

MAY 2003

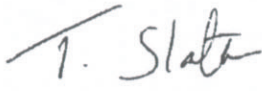
**RESERVOIR QUALITY OF THE
COASTAL BASINS OF
SOUTHEAST BRAZIL**

Volume 1: Text, Figures and Appendices

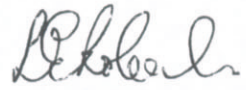
Robertson

Quality Control Approvals

Technical Content:

Signature: 
Name: TOM SLATER
Title: SNR RESERVOIR GEOLOGIST
Date: 5/6/2003

Editorial Content:

Signature: 
Name: LESLIE E. ROBERTS
Title: EDITOR
Date: 5/6/2003

COPYRIGHT

RESERVOIR QUALITY OF THE COASTAL BASINS OF SOUTHEAST BRAZIL

This copy of the above report has been sold to:

xx

.....
No part of it may be reproduced by or for any other company,
organisation or individual without the written consent of
ROBERTSON RESEARCH INTERNATIONAL LIMITED.

This limitation does not, however, apply to parent companies
or wholly owned subsidiaries within the same group.

**Robertson Research
International Limited**
Llandudno, North Wales LL30 1SA, United Kingdom

May 2003

Warranty

Robertson Research International Limited has made every reasonable effort to ensure that this report has been accurately prepared in accordance with accepted practices of the petroleum industry. Any interpretation or opinions expressed represent the best judgement of Robertson Research International Limited; however, any use made of the report shall be based solely on the client's own judgement and Robertson Research International Limited shall not be responsible or liable for any consequential loss or damages arising out of the use of this report.



CONTENTS**Volume 1: Text, Figures and Appendices (1-8)**

Chapters	Page
SUMMARY	0-1
1 INTRODUCTION	1-1
1.1 OBJECTIVES OF STUDY	1-1
1.2 DATA AND DATA SOURCES	1-1
1.2.1 Samples	1-1
1.2.2 Wireline logs	1-2
1.3 CONTRIBUTORS	1-2
2 ANALYTICAL PROCEDURES	2-1
2.1 INTRODUCTION	2-1
2.2 CORE DESCRIPTION AND INTERPRETATION	2-1
2.3 FACIES SCHEME	2-2
2.4 SAMPLE SELECTION	2-3
2.4.1 Conventional core analysis and petrography on cores	2-3
2.4.2 Petrography and lithological analysis of ditch cuttings	2-3
2.4.3 Biostratigraphy	2-4
2.4.4 Mercury injection	2-4
2.4.5 Particle size analysis	2-4
2.4.6 Image analysis	2-4
2.5 PETROGRAPHIC ANALYSES	2-4
2.6 XRD ANALYSES	2-5
2.7 CONVENTIONAL CORE ANALYSES	2-6
2.8 BIOSTRATIGRAPHIC ANALYSES	2-7
2.9 DEFINITION OF TIME SLICES	2-8
2.10 NET POTENTIAL RESERVOIR DEFINITION, CALCULATION AND MAPPING	2-9
2.11 RESERVOIR QUALITY ASSESSMENT	2-9
2.12 SCANNING ELECTRON MICROSCOPY ANALYSES	2-11
2.13 PARTICLE SIZE ANALYSIS	2-12
2.14 IMAGE ANALYSIS	2-12
2.15 MERCURY INJECTION ANALYSIS	2-13
3 FACIES ANALYSIS AND DEPOSITIONAL ENVIRONMENTS	3-1
3.1 INTRODUCTION	3-1

3.2	TIME SLICE 1, APTIAN AND OLDER LOWER CRETACEOUS	3-2
3.2.1	Introduction	3-2
3.2.2	Facies Association TL: Alluvial-lacustrine	3-3
3.2.2.1	Facies TLL: Low energy lake/lagoon margin siliciclastic muds	3-3
3.2.2.2	Facies TLC: Low energy lake/lagoon margin carbonate mud and evaporites	3-3
3.2.2.3	Facies TLS: Proximal lake/lagoon shoreface and shoal	3-4
3.2.2.4	Facies TLD: Central/distal lake/lagoon	3-6
3.2.3	Pre-Salt facies not studied in core	3-6
3.2.4	Depositional models	3-7
3.3	TIME SLICE 2, ALBIAN	3-8
3.3.1	Introduction	3-8
3.3.2	Facies Association SC: Wave or storm dominated coast	3-9
3.3.2.1	Facies SCO (Oolitic shoal), SCB (Bioclastic shoal/barrier crest), SCC (Peloidal/oncolitic shoal flank) and SCF (Bioclastic shoal flank)	3-9
3.3.3	Facies Association SD: Distal shelf	3-10
3.3.3.1	Facies SDL: Distal shelf wackestone/packstone	3-10
3.3.4	Other facies not seen in core	3-11
3.3.5	Depositional models	3-11
3.4	TIME SLICE 3, UPPER CRETACEOUS	3-12
3.4.1	Introduction	3-12
3.4.2	Facies Association SC: Wave or storm dominated coast	3-12
3.4.2.1	Facies SCL: Lower to middle shoreface	3-13
3.4.3	Facies Association SD: Distal shelf	3-13
3.4.3.1	Facies SDS: Distal shelf argillaceous sand	3-13
3.4.4	Facies Association DP: Deep marine 'proximal' lobes, channels and aprons	3-14
3.4.4.1	Facies DPS: Thick, massive, dewatered sands	3-14
3.4.5	Facies Association DD: Deep marine 'distal' lobes, levees and aprons	3-15
3.4.5.1	Facies DDS: >50% medium bedded turbiditic sandstones	3-15
3.4.6	Facies Association DF: Basin floor	3-15
3.4.6.1	Facies DFB: Bioturbated basinal muds	3-16
3.4.7	Facies Association TF: Sheetflood/braided channel	3-16
3.4.7.1	Facies TFS: Sheetflood/braided channel	3-16
3.4.8	Other facies not seen in core	3-17
3.4.9	Depositional models	3-17
3.5	TIME SLICES 4 AND 5, TERTIARY	3-19
3.5.1	Introduction	3-19
3.5.2	Facies Association SC: Wave or storm dominated coast	3-19
3.5.2.1	Facies SCC: Peloidal/oncolitic shoal flank	3-20
3.5.3	Facies Association SD: Distal shelf	3-20
3.5.3.1	Facies SDT: Transition zone (siliciclastics)	3-20
3.5.3.2	Facies SDL: Distal shelf wackestone/packstone	3-21
3.5.3.3	Facies SDS: Distal shelf argillaceous sand	3-22
3.5.4	Facies Association DP: Deep marine 'proximal' lobes, channels and aprons	3-22
3.5.4.1	Facies DPS: Thick massive dewatered sands	3-22
3.5.4.2	Facies DPM: Slumps, muddy debris flows	3-24
3.5.5	Facies Association DD: Deep marine distal lobes, levees and aprons	3-24
3.5.5.1	Facies DDS: >50% medium bedded sandstones	3-24
3.5.5.2	Facies DDM: <50% medium bedded sandstones	3-25
3.5.6	Facies Association DF: Deep marine slope and basin floor	3-25
3.5.6.1	Facies DFB: Bioturbated basinal muds	3-26

	3.5.6.2 Facies DFC: Bioturbated basinal carbonates	3-26
	3.5.6.3 Facies DFL: Laminated basinal mud	3-27
3.5.7	Tertiary facies not studied in core	3-27
3.5.8	Depositional models	3-27
	3.5.8.1 Evidence for deepwater interpretation	3-27
	3.5.8.2 Controls on sand distribution in deep water	3-27
4	PETROGRAPHY	4-1
4.1	INTRODUCTION	4-1
4.2	TIME SLICE 1, APTIAN AND OLDER LOWER CRETACEOUS	4-3
	4.2.1 Introduction	4-3
	4.2.2 Textural characteristics	4-3
	4.2.3 Grain types and mud	4-3
	4.2.4 Classification	4-5
	4.2.5 Diagenesis	4-5
	4.2.6 Pore types	4-7
4.3	TIME SLICE 2, ALBIAN	4-8
	4.3.1 Introduction	4-8
	4.3.2 Textural characteristics	4-8
	4.3.3 Grain types and mud	4-8
	4.3.4 Classification	4-9
	4.3.5 Diagenesis	4-9
	4.3.6 Pore types	4-12
4.4	TIME SLICE 3, UPPER CRETACEOUS	4-12
	4.4.1 Introduction	4-12
	4.4.2 Textural characteristics	4-12
	4.4.3 Grain types and mud	4-13
	4.4.4 Classification	4-14
	4.4.5 Diagenesis	4-14
	4.4.6 Pore types	4-15
4.5	TIME SLICE 4, PALEOCENE - LOWER OLIGOCENE	4-15
	4.5.1 Introduction	4-15
	4.5.2 Textural characteristics	4-16
	4.5.3 Grain types and mud	4-16
	4.5.4 Classification	4-16
	4.5.5 Diagenesis	4-17
	4.5.6 Pore types	4-17
4.6	TIME SLICE 5, UPPER OLIGOCENE - MIOCENE	4-17
	4.6.1 Introduction	4-17
	4.6.2 Textural characteristics	4-18
	4.6.3 Grain types and mud	4-18
	4.6.4 Classification	4-18
	4.6.5 Diagenesis	4-18
	4.6.6 Pore types	4-19
5	STRATIGRAPHY	5-1
5.1	INTRODUCTION	5-1
5.2	TIME SLICE 1: APTIAN AND OLDER LOWER CRETACEOUS	5-2
5.3	TIME SLICE 2: ALBIAN	5-2
5.4	TIME SLICE 3: UPPER CRETACEOUS	5-2

5.5	TIME SLICE 4: PALEOCENE - LOWER OLIGOCENE	5-2
5.6	TIME SLICE 5: UPPER OLIGOCENE - MIOCENE	5-2
6	RESERVOIR QUALITY ASSESSMENT	6-1
6.1	INTRODUCTION	6-1
6.2	TIME SLICE 1: APTIAN AND OLDER LOWER CRETACEOUS	6-1
6.2.1	Petrography and image analysis	6-1
6.2.2	Conventional core analysis	6-2
6.2.3	Wireline log analysis	6-2
6.2.4	Controls on reservoir quality	6-3
6.2.4.1	Facies controls	6-3
6.2.4.2	Diagenetic controls	6-3
6.2.5	Mapping	6-3
6.3	TIME SLICE 2: ALBIAN	6-3
6.3.1	Petrography and image analysis	6-4
6.3.2	Conventional core analysis	6-5
6.3.3	Wireline log analysis	6-5
6.3.4	Controls on reservoir quality	6-6
6.3.4.1	Facies controls	6-6
6.3.4.2	Diagenetic controls	6-6
6.3.5	Mapping	6-8
6.4	TIME SLICE 3: UPPER CRETACEOUS	6-8
6.4.1	Petrography and image analysis	6-8
6.4.2	Conventional core analysis	6-12
6.4.3	Wireline log analysis	6-13
6.4.4	Sieve analysis	6-13
6.4.5	Controls on reservoir quality	6-13
6.4.5.1	Facies controls	6-13
6.4.5.2	Diagenetic controls	6-14
6.4.6	Mapping	6-15
6.5	TIME SLICE 4: PALEOCENE - LOWER OLIGOCENE	6-15
6.5.1	Petrography and image analysis	6-15
6.5.2	Conventional core analysis	6-17
6.5.3	Wireline log analysis	6-17
6.5.4	Controls on reservoir quality	6-18
6.5.4.1	Facies controls	6-18
6.5.4.2	Diagenetic controls	6-18
6.5.5	Mapping	6-18
6.6	TIME SLICE 5: UPPER OLIGOCENE - MIOCENE	6-19
6.6.1	Petrography and image analysis	6-19
6.6.2	Conventional core analysis	6-22
6.6.3	Wireline log analysis	6-23
6.6.4	Sieve analysis	6-23
6.6.5	Controls on reservoir quality	6-23
6.6.5.1	Facies controls	6-23
6.6.5.2	Diagenetic controls	6-24
6.6.6	Mapping	6-24
7	CONCLUSIONS	7-1
7.1	CONCLUSIONS	7-1

7.2	RECOMMENDATIONS	7-2
8	REFERENCES	8-1

Tables

1.1	List of wells included in study
2.1	Distribution of studied core by basin and time slice
2.2	Facies scheme for cored intervals
3.1	Distribution of facies in studied cores by well, time slice and basin
4.1	Summary of analyses per well per time slice
5.1	Time slice tops
6.1	Net thickness and average log derived porosity results

Figures

1.1	Simplified structural elements map
1.2	Stratigraphic summary diagram: Cretaceous
1.3	Stratigraphic summary diagram: Cenozoic
3.1	Aptian and older Lower Cretaceous fluvial/lacustrine depositional model
3.2	Albian platform carbonate depositional model
3.3	Upper Cretaceous and Tertiary confined turbidite depositional model
3.4	Upper Cretaceous of Santos Basin, sandy ramp depositional model
3.5	Oligocene - Miocene unconfined turbidite depositional model, e.g. Marlim Field
3.6	Time slice 1 (Aptian and older Lower Cretaceous): Montage illustrating lacustrine deposits evident in core, well 4-RJS-514
3.7	Time slice 2 (Albian): Montage illustrating coastal/shoal deposits evident in core, well 3-PM-02-RJS
3.8	Time slice 3 (Upper Cretaceous): Montage illustrating distal shelf deposits evident in core, well 1-BSS-081
3.9	Time slice 3 (Upper Cretaceous): Montage to illustrate deep marine turbiditic deposits evident in core, well 1-BSS-083
3.10	Time slice 3 (Upper Cretaceous): Montage to illustrate deep marine turbiditic deposits evident in core, well 1-RJS-455
3.11	Time slice 3 (Upper Cretaceous): Montage to illustrate distal shelf deposits evident in core, well 1-BSS-074
3.12	Time slice 5 (Upper Oligocene - Miocene): Montage to illustrate deep marine turbiditic deposits evident in core, well 3-MLS-02-RJS
3.13	Time slice 5 (Upper Oligocene - Miocene): Montage to illustrate deep marine turbiditic deposits evident in core, well 6-MLS-03B-RJS

- 4.1 Sandstone classification diagram, time slice 3, Upper Cretaceous: arenites (Nagtegaal, 1978)
- 4.2 Sandstone classification diagram, time slice 3, Upper Cretaceous: wackes and psammites (Nagtegaal, 1978)
- 4.3 Sandstone classification diagram, time slice 4, Paleocene - Lower Oligocene: arenites (Nagtegaal, 1978)
- 4.4 Sandstone classification diagram, time slice 4, Paleocene - Lower Oligocene: wackes and psammites (Nagtegaal, 1978)
- 4.5 Sandstone classification diagram, time slice 5, Upper Oligocene - Miocene: arenites
- 4.6 Sandstone classification diagram, time slice 5, Upper Oligocene - Miocene: wackes and psammites (Nagtegaal, 1978)

- 5.1 Stratigraphic summary diagram: Cretaceous
- 5.2 Stratigraphic summary diagram: Cenozoic

- 6.1 Crossplot of porosity versus permeability for time slice 1
- 6.2 Crossplot of helium porosity versus macroporosity for time slice 1
- 6.3 Crossplot of porosity versus permeability for time slice 2
- 6.4 Crossplot of calcite cement versus macroporosity for time slice 2
- 6.5 Crossplot of porosity versus permeability for time slice 3
- 6.6 Crossplot of porosity versus total macropores for time slice 3
- 6.7 Crossplot of permeability versus total macropores for time slice 3
- 6.8a Crossplot of porosity versus total authigenic clay for time slice 3
- 6.8b Crossplot of porosity versus total authigenic clay for time slice 3
- 6.9a Crossplot of permeability versus total authigenic clay for time slice 3
- 6.9b Crossplot of permeability versus total authigenic clay for time slice 3
- 6.10 Crossplot of permeability versus total mud for time slice 3
- 6.11 Crossplot of porosity versus total mud for time slice 3
- 6.12 Bubble plot of log depths versus permeability versus porosity for time slice 3
- 6.13 Crossplot of porosity versus permeability for time slice 4
- 6.14 Crossplot of porosity versus total macropores for time slice 4
- 6.15 Crossplot of horizontal permeability versus total macropores for time slice 4
- 6.16 Crossplot of total cement versus total macropores for time slice 4
- 6.17 Crossplot of total mud versus horizontal permeability for time slice 4
- 6.18 Crossplot of porosity versus permeability for time slice 5
- 6.19 Crossplot of porosity versus total macropores for time slice 5
- 6.20 Crossplot of permeability versus total macropores for time slice 5
- 6.21 Crossplot of total cement versus total macropores for time slice 5
- 6.22 Crossplot of total cement versus horizontal permeability for time slice 5
- 6.23 Crossplot of total mud versus horizontal permeability for time slice 5
- 6.24 Crossplot of total mud versus porosity for time slice 5
- 6.25 Crossplot of sample condition versus helium porosity for time slice 5
- 6.26 Crossplot of sample condition versus horizontal permeability for time slice 5

- 7.1 Crossplot of average log derived porosity versus average depth of reservoir, per time slice for the Campos Basin
- 7.2 Crossplot of average log derived porosity versus average depth of reservoir, per time slice for the Santos Basin
- 7.3 Crossplot of average log derived porosity versus average depth of reservoir, per time slice for the Espirito Santo Basin

- 7.4 Crossplot of average log derived porosity versus average depth of reservoir, per time slice for all basins

Appendices

- 1 Glossary of codes for petrographic data
- 2 XRD results
- 3 Particle size (sieve) analysis results
- 4 Petrographic results: ditch cuttings
- 5 Reservoir quality data
- 6 Core analysis data
- 7 Mercury injection results
- 8 Biostratigraphic analyses

Volume 2: Plates (including Appendices 9 & 10)

Reservoir quality maps for the Campos Basin

Plate 1	Time slice 1: Aptian and older Lower Cretaceous
Plate 2	Time slice 2: Albian
Plate 3	Time slice 3: Upper Cretaceous
Plate 4	Time slice 4: Paleocene - Lower Oligocene
Plate 5	Time slice 5: Upper Oligocene - Miocene

Appendices

9	Sedimentological core descriptions <ul style="list-style-type: none">Contents of core packageLocation map for cored wellsLegend for lithologies, grain types, diagenetic features and core conditionLegend for sedimentary structuresLegend for fractures and facies schemeSedimentological core descriptions
10	SEM analyses

Volume 3: Maps, Charts and Diagrams

Enclosures

- 1 Study wells location map
- 2 Structural elements map

Petrographic data summary charts

- 3a Petrographic data summary chart: siliciclastics, time slices 3(part) - 5
- 3b Petrographic data summary chart: siliciclastics, time slice 3(continued)
- 4a Petrographic data summary chart: carbonates, time slices 2-5
- 4b Petrographic data summary chart: carbonates, time slice 1

Petrography: simple statistics

- 5 Clastic petrographic simple statistics: all data
- 6 Clastic petrographic simple statistics: moderately and well preserved arenites only
- 7 Carbonate petrographic simple statistics: all data

Photomontages

- 8 Time slice 1: Aptian and older Lower Cretaceous
- 9 Time slice 2: Albian
- 10 Time slice 3: Upper Cretaceous
- 11 Time slice 4: Paleocene - Lower Oligocene
- 12 Time slice 5: Upper Oligocene - Miocene

Image analysis montages

- | | | |
|-------|--------------------------------------|--------------|
| 13-20 | Back scatter analysis images | |
| 13 | Well 1-BSS-081, core depth 3130.3m | Time slice 3 |
| 14 | Well 1-BSS-081, core depth 3132.5m | Time slice 3 |
| 15 | Well 1-BSS-081, core depth 4660.4m | Time slice 3 |
| 16 | Well 1-BSS-081, core depth 4662.3m | Time slice 3 |
| 17 | Well 1-BSS-083, core depth 4546.6m | Time slice 3 |
| 18 | Well 1-RJS-199B, core depth 3405.1m | Time slice 3 |
| 19 | Well 1-RJS-199B, core depth 3406.1m | Time slice 3 |
| 20 | Well 1-RJS-460, core depth 2888.7m | Time slice 4 |
| 21-29 | Thin section images | |
| 21 | Well 3-PM-02-RJS, core depth 1959.3m | Time slice 2 |
| 22 | Well 3-PM-02-RJS, core depth 1961m | Time slice 2 |
| 23 | Well 3-PM-02-RJS, core depth 1961.4m | Time slice 2 |
| 24 | Well 3-PM-02-RJS, core depth 2078.5m | Time slice 2 |
| 25 | Well 1-RJS-492, core depth 3684m | Time slice 1 |
| 26 | Well 1-RJS-492, core depth 3688.3m | Time slice 1 |
| 27 | Well 1-RJS-492, core depth 3691.8m | Time slice 1 |

28	Well 4-RJS-514, core depth 4096.25m	Time slice 1
29	Well 4-RJS-514, core depth 4097.2m	Time slice 1

Reservoir quality assessment charts

30	1-BSS-069
31	1-BSS-074
32	1-BSS-075
33	1-BSS-077
34	1-BSS-080
35	1-BSS-081
36	1-BSS-083
37	1-ESS-034
38	1-RJS-083
39	1-RJS-096A
40	1-RJS-135
41	1-RJS-199B
42	1-RJS-332B
43	1-RJS-357
44	1-RJS-358
45	1-RJS-359
46	1-RJS-366
47	1-RJS-386A
48	1-RJS-455
49	1-RJS-460
50	1-RJS-492
51	1-RJS-498
52	1-RJS-504
53	1-RJS-507
54	1-RJS-535B
55	2-ESS-048A
56	3-MLS-02-RJS
57	3-MRL-04-RJS
58	3-PM-02-RJS
59	3-RJS-397
60	3-RJS-510A
61	4-RJS-382
62	4-RJS-441
63	4-RJS-446
64	4-RJS-514
65	6-MLS-03B-RJS