in the east and youngest in the west.

The rift phase on the south coast ended in the Lower Valanginian (drift-onset unconformity, 1At1) (Figure 6)
but was followed by at least three phases of inversion related to continued dextral shearing. This ended in the mid-Albian (14At1) with the final separation of the Falkland Plateau from Africa. This transitional rift-drift phase was followed by development of a true passive margin. The Lower Valanginian drift-onset unconformity on the south coast is contemporaneous with the earliest oceanic crust in the South Atlantic.

The Orange Basin was initiated as a series of isolated and linked north-south trending grabens during the Lower Cretaceous. The drift-onset unconformity here is dated as Hauterivian (6At1), somewhat younger than in the Outeniqua Basin. A rift-drift transitional phase in the Orange Basin occurred until the Early Aptian (13At1). Later Cretaceous and Cenozoic sedimentation took place in a marine passive margin setting.
The first organised search for hydrocarbons in South Africa was undertaken by the Geological Survey of South Africa in the 1940’s. In 1965 Soekor (Pty) Ltd was formed by the government and began its search in the onshore areas of the Karoo, Algoa and Zululand Basins.

In 1967 a new Mining Rights Act was passed and offshore concessions were granted to a number of international companies including Total, Gulf Oil, Esso, Shell, ARCO, CFP and Superior. This led to the first offshore well being drilled in 1969 and the discovery by Superior of gas and condensate in the Ga-A1 well situated in the Pletmos Basin.

In 1970, Soekor (together with Rand Mines) extended its efforts to the offshore but, despite further encouraging discoveries, international companies gradually withdrew. This was largely as a result of political sanctions against South Africa. Thus from the mid 1970’s to the late 1980’s Soekor, the State owned oil and gas exploration company, was the sole explorer operating the entire offshore area of South Africa. The offshore areas were opened to international investors via a Licensing Round held in 1994.

In 1999 Petroleum Agency SA was established and in 2001 a new State oil company, PetroSA, was formed by the merger of Soekor and Mossgas.

The Mineral and Petroleum Resources Development Act was passed in 2002, and became operational on 1 May 2004.

In the entire offshore area there are now over 300 exploration wells including appraisal and production wells. In addition, 233 000 km of 2D seismic data and 10 200 km$^2$ of 3D seismic data have been acquired since exploration began offshore.

Exploration drilling was most active from 1981 to 1991 during which period some 181 exploration wells were drilled. The Bredasdorp Basin has been the focus of most seismic and drilling activity since 1980.

The results of this exploration are the discovery of several small oil and gas fields, and the commercial production of oil and gas from the Bredasdorp Basin (Figures 10 and 11). In the Pletmos Basin there are two undeveloped gas fields and a further six gas discoveries. One oil and several gas discoveries have been made in the South African part of the Orange Basin. One of these discoveries is currently being appraised and developed as the Ibhubesi gas field by Sunbird Energy.
Producing fields
The F-A/E-M and satellite gas fields, situated 90 km offshore, are owned and operated by PetroSA (Figure 11). Production began in 1992 and gas and condensate are piped ashore to the PetroSA GTL plant at Mossel Bay where they are converted to petrol, diesel, paraffin and petrochemicals. During 2006 average daily production from these fields was approximately 160 MMscf/d (million standard cubic feet of gas per day) and 3900 BOPD (barrels of oil per day).

South Africa's first oil production began in 1997 when the Oribi oil field began flowing at an initial rate of 25 000 bbl/d. A floating production facility (the Orca) is used to fill a shuttle tanker, which supplies crude oil to a refinery in Cape Town. In May 2000 the adjacent Oryx oil field was also brought on stream utilising the same facilities. A third field, Sable, commenced production in August 2003. During 2006 average daily production from Sable was 9700 BOPD. The Oribi/Oryx fields are now almost depleted with only minor production. Sable field is now producing gas to supplement the feedstock to the Mossel Bay GTL plant. Production from South Africa's gas fields is also in decline, making exploration for further domestic reserves imperative.

Database
A substantial database has been accumulated during 40 years of offshore exploration (Figures 12 and 13). This comprises well, seismic, gravity, magnetic, geochemical, geological, biostratigraphic and other data together with a large volume of interpretation reports and related studies. Most of this data is held by Petroleum Agency SA on behalf of the State and is well organised and accessible.

The quality of this database varies considerably from area to area. Seismic data coverage for example, varies greatly in quantity and vintage from one basin to another. Drilling activity shows a similar pattern with a heavy concentration in the Bredasdorp Basin.

Figure 11. Oil and gas discoveries of Bredasdorp Basin - depth contours on horizon 14At1 (mid-Albian).

Figure 12. 2D and 3D seismic acquisition by region.
Figure 13. Extent of offshore seismic data.
THE ORANGE BASIN

The Orange Basin is areally and volumetrically the largest of South Africa's offshore basins. It is underexplored with one well per 4000 sq km. Several petroleum systems (oil and gas) are known to be operating in the basin, and two fields with multi-trillion cubic feet potential natural gas reserves have been discovered to-date: the Ibhubesi gas field off South Africa and the Kudu gas field off southern Namibia. Seismic coverage is extensive (Figures 13 and 20).

Structure and stratigraphy

The Orange Basin is outlined by the isopach map of the post-rift sedimentary succession (Figure 14). It is the southernmost West African basin, and was fed by a major river system with a delta rivaling those of rivers further to the north in Africa. The underlying synrift succession comprises generally isolated, truncated remnants of half-graben to the east of the medial hinge (Figure 15). Sedimentary fill may be as old as Jurassic but the oldest dated sediments are Hauterivian. All the penetrated sediments are continental, with igneous lithologies in places. To the west of the hinge seismic seaward-dipping reflectors are interpreted as subaerial flood-basalts thought to have poured rapidly onto the attenuated continental crust at the close of the active rifting phase (6At1 or 117.5 Ma, see Figure 6). The basalts are coeval and in parts interbedded with continental to shallow marine sediments of the mainly Barremian “transitional”, overall transgressive ramp-like succession. The western margin is thus of the divergent volcanic type. True oceanic crust is located to the west of the seaward-dipping reflectors well beyond the prominent marginal ridge. The margin is segmented into a number of crustal segments, with the southern segment of the margin being possibly of the rifted margin type.

A major drowning of the margin closes the early history of the basin and forms the start of the typical full “drift” wedge with strongly prograding sequences punctuated by erosional sequence boundaries (Figures 6 and 16). The Cretaceous sediments are siliciclastic ranging from continental in the east to deep-marine in the west. The Tertiary succession is mainly composed of calcareous oozes and chemical sediments. The thick wedge of drift sediments underwent repeated deformation of the palaeo-shelf edges and palaeo-slopes due to sediment loading and slope instability, especially in the Upper Cretaceous. These sedimentary tectonic features typically comprise extensional gravity faults and folds up-dip, a detachment glide plane in
mobile/overpressured shales, and compressional toe-thrust faults and folds down-dip. The shelfal portion of the drift succession is largely unstructured.

**Petroleum systems, exploration plays and prospects**

Exploration to date has confirmed that several petroleum systems sourced from known source rocks are at work in the Orange Basin. Evidence for Aptian source rocks has been compiled by van der Spuy (2003), and there is some evidence for the presence of an active Cenomanian/Turonian source rock (Aldrich et al., 2003). These oil and gas systems contain a number of exploration plays and prospects which are currently being pursued. Only 38 exploration wells have been drilled in this vast repository off South Africa (Figure 20). The main play elements are shown in Figure 17. Forest Exploration is pursuing the Albian Gas Play, the Upper Cretaceous Shallow Gas Play and the Barremian Deep Gas Play in the shelfal portion of blocks 1 and 2A; and the Upper Cretaceous Deep-water Slope Turbidite Oil/Gas Play in block 2C. BHP Billiton is pursuing the Albian Gas Play in block 3A/4A, and the Upper Cretaceous Deep-water Turbidite Oil Play in block 3B/4B.

The most well documented petroleum system discovered to-date is the natural gas system sourced from the lower Aptian and Barremian source shales located in the depocentre of the Orange Basin (Figures 14, 16). The Albian Gas Play within this system has led to the Ibhubesi gas field currently being appraised by Forest Exploration. The reservoirs are stratigraphically trapped fluvial channel-fill sandstones, which yielded 68 MMscfg/d and 340 bbl of condensate per day during the testing of the A-K1 discovery well by Soekor in 1987.
Forest Exploration has drilled a further 8 wells during subsequent appraisal of the field and combined tests yielded 221 MMscfge/d. Forest Exploration and its partners have been granted a Production right over this field. Bright spots and seismic gas chimneys are common occurrences in the play fairway. The Barremian Deep Gas Play has yielded the Kudu gas field in the Orange Basin off southern Namibia. The reservoirs are stratigraphically trapped aeolian sandstones with good gas deliverability. Both the Ibhubesi and Kudu plays are regarded as having the potential for multi-TCF reserves of natural gas.

Within the synrift succession, the only oil system confirmed to-date occurs in the isolated A-J half-graben (Figures 15, 16 and 18). The oil is sourced from typically rich Hauterivian lacustrine shales within the half-graben and is trapped stratigraphically within lake shore-line sandstones interbedded with the source shales. The maximum flow rate reached whilst testing is about 200 barrels per day of viscous oil. This geological success has shown the potential of the Synrift Oil Play. Several speculative petroleum systems and plays are also prognosed in the undrilled parts of the basin, notably in the deep water areas (Figures 16-18).

Seismic gas chimneys, seismic wipe-out zones, seafloor gas escape features (mounds, craters, mud volcanoes), bottom simulating reflectors (gas hydrates?) and discrete bright spots and flat spots indicate the likelihood of an active petroleum system in deep water coinciding with the zone of intense structuration.

The known Aptian-Barremian source rocks are postulated to become increasingly oil-prone westward on the basis of evidence from the more distal wells, the DSDP 361 borehole, and the nearby Bredasdorp Basin (Figure 19 and Van der Spuy, 2003). A Turonian oil source rock is envisaged as a possibility based on intersections in the distal part of the Bredasdorp Basin, in Namibia’s Walvis Basin, evidence of a wet-gas source shale in some of the Orange Basin wells, seismic character and possible organically rich, climatically-driven upwelling zones in the Late Cretaceous (Aldrich et al., 2003).
Wells

Stratigraphic, lowstand systems tract: prograding wedge (LST: pw)

Regional stratigraphic wedge-outs

Half-graben (strat.)

Fault traps

Domes

Proximal growth-faults

Figure 18. The main petroleum discoveries and shows in the Orange Basin (after Jungslager, 1999).

Figure 19. The active marine source rock kitchen at the lower Aptian level (after Jungslager, 1999).
During the Late Cretaceous, shelfal sand supply was ample and several canyons have been identified whereby sand could be supplied to the slope and basinal domains providing reservoirs for vertically migrating hydrocarbons. Trapping is visualized against the flanks of structures in the form of ponded and channelized turbidite sandstones.

These deep-water plays remain high risk but are believed to be attractive targets for future exploration, based on evaluation of a regional non-exclusive seismic survey acquired by PGS in 2002.

In summary, the Orange Basin is a large under-explored area with a very sizeable potential for both oil and gas. The oil potential may be greatest beyond the present day shelf, but the gas potential may be greatest on the shelf.
THE OUTENIQUA BASIN

Structure and stratigraphy
Maps and cross-sections of the Outeniqua Basin (Figures 21, 22) clearly illustrate the half-graben geometry of the synrift sediments and the variable thickness of the later drift sediments. The size of the sub-basins increases systematically from east to west and the initial trends of the half-graben bounding faults were strongly influenced by the pre-existing fabric of the Cape Fold Belt. The deepwater extension of these sub-basins comprises the Southern Outeniqua Basin.

Source rocks and maturity
Rich, wet gas and oil-prone marine source rocks of Kimmeridgian to Berriasian age have been intersected in the Gamtoos and Algoa sub-basins. An oil-prone Lower Cretaceous lacustrine source rock is present in the onshore Algoa sub-basin. A number of deep marine oil and gas source rocks are known in the transitional rift-drift sequence (Lower Valanginian to mid-Aptian; 1A to 13A sequences). These are best developed in the Bredasdorp Basin where the 13A (mid-Aptian) source is probably the main source for the oil fields and a minor source for the gas condensate fields. These source rocks are also postulated to be thick and rich in the Southern Outeniqua Basin. All the synrift source rocks are mature over large parts of the area. The younger source intervals are mature in the west and south (Bredasdorp and Southern Outeniqua basins).

Reservoirs, seals and traps
Sandstone reservoirs are present in both the synrift and drift sections. The synrift reservoirs are shallow marine to fluvial whereas drift sandstones are deep marine turbidite deposits. The trapping mechanisms within the synrift are mainly structural as well as truncational. Drift marine shales provide the main seals but potential synrift seals also exist. Traps within the synrift section are mostly tilted fault blocks. In the drift section a wide variety of mainly low relief closures is developed. These include compactional drape anticlines, stratigraphic pinch-out traps and inversion-related closures.

Oil and gas fields
The Oribi and Oryx oil fields (Figure 11) produce a light oil (42 degree API gravity) from Lower Cretaceous (mid-Albian) age sandstone reservoirs which were deposited in a deep water fan channel complex in the axial part of the Bredasdorf Basin. The reservoir of the Sable field, a similar Albian age basin floor fan complex, produces oil, condensate and gas. The F-A / E-M gas fields produce from Lower Cretaceous (Late Valanginian) sandstones which were deposited as shallow marine shelf deposits along the northern flank of the basin.

Prospectivity
The prospectivity of the Outeniqua’s sub-basins is shown in Figure 23.

Bredasdorp and Pletmos basins
The hydrocarbon prospectivity is rated high in these basins which contain almost all of South Africa’s proven hydrocarbons. Numerous small oil and gas accumulations have been discovered in the Bredasdorp Basin and some are currently under appraisal. Further exploration in these basins is expected to yield continued success.

Southern Outeniqua Basin
For operational reasons (deep water and strong ocean currents) this basin has been left virtually unexplored. No wells have been drilled and until recently, the only control was provided by a wide grid of old seismic lines. 2D seismic data acquired by Canadian Natural Resources (formerly Ranger Oil) in 2001 and 2005 has confirmed the presence of major structures in this deep water frontier area. Domally closed synrift structures are generally within the oil window and expected to contain gas. Latest seismic interpretation of this new data indicates the possibility of a gigantic basin floor fan complex (named “Paddavissie”) with an upside potential of billions of barrels of oil also confirmed by the latest infill seismic data. The Southern Outeniqua Basin is highly rated for oil in the central and southern extent of the basin, and more gas-prone towards the northern periphery with its thicker overburden. Regional studies suggest the presence of multiple source rocks, shallow marine and turbidite sandstones and large structural and stratigraphic traps.
**Algoa and Gamtoos basins**

Active petroleum systems have been confirmed in both these sub-basins. The Algoa Basin has Kimmeridgian age good quality oil prone source rocks, encouraging oil shows, good reservoirs and traps and hosts a large wet-gas shallow water seep anomaly. The Gamtoos Basin is more gas-prone, although basin floor fan sandstones in the drift succession may contain oil sourced from an underlying Hauterivian source.

![Figure 21. Major tectonic elements in the Outeniqua Basin.](image)

![Figure 22. Cross-sections of the Outeniqua Basin](image)
Figure 23. Ranking of areas of the Outeniqua Basin.

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THE EAST COAST

The eastern offshore extends from the Port Alfred Arch (near East London) in the south to the Mozambique border in the north. It is divided into the Transkei Swell, the Durban Basin and the Zululand Basin. This large area has seen very limited exploration. Seismic lines are mostly old and widely spaced (typically a 25km grid) and only four offshore wells have been drilled. The continental shelf is very narrow along the Transkei Swell, broadening northwards in the Durban and Zululand Basins.

Transkei Swell
The Transkei Swell stretches from the Port Alfred Arch to just south of Durban (Figure 24). It has a narrow continental shelf and a steep continental slope both of which contain a veneer of mainly Tertiary sediments resting on basement. Locally, however, some structurally controlled Jurassic - Cretaceous basins are developed but are poorly defined on old seismic data.

Durban Basin
The Durban Basin is bounded to the south by the Port Shepstone Arch and merges northwards into the Zululand Basin which represents the southern tip of the large Mozambique Basin which hosts the Pande and Temane gas fields (Figure 24). It covers an area of some 4000 sq km between the coast and the 1500 m isobath. The continental shelf is approximately 35km wide between Durban and Richards Bay. The shelf and slope areas contain thick Tertiary successions and lesser thicknesses of Early Cretaceous sediments that rest on Jurassic to Palaeozoic basement. North-south oriented graben are thought to contain substantial thicknesses of synrift sediment and several large structural traps have been defined in water depths between 400 m and 600 m.
Zululand Basin (onshore and offshore)
The offshore Zululand Basin covers an area of approximately 13,500 sq km out to the 1500 m isobath although most of this lies in water depths of more than 200 m. It is undrilled but 10 wells were drilled in the 1960’s / 70’s in its onshore extension. Late Cretaceous source rocks and porous Cretaceous sandstones were demonstrated, but no shows were encountered. The scant offshore seismic data shows evidence of asymmetrical grabens that are interpreted to contain oil prone Cretaceous sediments. Extrapolation from wells drilled in Mozambique suggests that Late Cretaceous source rocks (the Domo Shales) could be widely developed in the offshore Zululand Basin and may be gas prone.

Basin evolution
The Durban and Zululand basins initially developed during the early Jurassic to early Cretaceous break-up of the Gondwana super-continent. Plate tectonic reconstructions suggest that early divergent plate movements between East and West Gondwana resulted in transtentional stress, which resulted in the development of rift basins along the break-up margin. Right lateral strike-slip faulting dominates segments of the Durban Basin break-up margin. Both divergent and transtentional movements served to extend the continental crust and formed horst and graben structures. The early Cretaceous was characterised by the movement of the Maurice Ewing Bank (Falklands microplate) from its original position adjacent to the Durban Basin. This occurred as part of a late north-south orientated extensional event.

Chronostratigraphy
Using regional seismic data and limited well control, the stratigraphy has been correlated from the modern shelf into the deepwater areas of the basins. Figure 25 provides a summary of the main geological events that influenced the development of the Durban and Zululand basins.

The Tugela Delta
The Tugela River system has played a major role in shaping the landscape of the eastern offshore. In the Late Cretaceous to Tertiary, the Tugela River was a major source of sediment and built up the extensive sediment pile of the Tugela Cone. This cone comprises a large constructional delta that extends out across the shelf margin and a distal fan which extends to water depths of 2000 meters and beyond. Two sediment growth phases are present, one related to synrift and early drift sediment supply, the other to a renewal of progradation during the Early Tertiary. The resultant Tugela Fan, associated with prolonged sediment input from the palaeo-Tugela River, dominates the mid-Cretaceous geology of the Durban Basin. The Tugela Fan has not been explored for hydrocarbons but recent seismic mapping reveals extensive systems of basin floor fan complexes extending into deeper water.

Northwest trending seismic dip lines show prograding Tertiary reflectors with oblique seismic signatures. Well Jc-A1 intersected prodelta shales comprising upward-coarsening regressive cycles. The deltaic signature is particularly well displayed in the Tertiary succession.
Petroleum elements of the Durban and Zululand basins

The hydrocarbon potential of the Durban Basin has been tested by only four wells, all of which were non-commercial but two of which had shows. Jc-D1 (drilled by Phillips in 2000) provides evidence for oil and gas petroleum systems (Figure 26).

Source rocks

Possible source rocks within the Durban and Zululand basins are as follows:

- A Jurassic source within graben sediments of the basins as indicated by extract analysis from Jc-D1.
- An early to mid-Cretaceous source as intersected within the Durban Basin and the Mozambique Basin.
- Cenomanian-Turonian and Barremian-Aptian source rocks as intersected by wells in the Durban Basin.
- Possibly the Domo Shale equivalent in the deep synrift sections, as seen in the Mozambique Basin to the north.

Evidence supporting the presence of source rocks and active petroleum systems is:

- DSDP wells 330 and 511, located on the Maurice Ewing Bank, intersected thick oil prone source rocks of Kimmeridgian to Aptian age. Similar age source rocks are postulated to occur within the Durban Basin in the rift and early drift succession that underlies the Tugela Cone.
- Jc-B1 exhibited a minor gas show and the associated shale has total organic carbon values, ranging from 2.75 to 5%.
- Jc-D1 mud gas values indicate a trend of increasing wetness with depth. In addition, fluid inclusion studies of Jc-D1 samples provide evidence for seeping light hydrocarbons and an extract sample yielded slightly biodegraded oil. Fluorescence was also observed in this interval and in the basal section of the well in association with bitumen staining. An extract from the latter yielded evidence for a light oil derived from a marine claystone of Cretaceous to Jurassic age.
- Possible gas escape features, sea floor craters and mounds have been identified in the Durban and Zululand basins (Figures 26, 27 and 28).

Reservoirs

With the existing wells positioned on shelf-margin highs, none encountered any sandstone of significant thickness. Seismic evidence suggests that reservoir rocks are present in deeper water and are associated with basin floor fans, turbidites and channel systems. Well Jc-B1 intersected a 17 m thick marine sandstone, which represents the last sand associated with retrograde deposition.
In the onshore Zululand Basin, a borehole located on the Bumbeni Ridge, encountered early Cretaceous sandstones with porosities ranging from 15 to 21%. Channel and basin floor fan systems are evident within the offshore Zululand Basin.

**Play types**
Tilted fault blocks, faulted anticlines, stratigraphic traps, basin floor fans and channel sands constitute the principal exploration targets of the Durban and Zululand basins (Figure 27). The following plays are evident on seismic sections and are supported by existing well and outcrop data:

- Large four-way dip closed anticlines at break-up unconformity level.
- Distal turbidite slope fan reservoirs.
- Turbidite sands over basement features.
- Basin floor fan complexes (Figure 29)
- Channel sands

**Petroleum potential**
Existing wells and sparse seismic data are inadequate for effective evaluation of the petroleum potential of this large area. However there is sufficient encouragement in the presence of reservoirs, traps, source rocks and active petroleum systems to justify further exploration. The acquisition of modern seismic data, particularly in the extensive deep water areas is regarded as essential for further exploration.
Figure 28. Possible gas escape features.

Figure 29. Basin floor fan systems in the Durban Basin: The Lion Prospect.
THE ONSHORE ENVIRONMENT

The Main (or Great) Karoo Basin and subsidiary basins occupy more than half of South Africa’s land surface (~700,000 km²; Figure 30). Although early exploration efforts by former national oil company SOEKOR for conventional oil resources during the 1960s and 1970s did not meet with commercial success, the Karoo basins nevertheless constitute a petroleum province with significant potential, as evidenced by numerous oil and gas shows being noted in scientific publications since the 19th Century.

Today, the onshore Karoo basins are the focus of a renewed international exploration effort, with unconventional gas being the principal exploration target. Coal bed methane, microbial gas and shale gas are considered to be the most promising play types at present.

REGIONAL GEOLOGICAL SETTING

Tectonic setting

The deposition of Karoo sediments took place between the Late Carboniferous and the Early Jurassic (~300-180 Ma) in the heartland of the supercontinent Gondwana. Northern, subsidiary Karoo basins in South Africa are primarily fault controlled, although tectonic models for the evolution of the Main Karoo Basin (Figure 31) remain controversial. The Main Basin is traditionally described as a retro-arc foreland basin (e.g. Johnson et al., 2006) formed on the continental side of a fold-thrust belt (the Cape Fold Belt), possibly with a strike-slip structural component (Tankard et al., 2009). However, seismic data yields evidence of southward-dipping décollements and blind Palaeozoic thrusts within the southern Main Karoo Basin, but no significant foredeep thickening or deep suture zone, suggesting that southward subduction occurred to the south of the Cape Fold Belt, and not beneath the Main Karoo Basin (Lindeque et al., 2011). Other possible influences on basin evolution include isostatic crustal depression by Carboniferous ice sheets during the Dwyka glaciation, crustal flexure due to tectonic loading and unloading, and plume-induced uplift in the Triassic prior to volcanism and Gondwana rifting in the Jurassic.

Stratigraphy and thermal history

Karoo sedimentation occurred in a wide range of depositional environments. Sedimentary units include the glacial diamictites of the basal Dwyka Group, the epeiric marine/lacustrine black shales, turbidites, deltaic sediments and coals of the overlying Ecca Group, and the fluvial deposits, coals and aeolianites of the Beaufort Group and upper Karoo formations (e.g. Catuneanu et al., 2005).

During the Permian-Triassic Cape Orogeny, the extreme southwest margin of the Main Karoo Basin experienced lower greenschist facies metamorphism. Later regional magmatism in the Early Jurassic (Karoo Large Igneous Province; ~183 Ma) resulted in the basin-wide intrusion of Karoo dolerites. Zircon fission track data (Brown et al., 1994) from the southwest Main Karoo Basin indicates palaeo-temperatures of at least 250 ± 50 °C at this time. It has been suggested that intrusion of the Karoo dolerites may have been responsible for the explosive formation of hydrothermal vents and breccia pipes following the heating of sediments rich in organic matter (Aarnes et al., 2011). According to apatite fission track thermochronology studies (e.g. Tinker et al., 2008), major exhumation of the Karoo Basin occurred in the middle and late Cretaceous (~140-80 Ma) with low rates of denudation since that time.

Karoo Basin petroleum potential

Due to the generally low porosity and permeability of potential conventional reservoirs as well as the thermal effects of Karoo dolerite intrusion and prolonged deep burial, mid-20th Century exploration efforts for conventional oil resources in the Karoo Basin were unsuccessful (Rowsell and de Swardt, 1976; Rowsell and Conan, 1979). However, a large number of applications have been received for petroleum exploration rights in the Karoo since 2004, when the Mineral and Petroleum Resources Development Act of 2002 became effective.

Petroleum potential in the Karoo basins varies from north to south with increasing thermal maturity. The northern Main Karoo Basin and subsidiary basins are characterised by having oil and coalbed methane potential, with shale gas being the principal exploration target in the south-western Main Karoo Basin. In addition, Karoo strata that overly the Archean metasediments of the Witwatersrand Supergroup have been shown to be of commercial interest for the production of microbial gas.
Figure 30. Exploration boreholes and oil shows of the Karoo and other onshore basins (after van Vuuren, et al., 1998).
Figure 31. Geological map of the Karoo Basins of South Africa (top), and schematic SW-NE cross-section of the Main Karoo Basin (bottom).
Coalbed methane (CBM) is sourced from coal seams, and is becoming an increasingly important unconventional source of natural gas globally. Historically, in South Africa’s coal mining operations, methane gas discharge from coal has been a safety hazard and the primary cause of underground mine explosions. There is therefore potential to create a synergistic relationship between exploration for coal and exploitation of CBM. The development of the resource is strategically important and if proven to be economically feasible provides an energy source that will address South Africa’s growing energy demand. In addition, by comparison to coal and oil, methane is a cleaner form of energy as it emits less CO₂ per unit of energy released.

Coal Occurrence
Coal seams are hosted in Early to Late Permian and Triassic-aged rocks of the Karoo Supergroup (Cairncross, 2001). Overall, South Africa’s coal deposits occur in 18 coalfields distributed across the Main Karoo Basin and extensional rift-related sub-basins namely, Springbok Flats, Lephalale, Tshipise, and Tuli basins (Figure 32). Coals are predominantly high to medium volatile bituminous rank, and there is a general trend of increasing rank from west to east, across South African coalfields (Cairncross, 2001).

CBM Resource Potential
Exploration for coal during the past 30 years and more has significantly increased the knowledge base and understanding of the distribution of coal in South Africa. This knowledge base together with more recent exploration results for CBM has confirmed the presence of potentially economic volumes of methane in South African coals. The results of exploration efforts by Anglo Thermal Coal, Badimo Gas in partnership with Kinetiko Energy and Umbono Capital in partnership with Sunbird Energy, suggests that the most prospective areas for CBM development at present occur in the Waterberg coalfield in the Lephalale Basin, Ermelo coalfield in the Main Karoo Basin, and Mopane coalfield in the Tshipise Basin. In addition, access to over 2000 coal exploration core holes and analysis data has aided with the evaluation of the CBM resource potential for the Springbok Flats Basin. The following section provides an overview of the CBM resource potential of the prospective basins described above.

CBM Prospectivity
Lephalale
The Lephalale Basin containing the Waterberg coalfields is the most promising area for CBM production. This region contains 40% of South Africa’s remaining coal resources. The coals, which have high vitrinite content, are up to 70 m thick (net coal) and buried to depths greater than 250 m. Anglo Thermal Coal has drilled over 80 exploration core holes in their acreage and this includes a 5-spot pilot production well array. On the basis of their evaluation, Anglo Thermal Coal has reported technical recoverable CBM reserves of 1 Tcf of gas for the Waterberg coalfield.

Ermelo Coalfield
The Majuba coal colliery near Amersfoort was intended to supply the Majuba Power Station; however underground mine explosions associated with high concentrations of methane gas in the coal resulted in closure of the colliery in 1993. Average depths to the most significant coal seams range from 315 to 385 m and coal thicknesses range from less than 1 m to 16 m. The coals vary in rank from high volatile bituminous to medium bituminous. On the basis of studies associated with the various mining attempts, gas contents reported for the coals exceed 10 m³/t. This provides encouraging evidence for gas saturated coal and the development potential of CBM in the area. Badimo Gas and Kinetiko Energy in partnership have drilled more than 10 exploration core holes and five pilot production wells in the Amersfoort area. On the basis of exploration results, early evaluation of the CBM resource suggests P50 prospective resources to be approximately 2.4 Tcf of gas-in-place.

Mopane Coalfield
The Mopane coalfield is considered favourable for the occurrence of CBM due to the presence of extensive coal deposits and depths adequate for CBM development and preservation. Exploration results for this coalfield indicate coal-shale sequences up to 130 m thick, with net coal up to 38 m and buried to depths greater than 300 m below surface. Exploration drilling and gas content analysis by Sunbird Energy confirm excellent gas content for Mopane coals. Results have exceeded expectations with gas contents ranging from approximately 2.8 m³/t to 7.5 m³/t. Sunbird Energy reported best estimate gas-in-place of 1.90 Tcf with a High Estimate of 13.66 Tcf.

Springbok Flats
There is currently no mining activity in the Springbok Flats coalfields and the basin is largely untested, but it appears to have good CBM potential. The coal seams, which are 3 m to 9 m thick, with a net thickness of up to 18 m in places (Roberts, 1992), are buried to a depth of more than 600 m and have high vitrinite content. The Petroleum Agency SA on the basis of an empirical analysis of coal exploration core hole and proximate analysis data deterministically estimated a gas-in-place resource in the order of 5 Tcf for this basin. However, it is expected that the estimated volumes of gas-in-place will change over time as exploration gets underway and new data becomes available.
Figure 32. Distribution of coal fields in the Karoo-aged basins in South Africa (digital geological data sourced from Council for Geoscience)
DEEP BIOGENIC (MICROBIAL) GAS

The methane encountered in underground gold mining of the Archean Witwatersrand Basin in the Free State and Evander goldfields (Figure 33) was regarded only as a mine explosion hazard and flared in large quantities. Local gas shows at surface have also been known to burn for years without showing any evidence of depletion.

Substantial quantities of hydrocarbon gases have been observed within the Witwatersrand Basin during both coal and gold exploration activities (Hugo, 1963). The gas is composed predominantly of methane, and other gases including helium. Gas encountered is not generally contained in traps but rather is being continually generated at depth and migrating to surface along natural fracture systems, faults and dykes. A number of published analyses (Ward et al., 2004; Sherwood-Lollar et al., 2006; 2008) indicate that much of the produced gas is of microbial origin, generated by primitive bacteria that inhabit deep water-bearing fissures.

It is thought that additional gas may be generated within the shale or coal-bearing Karoo strata. However despite recent advances, knowledge about microbially mediated processes in the subsurface is still in its infancy. Thus, the source and migration pathway of the gas are unusual and present significant challenges to fully define the ultimate potential of the resources as no known analogues exist for this type of gas production.

Play types
The presence of hydrocarbons is, to a large extent, controlled by the geologic formations in which the gases are found. Possible traps or play types have been suggested to account for hydrocarbon gas to migrate up through faults/joints and become trapped within these fractures or sealed by Karoo Supergroup. The following plays are evident and supported by existing well data:

- Primary Play - comprises natural fractures (joint/faults) associated with major faults/folds in the Archean Witwatersrand Basin.
- Secondary Play - found within the Karoo Supergroup mainly Karoo sandstones sealed by claystone/siltstone and volcanics.

Hydrocarbon shows / production are associated with:

- Karoo Ecca / Dwyka Group
- Ventersdorp Supergroup
- Witwatersrand Supergroup

The Free State and Evander goldfields are structurally complex, with crustal fracture zones bounded by major faults. The abundance of semi-vertical cross-cutting dykes, kimberlite fissures and fractures throughout the Witwatersrand Basin suggest the potential for gas migration and transport along these structures.

Resource Potential
A considerable number of academic researchers and exploration companies have been investigating if the methane can be turned to commercial advantage. Most recently, a gas Production Right has been granted in the Free State, with first proven onshore gas reserves (1P) for the region. Given the unusual nature of this unconventional play, the estimated flow rates for the gas-emitting boreholes indicate a sustained gas rate of more than 1.2 million standard cubic feet per day. Without showing any evidence of depletion, this former mining hazard may therefore become a potential renewable future energy source for South Africa.

Future Gas Supply and real opportunity to:

- Recent changes to the electricity market in South Africa also offer opportunities for small scale power production, and
- Contribute to SA energy supply;
- Support developments of the small scale processing to either CNG or LNG.
Figure 33. Regional locality of Deep Biogenic Gas in the Archean Witwatersrand Basin in South Africa.
SHALE GAS

Resource potential
There is significant international interest in the Main Karoo Basin’s shale gas potential at present. A report commissioned by the U.S. Energy Information Administration (Kuuskraa et al., 2013) proposed that the Karoo hosts a technically recoverable shale gas resource of 370 Tcf. Petroleum Agency SA’s own ongoing research suggests that a smaller but nevertheless significant recoverable resource of the order of tens of Tcf is more probable. However, shale gas exploration in the Karoo remains at a very early stage, making any resource estimate necessarily speculative. The only production test of any significance in the region dates from 1968, when Soekor well CR1/68 near Pearston yielded a gas flow rate of 1.83 mmscf/day for 23 hours from natural fractures in the Fort Brown Formation shale. The Fort Brown was considered to be self-sourcing at the time, but may also have been charged by the underlying Whitehill Formation.

Prospectivity indicators
The Permian-aged lower Ecca Group in the southern Main Karoo Basin is comprised of a number of fine-grained formations of variable prospectivity. Of these, the Whitehill Formation is considered to be the most prospective for shale gas.

The Whitehill Formation’s depositional environment is a subject of some debate, with contrasting epeiric marine and brackish lacustrine models being proposed (Faure and Cole, 1999). However, the formation is characterised by high total organic carbon content (up to 14%; average 4.5 %), high thermal maturity (Ro = 1-4 %), high quartz content (50 % average with carbonate-rich intervals) and sufficient thickness for commercial development (35 m average). Legacy exploration data demonstrates that it is regionally continuous over some 200,000 km² and buried to depths of up to 4 km in the extreme south of the basin.

Additional positive indicators include numerous gas shows in the lower Ecca Group and underlying Dwyka Group in the southern Karoo Basin and the occurrence of pyrobitumen (pseudo-coal) in fissures, indicating the existence of an originally oil-prone source rock.

Risk and uncertainty
Intrusions of the Karoo dolerite suite outcrop across much of the Main Karoo Basin, with the exception the deep southern marginal zone. While their subsurface geometry and distribution is not well understood at present, it is possible that intrusion of the dolerite magma may have resulted in the fracturing, contact metamorphism and degassing of shales in places, resulting in reservoir compartmentalization. However, Karoo dolerites have also been reported to serve as cap rocks for conventional traps, and even serve as hydrocarbon reservoirs where fracture porosity exists (e.g. Hall, 1921).

High maturities along the basin’s southern margin (the Cape Fold Belt) indicate graphite-facies metamorphism of the Whitehill Formation (e.g. Branch et al. 2007), with maturities decreasing northwards. The effect of high maturity on the gas content of the Whitehill remains to be determined, with no gas content measurements of fresh deep core currently available.

Comparisons with analogue shale plays suggests that the Whitehill Formation may be the most prospective in areas of distal deposition, where stratigraphic thicknesses greater than 30 m are buried to depths greater than 1.5 km but not subjected to maturities greater than 3.5 % Ro, and where sub-surface dolerite intrusions are minor or absent (Figure 34). However, the location of any potential sweetspot must be considered speculative at present, due to the sparse distribution of legacy exploration data.

Outlook
Recent technological advances in hydraulic fracturing and horizontal drilling technologies, as well as growing global energy demands, have allowed for previously uneconomical, low permeability reservoirs to become economically viable. The long term market for gas in South Africa is likely to be strong, as the country’s economy develops and the demand for energy grows.

However, a significant investment in exploration and infrastructure will be required in the sparsely populated, ecologically sensitive and economically disadvantaged Karoo region if sustainable shale gas development is to become a reality.
Figure 34. The prospective Whitehill shale gas play. Thickness (black contours), depth (shading) and maturity (red stippled) contours based on legacy well data are shown. Also indicated is the surface distribution of Karoo dolerite and the approximate boundary between proximal and distal facies (green stippled) (after Visser, 1992).
UNCLOS 82 is a remarkable international agreement intended to ensure responsible management of the world’s oceans. Under maritime law a coastal state has sovereign right to a number of maritime zones including the Territorial Sea (up to 22kms from shore), the Contiguous zone (44 kilometres from shore) and the Exclusive Economic Zone (370 kilometres from shore). Article 76 of the Convention makes provision for states to claim an additional zone called the Extended Continental Shelf. This is intended to include the submarine plateaus and ridges that extend from the continental margins of coastal states beyond their exclusive economic zone limits. Each coastal state is responsible for the management of these zones according to the provisions of international law, with the remaining unclaimed areas being managed by the United Nations International Seabed Authority in trust for humanity.

South Africa’s claims, which jointly amount to approximately 1.87 million square kilometers, rank amongst the 10 largest claims in the world and, if endorsed by the United Nations, will more than double South Africa’s maritime territory (see figure 1).

The potential of this opportunity was initially recognized as being of national importance during the 1980s. The SA Navy Hydrographic Office with the assistance of the Institute for Maritime Technology carried out the initial investigations and lobbied for the establishment of a dedicated national project. This successfully resulted in a Cabinet decision to allocate responsibility to the Minister of the then Department of Minerals and Energy, who directed the Petroleum Agency to manage the project. The project officially started in April 2003 and the technical study took 6 years to complete. Initial phases included the search for and acquisition of existing and new data.

This was followed by the application of the scientific and legal principles prescribed by Article 76 of UNCLOS and the compilation of the submission documents and appendices. Finally, these were lodged with the United Nations in May 2009.

Benefits for the Nation

Many benefits beyond the acquisition of the extra territory were realized during this process. These included, inter alia, the identification and accessing of vast tracts of existing geophysical and hydrological data for the benefit of the State; the acquisition of new survey data; the building of international contacts and the close cooperation with France which led to the agreement to lodge a joint claim around the South African Prince Edward and French Crozet Islands.

It is important to remember that the rights to an Extended Continental Shelf zone are limited to mineral and living resources on and under the sea floor and that conventional fish stocks are not included. The benefits of the acquisition of the new territory are however still numerous. These include the potential for mineral resources including oil and gas, manganese nodules and crusts possibly enriched with precious metals. And, in the vicinity of the Prince Edward Islands, the possibility exists of discovering gold-bearing hydrothermal deposits and of exploiting the pharmaceutical and medical benefits of microbes associated with the inhospitable ultra-deep ocean floor and toxic hot water geysers. Many of these benefits are not immediately quantifiable or exploitable with current knowledge and technology, but through this project future access to these has been assured for coming generations of South Africans.

The successful completion of this part of the project represents an historic event for South Africa. If endorsed, South Africa will control one of the 10 largest maritime territories in the world. With this, should come not only a renewed sense of national pride but also the realization of South Africa’s huge obligation to contribute to the responsible management of the world’s oceans in order to ensure that their productivity and ecological balance is maintained for future generations.
Figure 35. White outlined areas shown above, illustrate South Africa’s Extended Continental Shelf Claim.
USEFUL REFERENCES


Useful References ...


DATA PACKAGES
A variety of information and data packages are available from the Agency. These packages contain well and seismic data together with short reports describing the petroleum potential. Interested investors are welcome to visit the Agency’s data room in Cape Town to view data and to obtain further information on exploration opportunities.

MORE INFORMATION
Interested parties are invited to contact the Agency for further information concerning technical, legal and contractual details or for any other queries regarding participation in exploration and production in South Africa.

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August 2017