High Definition Erosional Map from Recôncavo Basin, Brazil — A New Approach Based from Old Concepts*

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Abstract

The petroleum province of Recôncavo Basin, located in northeastern Brazil, is an aborted continental half-graben formed during the fragmentation of the Gondwana supercontinent in the Early Cretaceous. One of the main events that modified its physiography was the erosional process implanted at the end of the rift phase. This process was materialized by the Aptian unconformity. The main goal of this study was to evaluate the eroded thickness on the top of the Rift Sequence in that basin using in a different way, a consortium of sonic log and vitrinite reflectance methods. The equation that describes the behaviour of the transit time with depth (here modified from that proposed by Heasler and Kharitonova (1996) is an improvement, by analogy, of Athy's formula for porosity, with the addition of a constant term that represents the transit time in the fully compacted rock (ttmatrix): tt = Dtt exp (- c z) + ttmatrix, where tt = observed transit time; z = depth; c = decay constant; Dtt =ttsurf - ttmatrix; ttsurf = transit time at the unconformity level; ttmatrix = transit time of the matrix (or compacted rock). The approach used was to compare the sonic log curves from each lithotype, with those that represent the original compaction condition with a more complete and preserved sedimentary section. To obtain an original curve, it was necessary to add at the depth column of the reference sonic log the erosion calculated by means of vitrinite reflectance method. The transit time of Post-rift and Pre-rift sequences were excluded from the mathematical regressions that were performed with the Petrobras proprietary program: Erosion, the Post-rift unconformity, was placed at z depth equal to 0 (zero). The parameters of the original curves - the decay (c) and the transit time of the matrix (ttmatrix) - were fixed for each regression. This procedure avoids an overestimation of the erosion calculation, especially in cases in which a significant part of the original curve has been suppressed by erosive processes. A high definition erosional map was obtained for the Aptian event by applying that methodology using 114 sonic logs. An apparent tectonic control was observed by comparing the regional erosive features with the structural framework of Recôncavo basin.

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Presenter's Notes: This work represents an important part of a regional petroleum mass balance study in Recôncavo basin that provided a better understood of thermal history and petroleum migration in that basin.

Presenter's Notes: This presentation is subdivided in the following item:

The motivation of the study

The state of art of erosion calculations

The case study of Recôncavo Basin

The new applied approach

The main product or the high erosional map at the top of rift sequence at

Recôncavo Basin

The thermal history calibration that provides also the geohistory validation with focus at omitted sedimentary section by erosion

The conclusions

MOTIVATIONS

The thermal structure and the petroleum migration and accumulation within a basin only can be understandood with the comprehension of the tectonic and sedimentary processes that took place during its evolution.

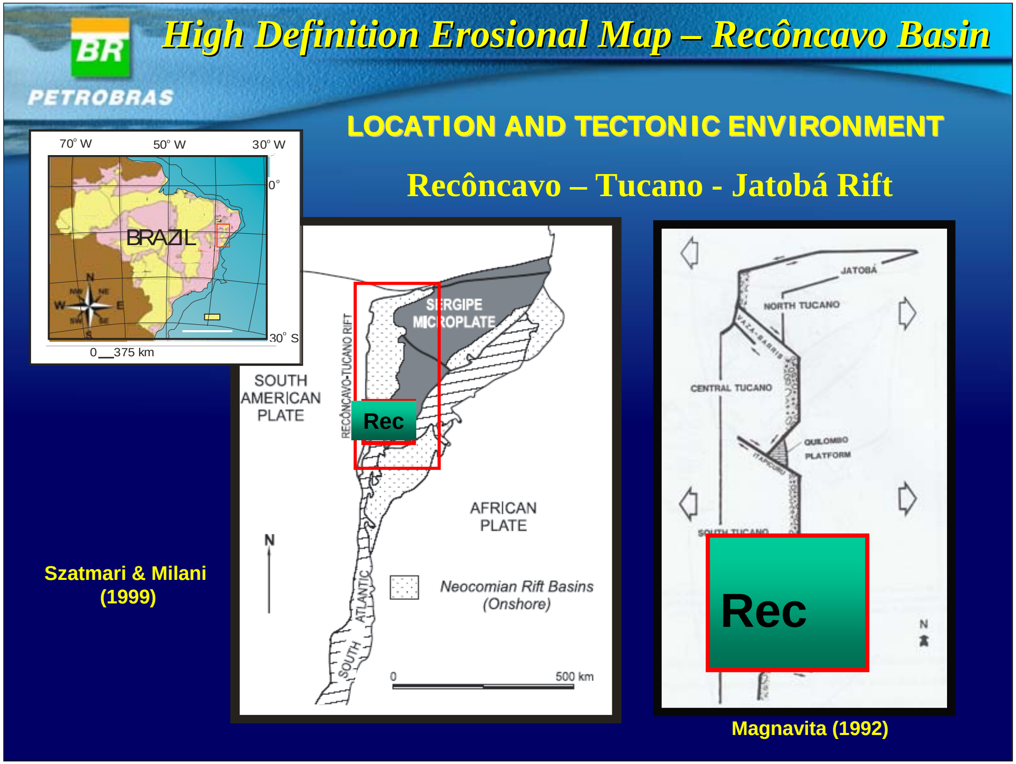
One of the main events that modify the topography of a rift is the erosive process that follows their rift phase with a great impact at their geohistory and thermal reconstruction.

As a consequence, to get a regional petroleum mass balance study in a Rift basin it is necessary to asses a HIGH DEFINITION EROSIONAL MAP at the top of the Rift Sequence.

This kind of map can be obtained by means of a special approach that combines sonic log and vitrinite reflectance profiles.

This methodology was first applied to the Recôncavo Basin case study.

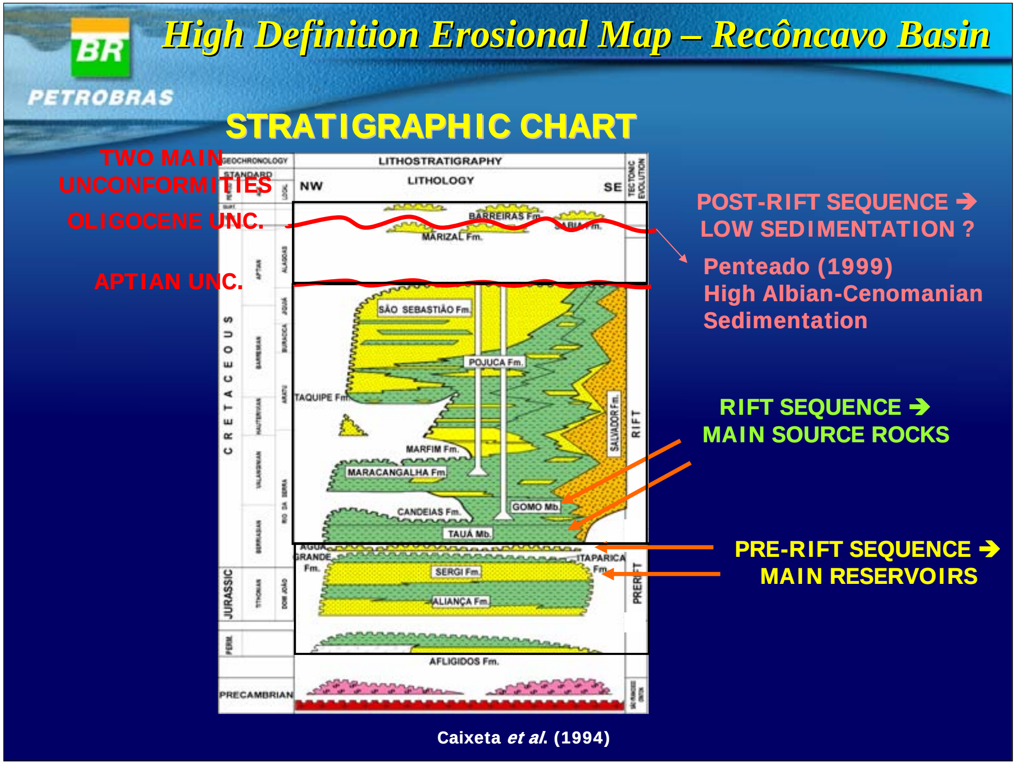
REGIONAL SETTING



Presenter's Notes: The Recôncavo Basin is the southermost part of the Recôncavo-Tucano-Jatobá Basin (NE Brazil) an elongated N-S rift 450 mi long and 150 mi wide.

This rift was formed in the Neocomian, Barremian and early Aptian as an initial tentative break of the Gondwana continent.

From the south to the north we have several half-grabens united by interaction.



Presenter's Notes: This is the stratigraphic chart of Recôncavo Basin.

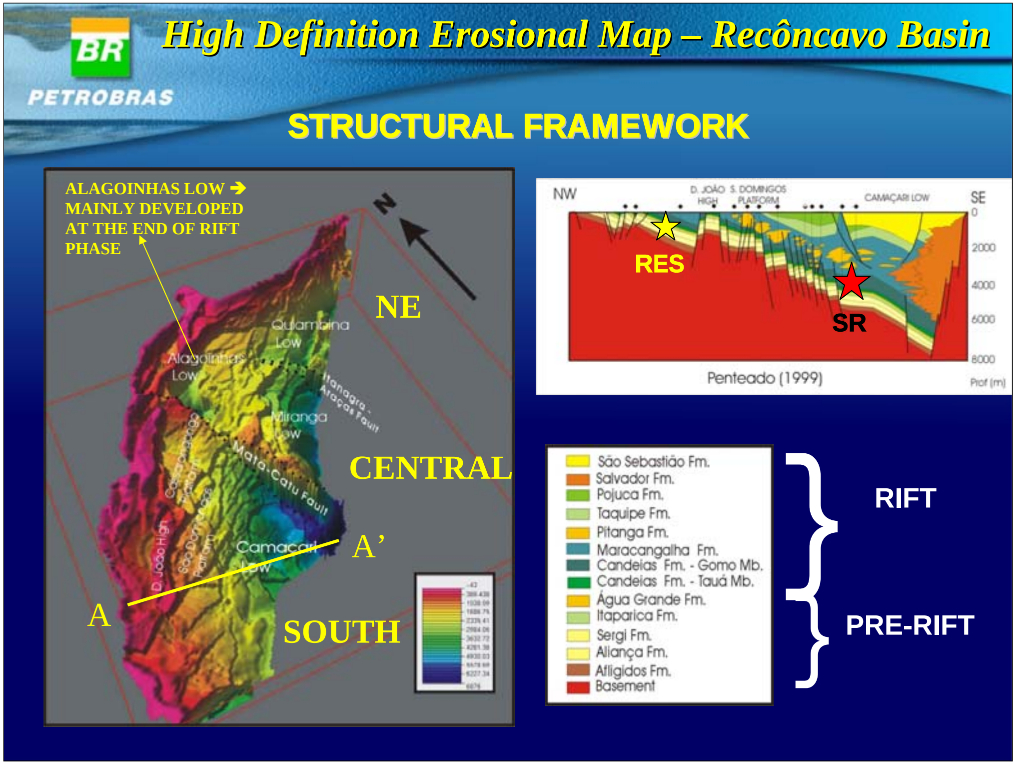
Three main sedimentary sequences occur:

The pre rift with continental sediments deposited during the Permian to Jurassic, containing the main reservoirs.

The rift sequence composed by continental sediments from lacustrine origin at the base, changing laterally and vertically to deltaic and fluvial domains at the top. this section; it contains the main source rocks, the Gomo and Tauá members of Candeias Fm.

The post-rift with little thickness with Aptian to Recent in age. I would like to highlight the two main erosional episodes that affects this section: the Aptian and Oligocene, with associated unconformities that merge in most of the basin.

Part of our work here is to determine the amounts of sediments eroded in each episode – combining the proposed approach with thermal modeling



Presenter's Notes: Here we present the structural framework of the Recôncavo Basin, basically a half-graben extending in a NE direction but subdivided into three main compartments by Mata Catu Fault – a released normal fault and Itanagra Araças, a transfer fault.

An interesting feature is the Alagoinhas Low that formed mainly at the end of rift stage.

STATE OF ART

High Definition Erosional Map – Recôncavo Basin

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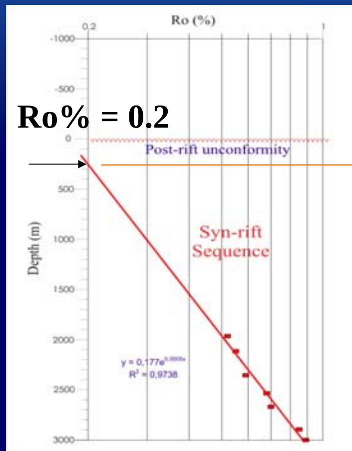
EROSION CALCULATION

The Ro% Method (Dow, 1977)



THE MONOLOG PLOT SOLUTION

NEGATIVE EROSION?

Bad distribution of vitrinite reflectance data gives us wrong calculated erosion
It must be avoided

Presenter's Notes: Here I present the well known vitrinite reflectance method proposed by Dow (1977), using vitrinite reflectance vs depth plots to determine maturation trends.

The question I propose: Is this method is universally useful? And why or why not?

Poor distribution of data gives us incorrect bad erosion calculations (e.g., preferred sampling of deep source rock). In some cases, we obtain negative erosion—of course an impossibility.

EROSION CALCULATION

The Sonic Log Method (Heasler & Kharitonova, 1996)

- THOSE AUTHORS PROPOSED A METHOD BASED ON NORMAL COMPACTION TREND OF TRANSIT TIME IN SONIC LOG PROFILES
- THIS METHOD WAS ORIGINALLY APPLIED TO THE TERTIARY SECTION (INTERBEDDED FLUVIAL, LACUSTRINE AND PALUDAL DEPOSITS) OF BIGHORN BASIN (USA)
- THIS METHOD IS BETTER APPLICABLE THAN THE Ro% METHOD (BETTER DATA DISTRIBUTION)
- THE ASSUMPTIONS OF HEASLER & KHARITONOVA ARE NOT APPLICABLE TO HIGHLY ERODED SECTIONS AS THAT VERIFIED AT THE TOP OF RIFT SEQUENCES (AS IN THE RECONCAVO STUDY CASE):

  A) THEY HAVE FIXED THE ORIGINAL TRANSIT TIME AT SURFACE WITH 180 μs/ft (ALL LITHOLOGIES)

  B) THEY DO NOT CONSIDER A REFERENCE CURVE (FOR EACH LITHOLOGY) AS A BASINAL PARADIGM.

Presenter's Notes: I present here the sonic log methodology developed by Heasler & Kharitonova (1996); their fundamental equation is used in this work.

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High Definition Erosional Map – Recôncavo Basin

METHODOLOGY

WORKING WITH VITRINITE REFLECTANCE DATA AND SONIC LOG PROFILES

Presenter's Notes: Here we present the proposed methodology to calculate post-rift erosion as a combination of vitrinite-reflectance and sonic-log erosion methods

High Definition Erosional Map – Recôncavo Basin

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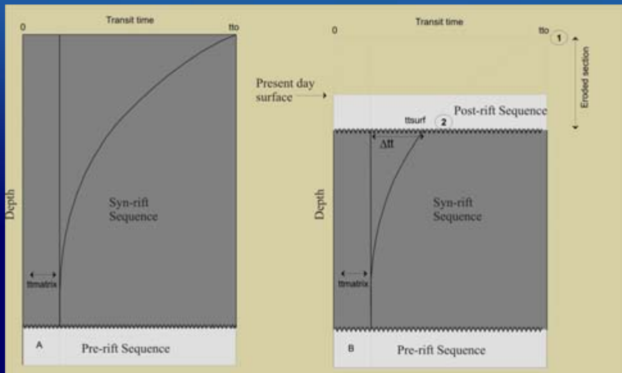
PRINCIPLE OF EROSION CALCULATION – SONIC LOGS APPLIED TO DEFINE THE POST RIFT EROSION



Transit time method to estimate erosion at the top of syn-rift sequence (adapted from Heasler & Kharitonova, 1996)

A = Syn-rift sequence before erosion.
B = Syn-rift sequence after erosion and post-rift deposition.
tto = transit time for a given lithology at the original depositional surface.
ttsurf = transit time for a given lithology at the unconformity level.

The vertical distance between the unconformity (point 2) and the extrapolated depositional level (point 1) provides the estimated erosion.
The transit time of the pre-rift and post-rift sections were not considered in the exponential regressions

FUNDAMENTAL EQUATION (MODIFIED FROM HEASLER & KHARITONOVA, 1996)

$tt = \Delta tt \exp(-c\,z) + tt_{matrix}$, where

tt = observed transit time.
z = depth.
c = decay constant.
$\Delta tt = tt_{surf} - tt_{matrix}$
tt_{surf} = transit time at the unconformity level.
tt_{matrix} = transit time of the matrix (or compacted rock).

IN OUR APPROACH THE tto WILL BE CALCULATED FOR EACH LITHOLOGY AND NOT FIXED AT 180 µs/ft

Presenter's Notes: The fundamental sonic-log equation is based on Heasler and Kharitonova's work. We can define the original transit-time curve by an exponential equation with these parameters.

HOW TO BUILD ORIGINAL TRANSIT TIME CURVES FOR EACH LITHOLOGY FROM THE SYN-RIFT SEQUENCE

A) CHOOSING A REFERENCE WELL WITH :

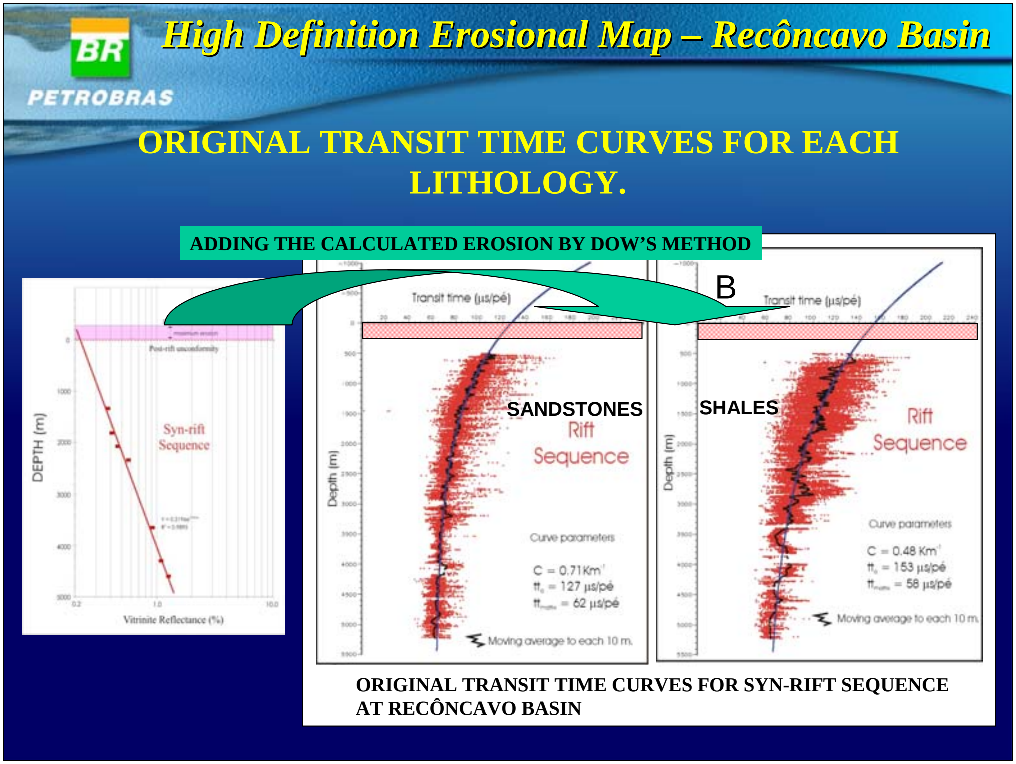
HIGH SYN-RIFT THICKNESS

SMALL EROSION AT THE TOP OF SYN-RIFT SEQUENCE

HOMOGENEOUS DISTRIBUTION AND QUALITY OF TRANSIT TIME AND VITRINITE REFLECTANCE DATA.

B) ADDING THE EROSION CALCULATED THROUGH THE DOW'S METHOD (1978) TO THE DEPTH VALUE OF SONIC LOGS.

C) MAKING THE REGRESSIONS WITH THE FUNDAMENTAL EQUATION



Presenter's Notes: The calculated erosion at post-rift unconformity using the vitrinite reflectance profile is added to the depth column in the sonic logs. The sonic logs for each lithology is shifted by this value – we obtain the original depositional transit-time curve to each lithology

HOW TO CALCULATE THE EROSION IN ANOTHER WELLS

USING THE REFERENCE CURVES AS PARADIGMS

The parameters of the original curves – the decay (c) and the transit time of the matrix (tt_{matrix}) – must be fixed for each regression. This procedure avoids an overestimation of the erosion calculation, especially in cases in which a significant part of the original curve has been suppressed by erosive processes.

EFFECTIVENESS OF PROPOSED APPROACH

The method is effective only in cases in which the erosion at the top of the analyzed syn-rift sequence is greater than the overlying post-rift sequence, considering similar compaction features between them.

High Definition Erosional Map – Recôncavo Basin

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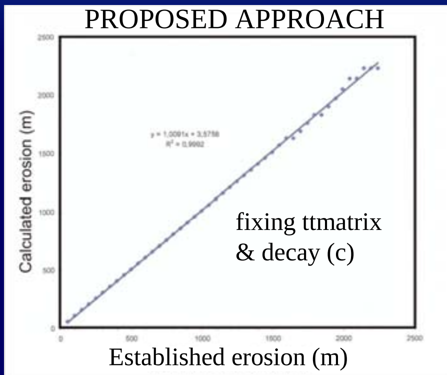
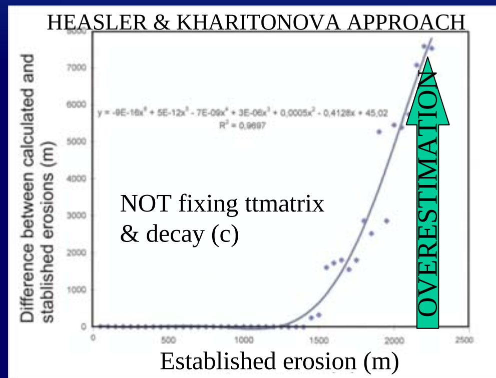
THE MAIN DIFFERENCES BETWEEN THE PROPOSED APPROACH AND THE METHOD OF HEASLER & KHARITONOVA

EXERCISE : MAKING AN ARTIFICIAL EROSION TAKING THE ORIGINAL SANDSTONE CURVE AS REFERENCE

WE CAN SIMULATE THE EROSIVE PROCESS BY DEDUCTING PRE-ESTABLISHED VALUES FROM THE DEPTH COLUMN OF THE TRANSIT TIME vs DEPTH CURVES





HIGH DEFINITION EROSIONAL MAP AT TOP OF RIFT SEQUENCE IN RECÔNCAVO BASIN

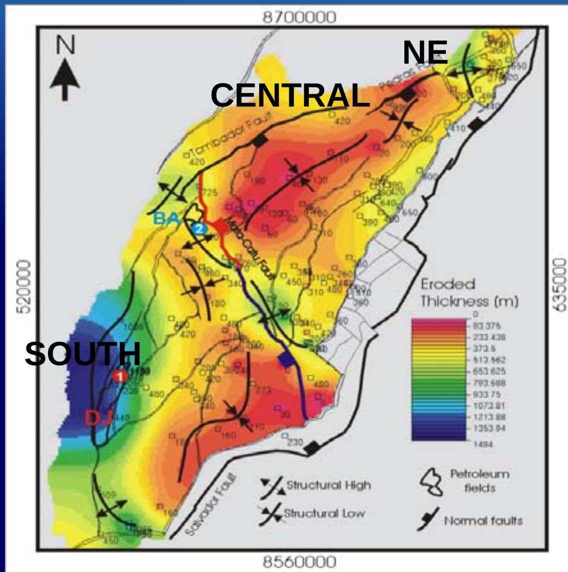
OPTION FOR TRANSIT TIME ORIGINAL CURVE FOR SANDSTONES – LESS DISPERSION OF DATA

THE CURVE FOR THE SHALES WAS USED FOR QUALITY CONTROL (erosion values calculated based on the two curves; those with error of 15% were discarded).

THE CURVE FOR THE SHALES WAS ALSO USED TO AVOID TIME TRANSIT UNDERESTIMATION IN REGIONS WHERE THE PRESERVED THICKNESS OF SEDIMENTS WAS SMALLER (E.G., DOM JOÂO HIGH)

High Definition Erosional Map – Recôncavo Basin

EROSIONAL MAP AT TOP OF SYN-RIFT SEQUENCE



It was possible to determine the amount of eroded sediments at the top of syn-rift sequence by applying the proposed method in

114 wells

from RECONCAVO BASIN

The calculated erosion matches locally with the values provided by different sedimentary, diagenetic and thermal (apatite fission track) studies focusing mainly on the Sergi Fm.

Example : Rodrigues (1990) and Rodrigues *et al.* (1992,1994) considered that Sergi Fm. has the same diagenetic aspects at Dom João (01) and Buracica fields (02).

MAXIMUM BURIAL OBTAINED FOR SERGI FM.
DOM JOÃO FIELD – 1370 m

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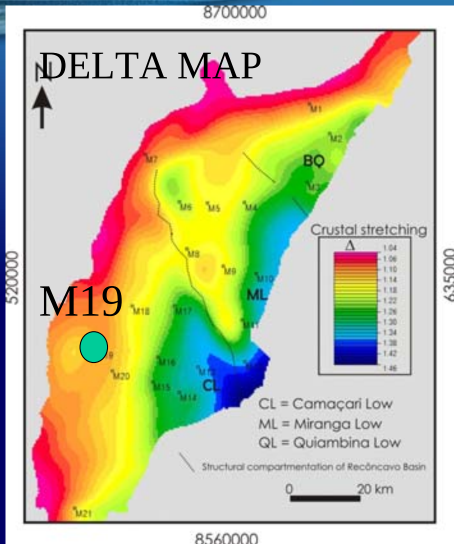
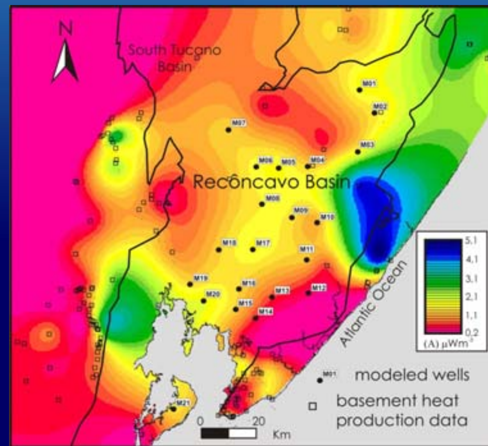
MODELING OF PETROLEUM SYSTEMS: THE THERMAL VALIDATION OF THE PROPOSED APPROACH

High Definition Erosional Map – Recôncavo Basin

Origin of the basal heat flow



Conductive Heat flow provided by generalised two-layer thermomechanical Model (ROYDEN & KEEN, 1978)



Radiogenic Heat production provided by integration of gamma spectrometric lab data from basement rocks (Argollo et al., 2006; Coutinho, 2008)

High Definition Erosional Map – Recôncavo Basin

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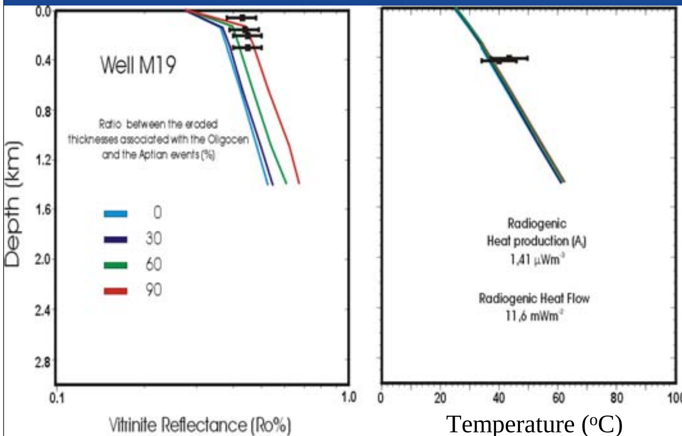
SENSITIVITY TESTS IN 1D THERMAL MODELING TO DEFINE THE ERODED THICKNESS AT OLIGOCENE EVENT

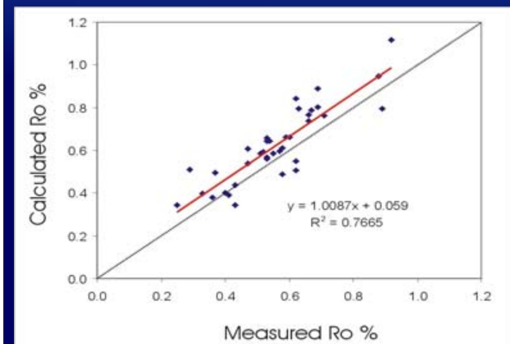


TO THE MODELING WE CONSIDER THAT THE OLIGOCENE EVENT ONLY ERODES THE ALBIAN-APTIAN SEDIMENTS

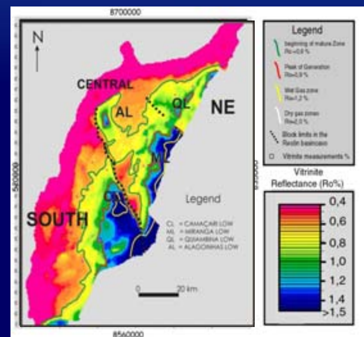
The best ratio (90%) was applied to the entire basin and contributed to acquiring a best thermal calibration in the 20 simulated wells. This ratio has permitted the construction of the Oligocene erosion map, applied to the 3D block

Thermal History Calibration

Besides the good calibration in the wells, the quality of the 3D thermal modeling could be evaluated by comparing the first reflectance registers at the top of Candeias source rocks with the modeled corresponding values, validating the thermal structure of the basin and also their geohistory (including the erosional post-rift events)



Crossplot of measured vs calculated Ro% values.at top of Candeias Fm.



Computed 3D map at the top of Candeias Fm.

CONCLUSIONS

A) The application of transit time sonic logs, together with vitrinite reflectance data following the proposed method, provided more reliable estimates of the eroded section at the top of the syn-rift sequence in the Recôncavo Basin with values varying from 0 m to 1500 m and average values of 500 m.

B) The 1D to 3D thermal calibration, using extrapolated temperature and vitrinite reflectance data, indicated eroded sections at Oligocene that represent 90% of total erosion related to the Aptian.

C) Such results were of great importance for the numerical modeling for petroleum generation and expulsion and for the comprehension of the petroleum systems of the Recôncavo Basin (Coutinho, 2008).

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