REPUBLIC OF SOUTH AFRICA

PETROLEUM EXPLORATION POTENTIAL OF THE ORANGE BASIN

REGIONAL GEOLOGY

STRUCTURAL SETTING

The Orange Basin forms part of the Southwest African Coastal Basin which lies offshore Namibia and western South Africa, extending from the Walvis Ridge in the north to the Agulhas Falkland Fracture Zone in the south (figure 1). Three depocentres are recognized from north to south: the Walvis, Lüderitz and Orange sub-basins (figure 1). The Orange Basin which is the largest of the three, covers an area of approximately 160 000km^2 to the 2000m isobath, defined by the extent of the infill post-rift sediments.

BASIN EVOLUTION

The Orange Basin formed in response to the fragmentation of Western Gondwanaland, and the associated opening of the South Atlantic Ocean through sea-floor spreading. As with classic divergent plate tectonic settings, the geological succession displays a typical two-fold subdivision. This comprises an older syn-rift unit, overlain by a younger post-rift unit. The South West African continental margin is a rifted plate margin that is underlain by pre-rift and syn-rift grabens, covered by post-rift sediments. Four main tectono-stratigraphic sequences represent the major phases that resulted in the opening of the South Atlantic Ocean namely: Syn-rift, Post-rift (Transitional), Drift and Late-Drift (Cretaceous and Tertiary).

During the Middle to Late Jurassic, the extensional stress associated with the breakup, caused the formation of a series of coast-parallel graben systems (figure 2). These graben systems are separated laterally from an outbound synrift wedge by a flexural high which is known as the Medial Hinge (Gerrard & Smith 1982). The graben fill comprises Lower Cretaceous siliclastics and volcanics, the former including fluvio-lacustrine sediments and coarse continental clastics.

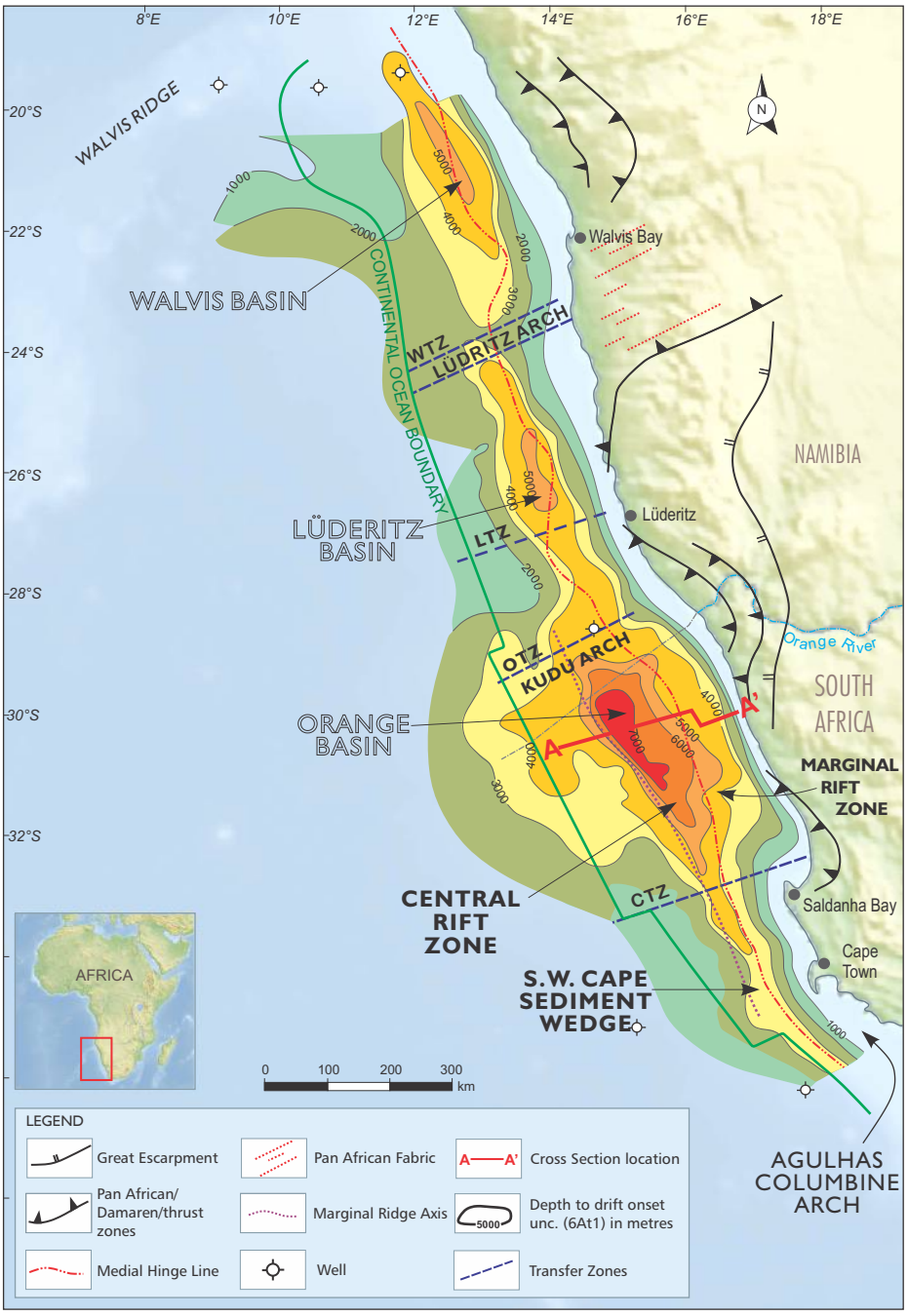


Figure 1: Structural framework and main depocentres of the Southwest African Coastal basin (modified after IHS Energy Group, 2008)

The drift succession is characterized by a thick seaward and landward thinning sedimentary wedge that overlies the rift basins representing a longstanding sedimentary depocentre, mainly supplied by the Orange and Olifants Rivers and their ancestral equivalents. The margins of the Orange Basin depocentre, in a strike sense, are defined by flanking basement highs. These comprise the Kudu Basement Arch in Southern Namibia, and the Agulhas Columbine Arch in the South (figure 1).

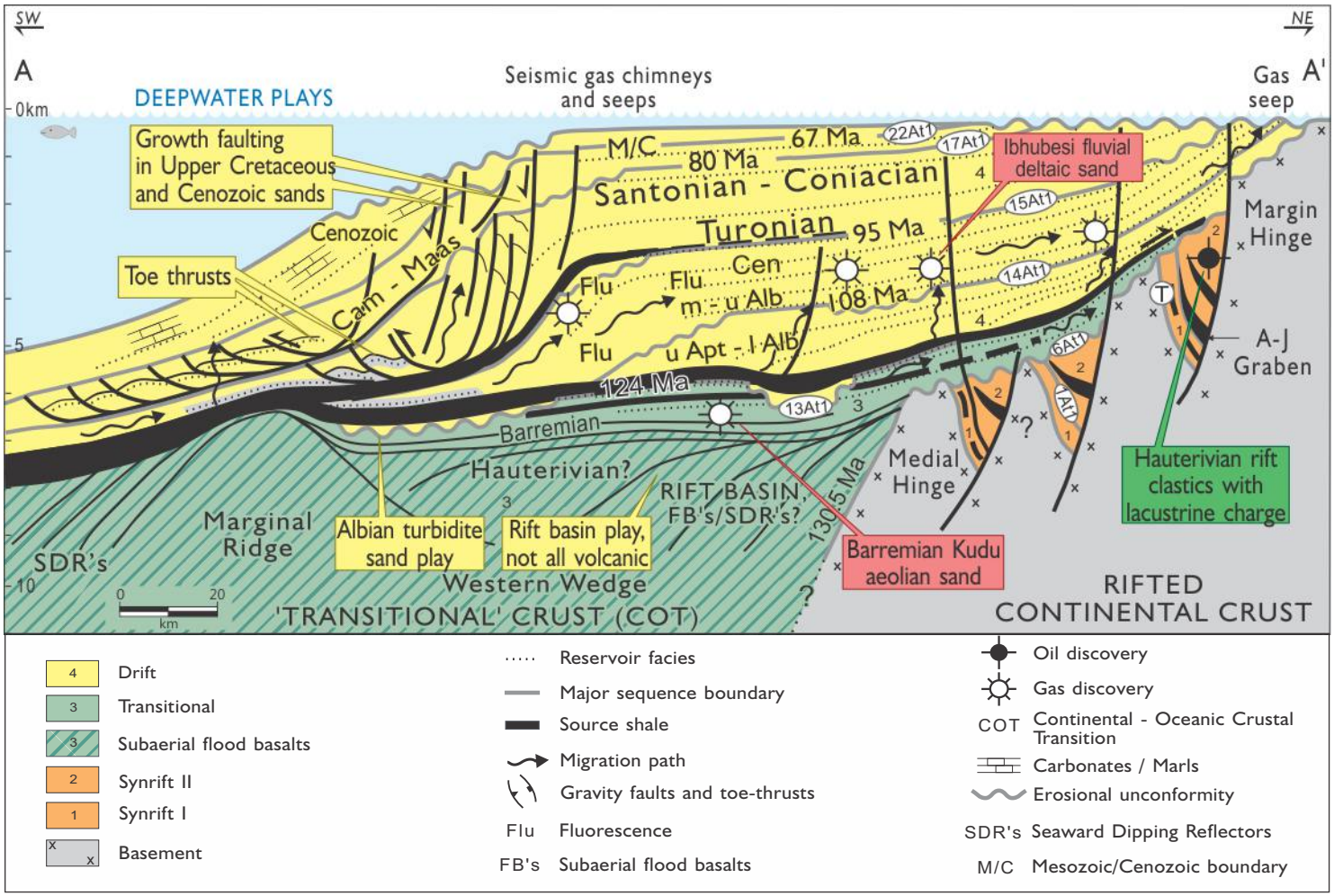


Figure 2: Schematic geologic cross section across the central Orange Basin (Jungslager, 1999)

The termination of rifting and onset of drifting on the Southern African West Coast occurred in the Hauterivian. This marks the time at which the proto-South Atlantic Ocean was established, with the permanent imposition of a marine influence on the west coast. The Cretaceous succession is subdivided into five major super-sequences each defined by major, tectonically enhanced, eustatic sequence boundaries (Brown et al., 1996) (figure 3). During the initial phase of this period of the margin's history, the South Atlantic remained relatively shallow and restricted. The depositional setting thus was transitional between rift and drift. The continental shelf/slope profile in existence at this time was poorly developed and ramp-like. Associated depositional environments included restricted marine, deltaic and coastal plain settings.

A prolonged northerly sediment input during the Mid to Late Cretaceous explains both the presence of the principal depocenter in this region, as well as the relatively more basin-ward offlap position of younger super-sequences, when, compared to in the south. Subsidence rates on the South African West Coast had diminished by the onset of the Tertiary, with the underlying Cretaceous platform becoming increasingly stable (Dingle & Scrutton, 1974). As a result, Tertiary depocenters shifted significantly basinward of their Cretaceous counterparts, with sedimentation now being focused in a former slope setting. Prolonged vertical stacking of continental slopes during the aggradational phases resulted in spectacular gravity faulting at the shelf edge, occurring contemporaneously with sedimentation.

PLAY DETAILS

ALBIAN

The Albian Stratigraphic-Structural Play has been confirmed in several gas discoveries off South Africa, the best of which is the A-K1 (Ibhubesi) (figures 3,4,5). It is the most significant play in the South African portion of Orange Basin to date. The more important features of this play type exemplified by the A-K1 discovery are its stratigraphic trapping; the excellent porosity-permeability qualities and the extremely good flow rates for relatively thin sandstones; seismic amplitude anomalies associated with the gas-bearing sandstones; and the absence of gas-water contacts indicating possibly large stratigraphically trapped systems. Although this play can be confidently mapped seismically over the entire main depocentre area between the A-K1 location and the Namibian border, individual traps are difficult to identify mainly because of the almost total absence of structure.

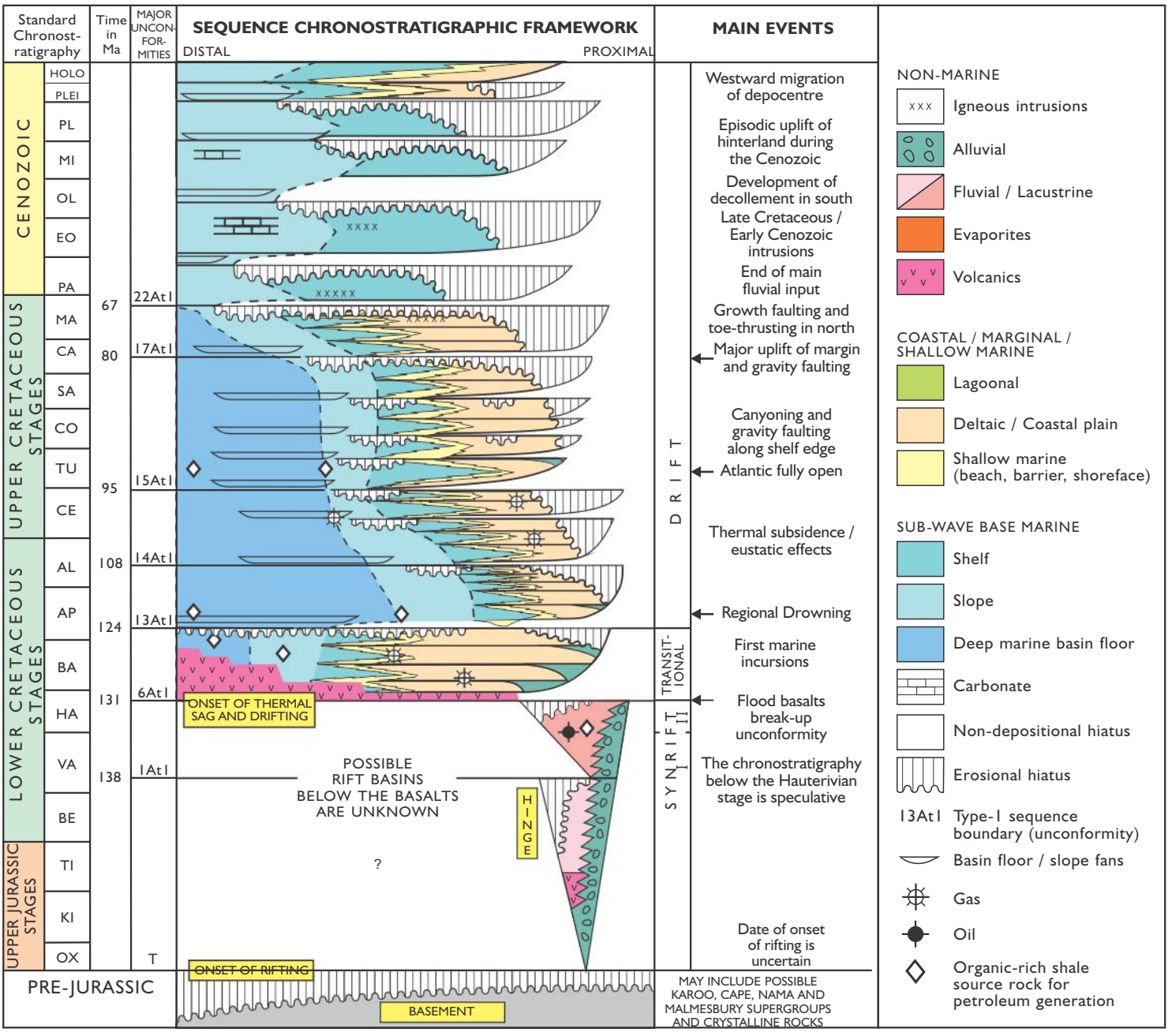


Figure 3: Generalized chronostratigraphy of the Orange Basin

BARREMIAN

The Barremian Stratigraphic Play is confirmed by the Kudu gas field offshore southern Namibia, in the northern part of the Orange Basin depocentre (figures 3,4,5). The most striking features of this gas accumulation are that it is stratigraphically trapped in continental aeolian sandstones. No water contact was encountered; the reservoir is some 1,600 psi overpressured; the porosities average 12% and permeabilities 43 mD at about 4,400 m. The deliverability of the reservoir is substantial despite the depth of burial and the reservoir sands are closely associated with basalts. The gas is about 96% methane and the reservoir is overlain by a gas-charged, but tight, shallow marine sandstone, itself overlain by some 200 m of spent source rocks (Jungslager, 1999).

It is suggested that the Kudu-type aeolian play extends southward into the South African portion of the Orange Basin where evidence of a major gas charge is evidenced, including a large thermogenic methane seep near the mouth of the Orange River. This play has not been drilled yet off South Africa, but is currently being explored by companies with concessions over the northern and parts of the central Orange Basin. Of the two source intervals identified in the Kudu wells, the lowermost (Barremian) source interval is regarded as the principal source for the Kudu reservoirs, which are also Barremian in age, although an older downdip source cannot be ruled out. The hydrocarbons must have migrated up-dip into the Barremian sandstone reservoirs of Kudu, as no pyro-bitumen residues were encountered in the reservoirs (ie the oil was not cracked in situ). In this petroleum system, the source rocks are wet gas to oil-prone. They may have started to generate oil during the Campanian and by the Oligocene had passed through the oil window and were generating gas.

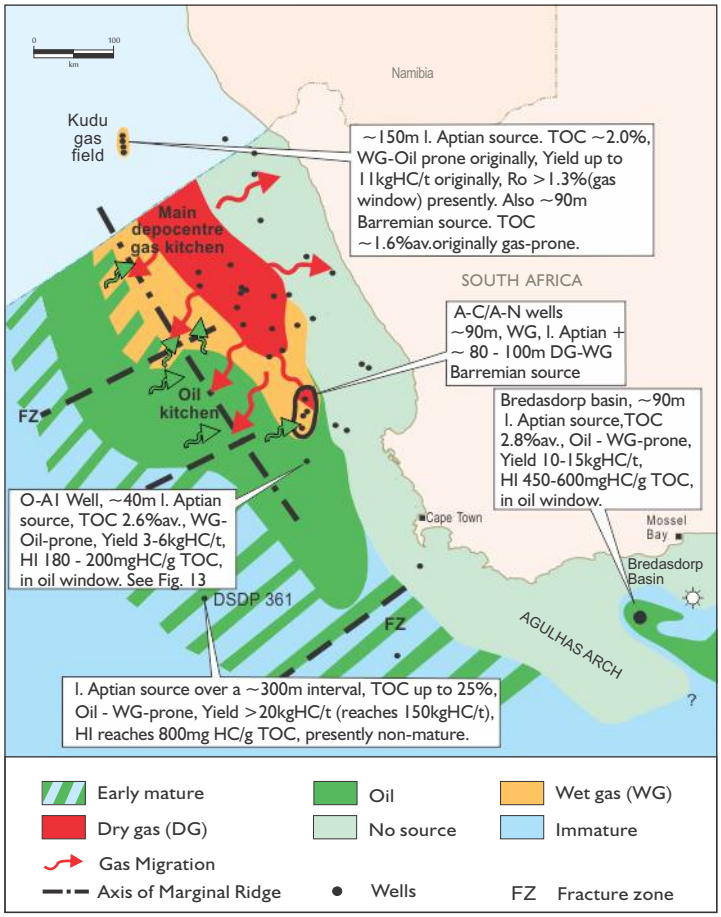


Figure 4. The active marine source rock kitchen at the lower Aptian level (after Jungslager, 1999).

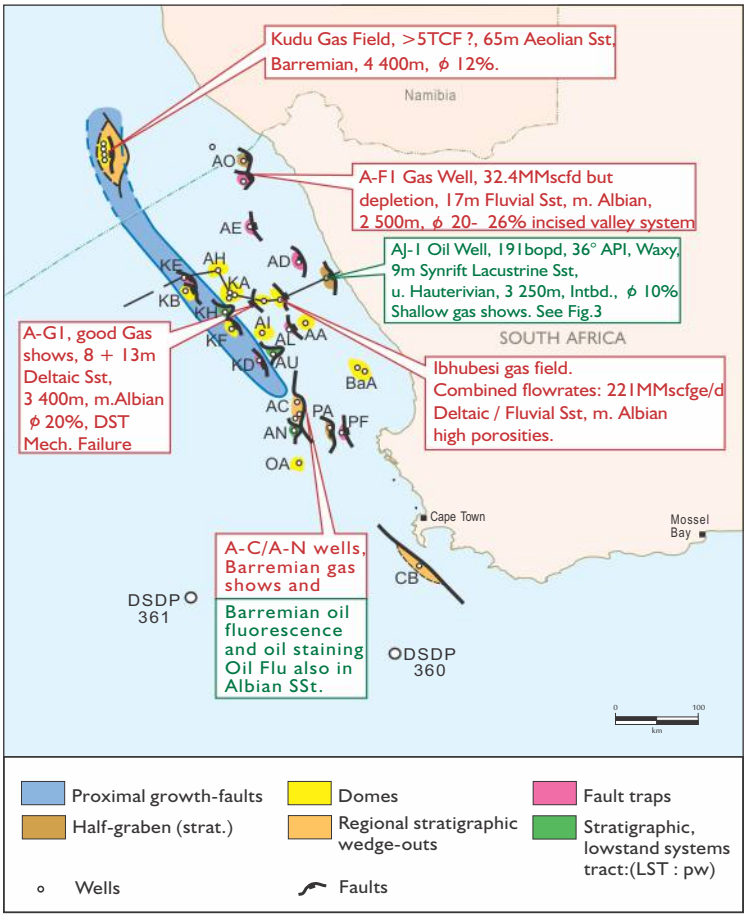


Figure 5. The main petroleum discoveries and shows in the Orange Basin (after Jungslager, 1999).

Expulsion and migration postdated the sealing of the structural-stratigraphic traps, which was penecontemporaneous with reservoir deposition in the Early Cretaceous.The source for A-F1 and A-K1 (Albian) is accepted to be the widespread Lower Aptian shales. The sealing of the structural- stratigraphic traps, was penecontemporaneous with reservoir deposition in the Early Cretaceous.

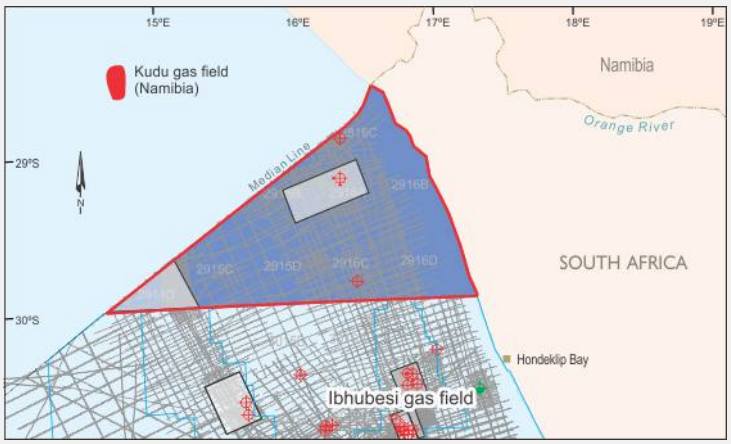
HAUTERIVIAN

To date, this play is known in only one discovery in the AJ Graben at well A-J1. (figures 3,4,5. The significance of the play is that it establishes a working petroleum system in the non-marine part of the syn-rift succession and in the eastern marginal graben province. It is also the only play in which oil has been found in the Orange Basin.

The Hauterivian Stratigraphic Play is located in the eastern marginal graben province, beneath the Aptian transgression.

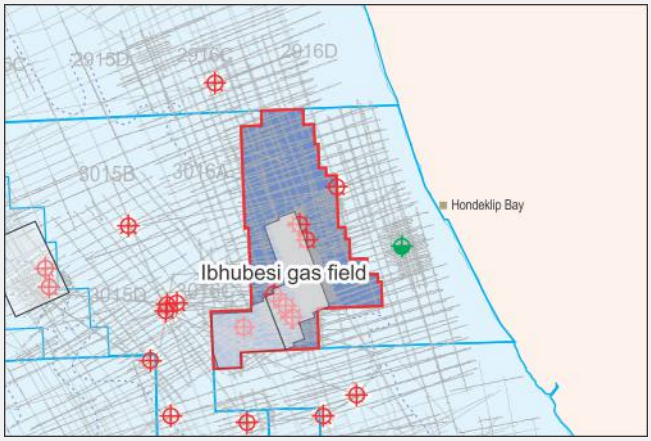
Trapping results from the pinching out of the syn-rift reservoir in a halfgraben structure. The reservoir comprises lacustrine, fluvial or deltaic sandstones. Porosity (10-15%) and permeability (0.01-468 mD) are locally reduced by calcareous cementation and silicification. Although the petroleum system is represented by a single small oil accumulation, it is important as it demonstrates that the basin is not exclusively a gas basin. Oil and gas prone Hauterivian lacustrine syn-rift shales are the main source rocks. These shales are presently within the oil window but probably reached maturity during the Late Cretaceous as there is virtually no Tertiary overburden in the inner graben area where A-J1 is located. Oil migrated short distances laterally to syn-rift lacustrine sandstone reservoirs in structural-stratigraphic traps. Sealing took place soon after deposition of the reservoir rock.

CURRENT EXPLORATION ACTIVITIES AND CONCESSIONS (as at February 2018)



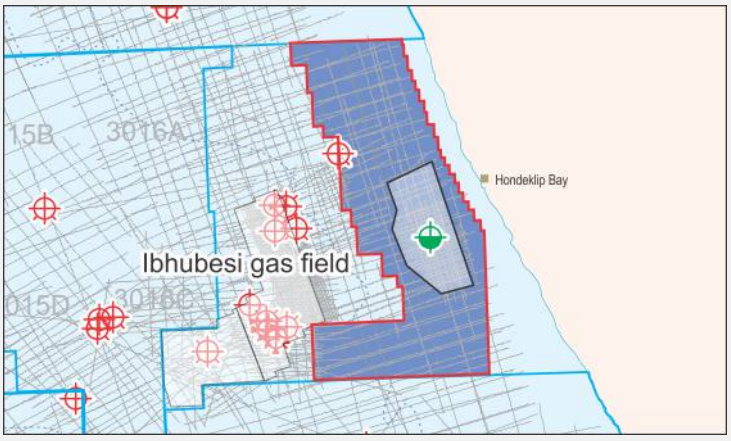
BLOCK 1

OPERATORS	:	CAIRN INDIA (60%)
		PETROSA (40%)
RIGHT	:	EXPLORATION RIGHT
BLOCK SIZE	:	21 000 km^2
SEISMIC DATA	:	2D and 3D
WELLS	:	3



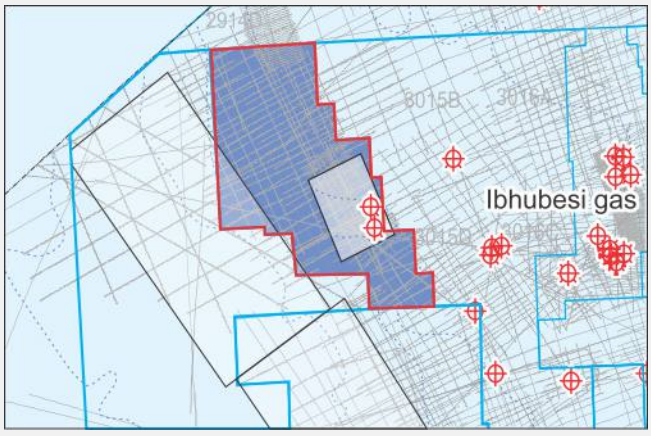
BLOCK 2A

OPERATORS	:	SUNBIRD ENERGY(76%)
		PETROSA (24%)
RIGHT	:	PRODUCTION RIGHT
BLOCK SIZE	:	5010 km^2
SEISMIC DATA	:	2D and 3D
WELLS	:	11



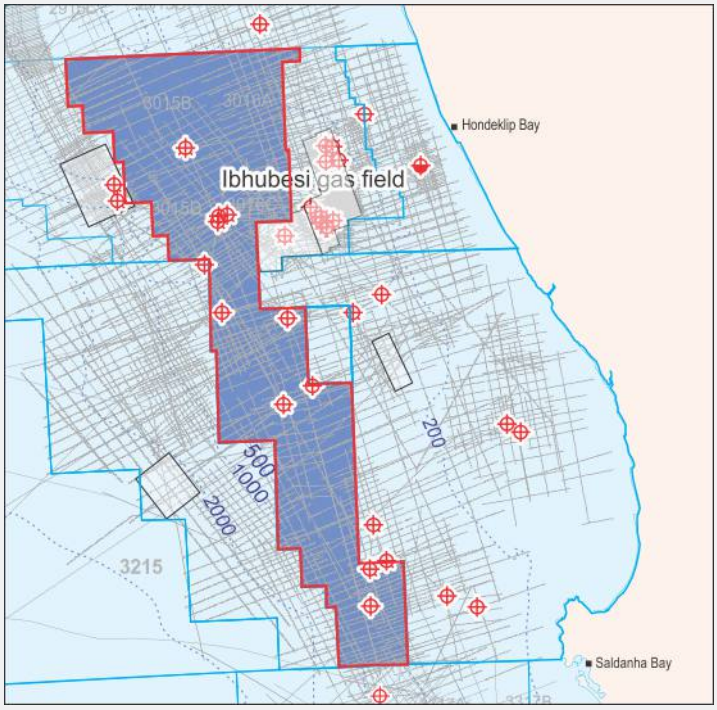
BLOCK 2B

OPERATORS	:	THOMBO PETROLEUM (34.5%)
		MAINSTREET (25%), SIMBO (40.5%)
RIGHT	:	EXPLORATION RIGHT
BLOCK SIZE	:	5450 km^2
SEISMIC DATA	:	2D and 3D
WELLS	:	1



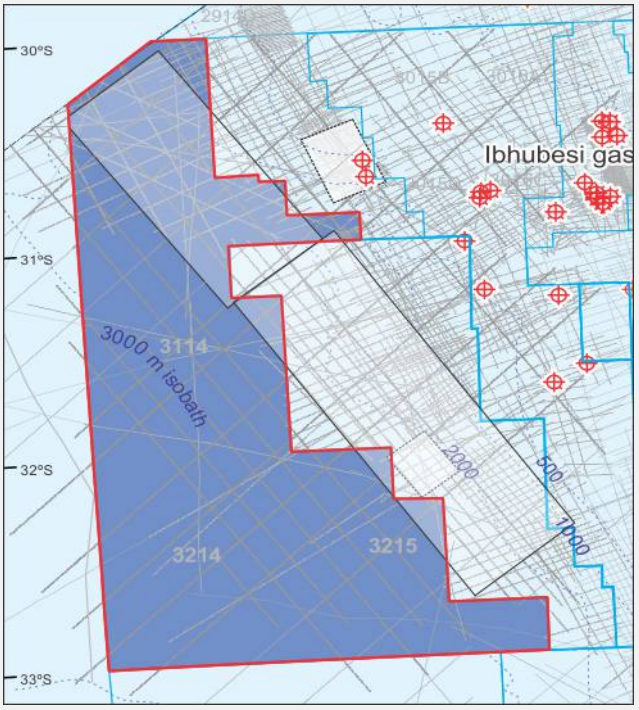
BLOCK 2C

OPERATORS	:	ANADARKO (65%
		PETROSA(35%)
RIGHT	:	ER UNDER APPLICATION
BLOCK SIZE	:	6224 km^2
SEISMIC DATA	:	2D and 3D
WELLS	:	2



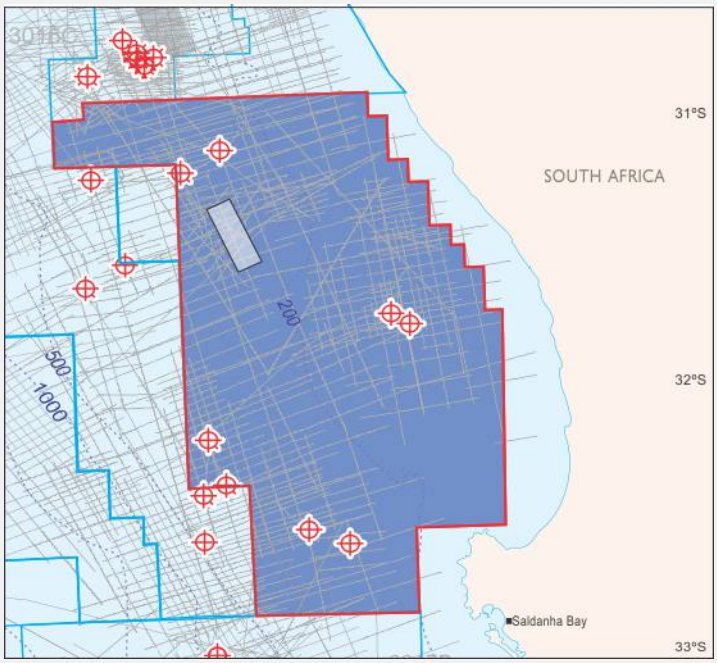
CENTRAL ORANGE BASIN

OPERATORS	:	SUNGU SUNGU - ER Northern Block (24 215km^2) SEZIGYN - TCP Southern Block (6 181km^2)
SEISMIC DATA	:	2D
WELLS	:	9



DEEPWATER ORANGE BASIN

OPERATOR	:	SEZIGYN - TCP
BLOCK SIZE	:	37 290 km^2
SEISMIC DATA	:	2D and 3D
WELLS	:	NONE

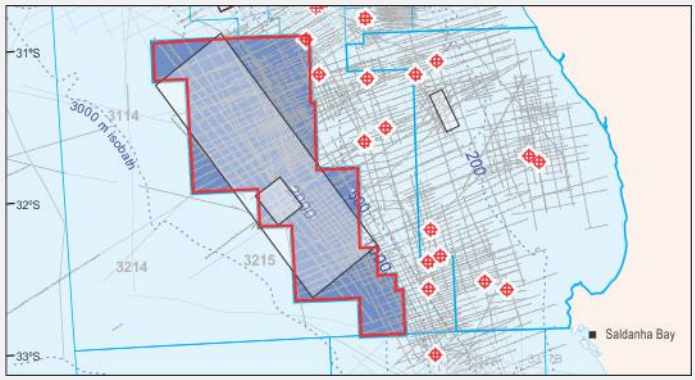


BLOCK 3A/4A

OPERATORS	:	SASOL (50%), PETROSA(50%)
RIGHT	:	ER (under application)
BLOCK SIZE	:	21 000 km^2
SEISMIC DATA	:	2D and 3D
WELLS	:	6

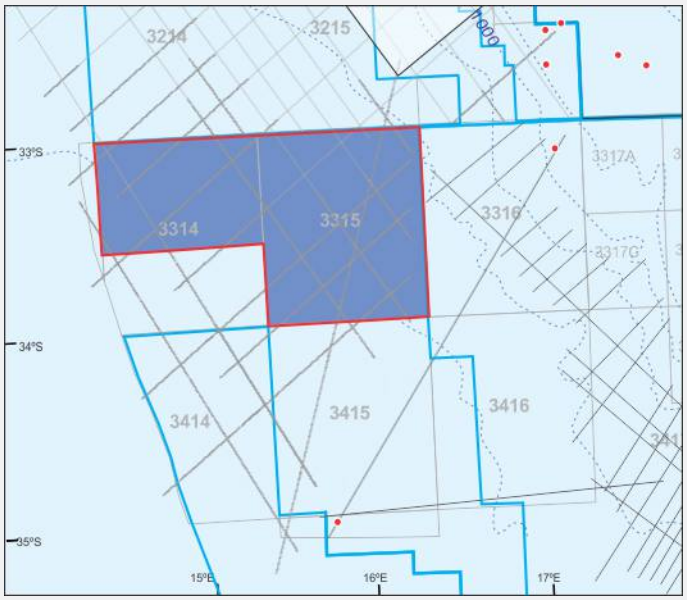
N CAPE ULTRA DEEP WATER

OPERATORS	:	OK ENERGY (100%)
RIGHT	:	ER (under application)
BLOCK SIZE	:	6 930 km^2
SEISMIC DATA	:	2D
WELLS	:	NONE



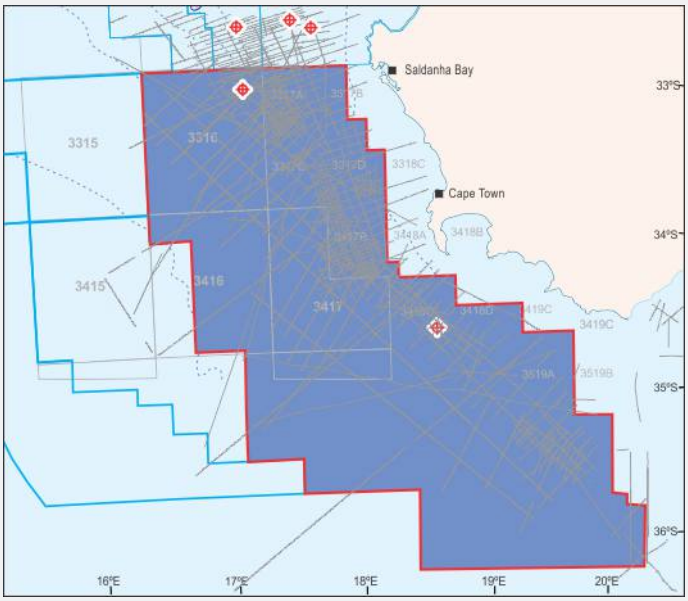
BLOCK 3B/4B

OPERATOR	:	RICOCURE - TCP
BLOCK SIZE	:	17 570 km^2 & 960 km^2
SEISMIC DATA	:	2D and 3D
WELLS	:	2 (WITHIN INBOARD BLOCK)



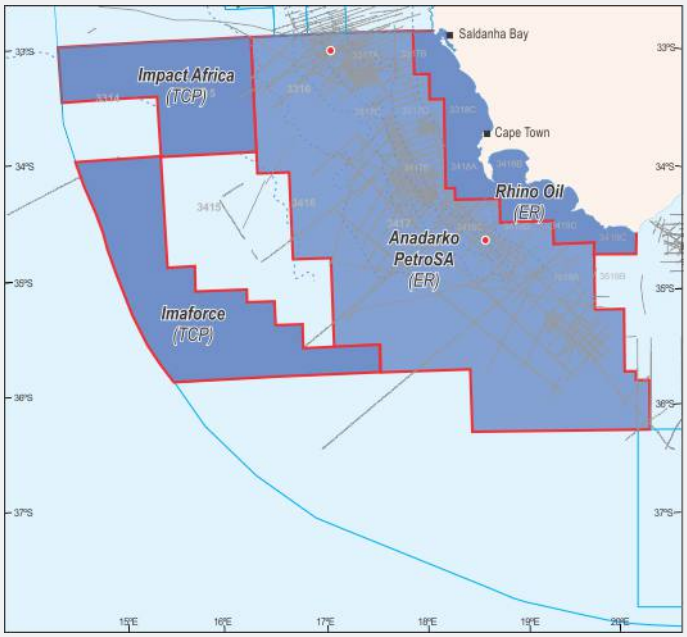
SW DEEP WATER ORANGE BASIN

OPERATOR	:	IMPACT AFRICA TCP
RIGHT	:	TCP APPLICATION
BLOCK SIZE	:	27 508 km^2
SEISMIC DATA	:	2D
WELLS	:	NONE



BLOCK 5/6/7

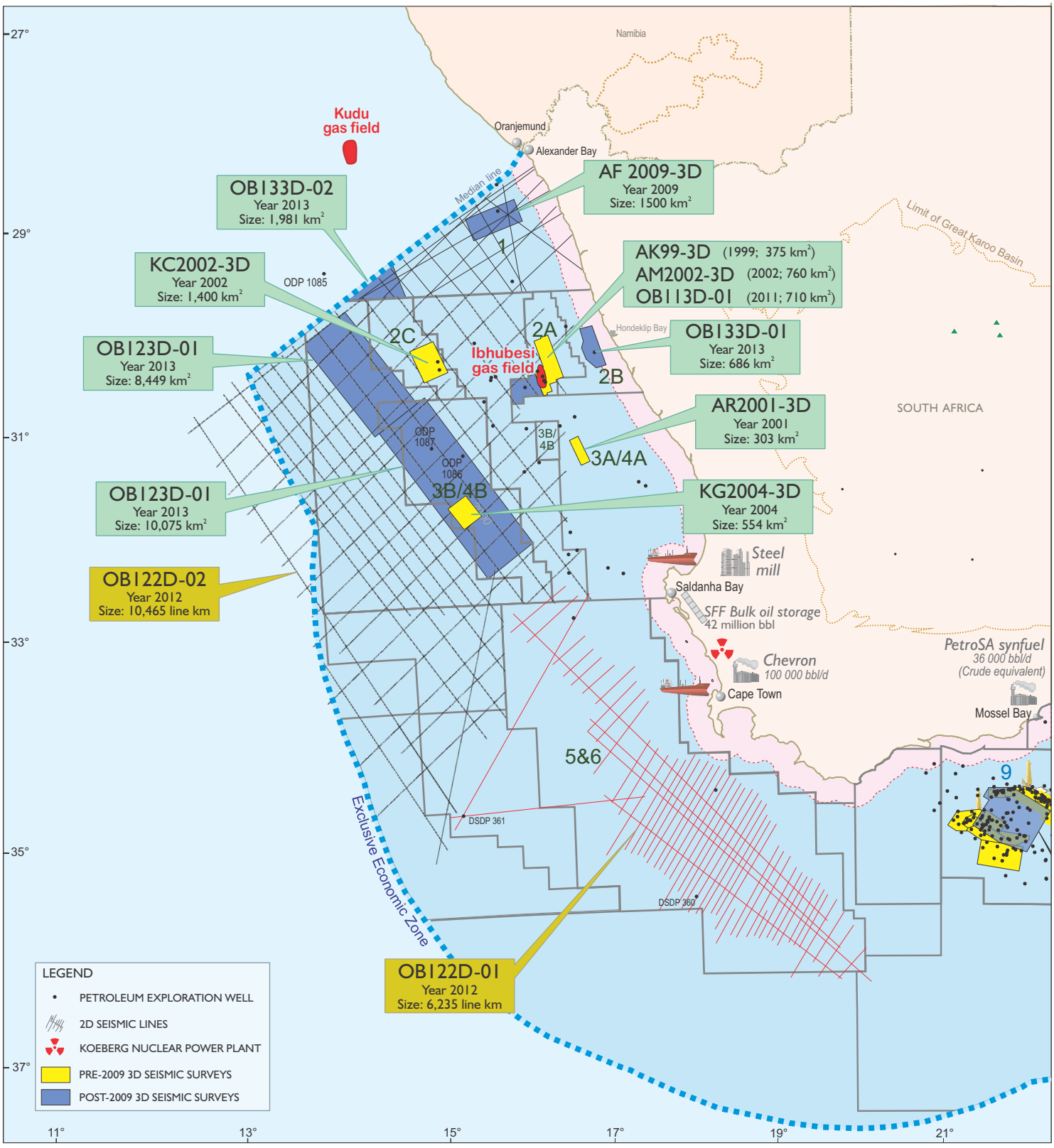
OPERATORS	:	ANDARKO (80%) PETROSA (20%)
RIGHT	:	EXPLORATION RIGHT
BLOCK SIZE	:	80 333 km^2 (5&6), 13 675 km^2 (7)
SEISMIC DATA	:	2D
WELLS	:	3



SOUTHERN ORANGE BASIN TCP'S

IMAFORCE	:	TCP
RHINO OIL	:	ER APPLICATION
IMPACT AFRICA	:	TCP
ANADARKO/PETROSA		ER APPLICATION
SEISMIC DATA	:	NONE
WELLS	:	NONE

RECENTLY ACQUIRED SEISMIC SURVEYS INCLUDING PRE-2009 3D SEISMIC DATA



References:

1. Broad, D.S., Jungslager, E.H.A., McLachlan, I.R., Roux, J., 2006. *Offshore Mesozoic basins.* In. Johnson, M.R., Anhaeusser,C.R, Thomas, R.J.(eds.) The Geology of South Africa, Geological Society of South Africa and Council for Geoscience,553–571.
2. Brown, L.F., Benson, J.M., Brink, G.J. et al., 1996. *Sequence Stratigraphy in Offshore South Africa Divergent Basins.* American Association of Petroleum Geologists, Studies in Geology, 41.
3. Dingle, R. V. and Scrutton, R. A. (1974). *Continental Breakup and theDevelopment of Post-Paleozoic Sedimentary Basins around Southern Africa.*Geol. Soc. Amer. Bull., 85.
4. Gerrard, I. and Smith, G. G., 1982. *Post-Paleozoic Succession and Structure of the Southwestern African Continental Margin.* In: Watkins, J. S. and Drake, C. L. (eds). Studies in Continental Margin Geology. AAPG Mem., 34, 49-74.
5. Jungslager, H. A., 1998. *Petroleum Habitats of the Atlantic Margin of South Africa.* Petroleum Agency SA Internal Report.
6. Stevenson, I.R. and McMillan I.K. 2004. *Incised valley fill stratigraphy of the Upper Cretaceous succession, proximal Orange Basin, Atlantic Margin of southern Africa.* Journal of the Geological Society, Vol. 161, 185-208.
7. Van der Spuy,D. 2003. *Aptian source rocks in some South African basins.* In: Arthur,T.J, MacGregor,D.S. & Cameron,N.R.(Eds) Petroleum Geology of Africa: New Themes and Developing Technologies. Geological Society, London, Special Publications.

Petroleum Agency SA

Petroleum House
151 Frans Conradie Drive
PAROW 7500
REPUBLIC OF SOUTH AFRICA

For more information, contact :

The Chief Executive Officer: Petroleum Agency SA

Fax: (27) 21 938-3520
Email: plu@petroleumagencysa.com
Web: www.petroleumagencysa.com

P.O. Box 1174
PAROW 7499
RSA
(27) 21 938-3500

Having made all reasonable efforts to ensure the quality of the data, Petroleum Agency SA shall not be liable for the integrity, accuracy or quality thereof and accepts no liability for the results of any decisions or actions of the recipient arising from use of the data in any way. This document and the copyright therein is the property of The South African Agency for Promotion of Petroleum Exploration and Exploitation (Pty) Ltd. No part thereof may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording or by any information storage and retrieval system without the prior written permission of The South African Agency for Promotion of Petroleum Exploration and Exploitation (Pty) Ltd.