

THE COALBED METHANE POTENTIAL OF THE PARANÁ BASIN, BRAZIL

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Resumo – Este estudo tem como objetivo avaliar o potencial de gás metano das camadas de carvão (CBM) do período Permiano da Bacia do Paraná no Brasil, dos quais a maior parte ocorre no estado do Rio Grande do Sul. Nesta região as jazidas de Chico Lomã e de Santa Terezinha são as de maior potencial de CBM, baseado no *rank*, distribuição e profundidade de reservatório dos carvões.

A análise estratigráfica sequencial dos estratos portadores de carvão identificou seis parasequências, com o desenvolvimento dos carvões mais importantes na parasequência 2, base de um trato de sistemas transgressivos. As zonas de carvão foram correlacionados com base na distribuição das parasequências, e métodos petrográficos foram usados para determinar *rank* e composição dos carvões. Experimentos com isotermas de metano foram realizados para avaliar a capacidade de absorção de gás das camadas de carvão.

Os dados sugerem que a parte leste da jazida de Santa Terezinha tem o maior potencial de CBM, com espessura cumulativa de carvão até 10 m, refletância da vitrinite entre 0,75 e 0,90% Rrandom, e profundidade de reservatório entre 450 e 900 m.

A fase final deste estudo consiste no modelamento geológico 3D para identificar áreas para exploração (locação para perfuração de teste), através do cálculo de volume de carvão e do teor de metano associado com as camadas de carvão, baseados no *rank* do carvão e na profundidade de reservatório.

Palavras-Chave: energia, Bacia do Paraná, carvão, metano

Abstract – The present study evaluates the coalbed methane (CBM) potential of Permian age Paraná Basin coals in Brazil, of which the majority occurs in the state of Rio Grande do Sul. In this area the Chico Lomã/Santa Terezinha Coalfields have been identified as having the highest CBM potential based on coal rank, coal distribution and reservoir depths.

Sequence stratigraphic analysis of the coal-bearing strata have identified six parasequences, with major coal development in the transgressive systems tract of parasequence 2. The coal zones have been correlated across the coalfields based on the parasequence distribution, whereas coal petrographic methods have determined coal rank and composition. Methane isotherm experiments were aimed to evaluate the gas adsorption capacities of the coal seams.

Coal distribution, coal rank and reservoir depths suggest that the eastern part of the Santa Terezinha Coalfield has the highest CBM potential, with cumulative coal thickness of up to 10 m, vitrinite reflectance between 0.75 and 0.90 % Rrandom and reservoir depths between 450 and 900 m.

The final stage of the study uses currently 3D geological modeling to identify favorable areas for exploration (locations for CBM test holes) by calculating coal volumes and associated methane contents, based on coal rank and reservoir depth.

Keywords: energy; Paraná Basin, coal, methane

1. Introduction

In Brazil, the economically most important coal-measures occur in the southern part of the Paraná Basin, comprising Santa Catarina and Rio Grande do Sul states (Fig.1). The coal occurrences are assigned to the Rio Bonito Formation, a fluvial to marine sand- and shale-prone lithostratigraphic unit of Early Permian age (Artinskian-Kungurian). The Santa Terezinha and Chico-Lomã coalfields (Fig.1) in Rio Grande do Sul state appear to have the highest coalbed methane (CBM) potential, based on coal distribution and coal rank, with an estimated CBM volume in the order of 19 Billion m³ (Kalkreuth and Holz , 2000).

Sequence stratigraphic analysis identified six parasequences (Fig. 2). Four of these parasequences contain coal seams, developed in a series of up to seven coal zones, showing a cumulative coal thickness of up to 10 m. The depositional setting is that of a barrier-lagoonal system, where coastal mires were formed behind barrier islands (Holz, 1998).

In the context of this study the following parameters were used to evaluate the CBM potential a) coal characteristics, i.e. coal rank, coal type and coal grade; b) methane adsorption tests and c) basin geology, i.e. reservoir size, coal distribution (depth and thickness of coal seams), including 3D modeling.

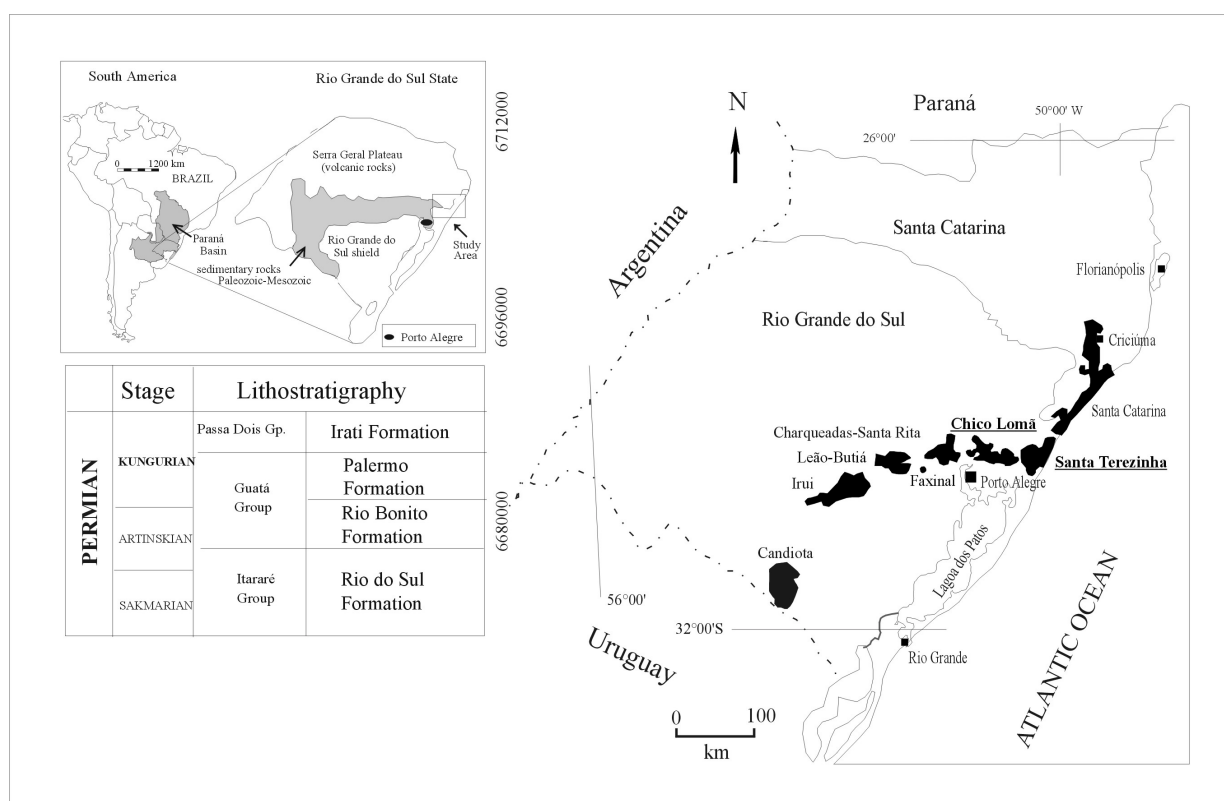


Figure 1. Distribution of major coalfields and Permian lithostratigraphy in the Paraná Basin of southern Brazil. Coalfields discussed in this paper are underlined.

2. Coal Distribution, Coal Rank and Composition

Coal distribution was determined by analysis of geophysical logs from more than a hundred coal exploration wells (Fig. 3), which shows cumulative coal thickness in excess of 10 m in the eastern part of the study area (Kern, 2002).

Coal rank determination is based on vitrinite reflectance measurement and shows that vitrinite reflectances increase from SW to NE across the coalfield (Fig. 3). The reflectance values (0.53-0.99 % R_{random}) indicate subbituminous to high volatile A bituminous coals. Locally, diabase intrusions have altered the rank of the coal seams to anthracite, with vitrinite reflectances of up to 5.46 %.

Petrographic characteristics of 14 coal seams analyzed from the Santa Terezinha Coalfield indicate that many have inertinite contents in excess of 50 Vol%, grading into carbonaceous shales as indicated by high mineral matter contents. The results are similar to those described by Araujo et al. (1995), noting also high inertinite and mineral matter contents in many of the seams. However, it has to be taken into account that in both studies the thick and economically important seams were not available for analysis, since they had been removed for analysis at the time of the exploration program.

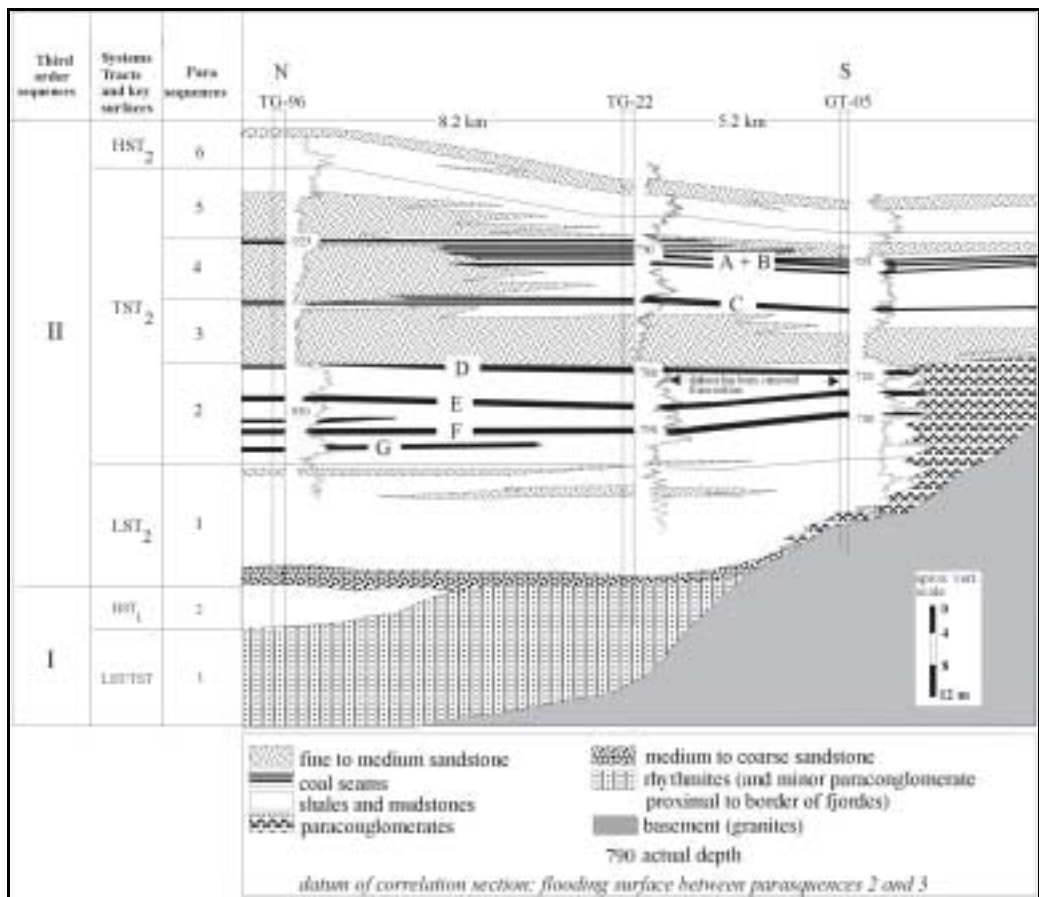


Figure 2. North-South section of the northern part of the Santa Terezinha Coalfield showing major coal zones and associated lithologies, modified from Holz (1998). HST – highstand systems tract; TST – transgressive systems tract; LST – lowstand systems tract.

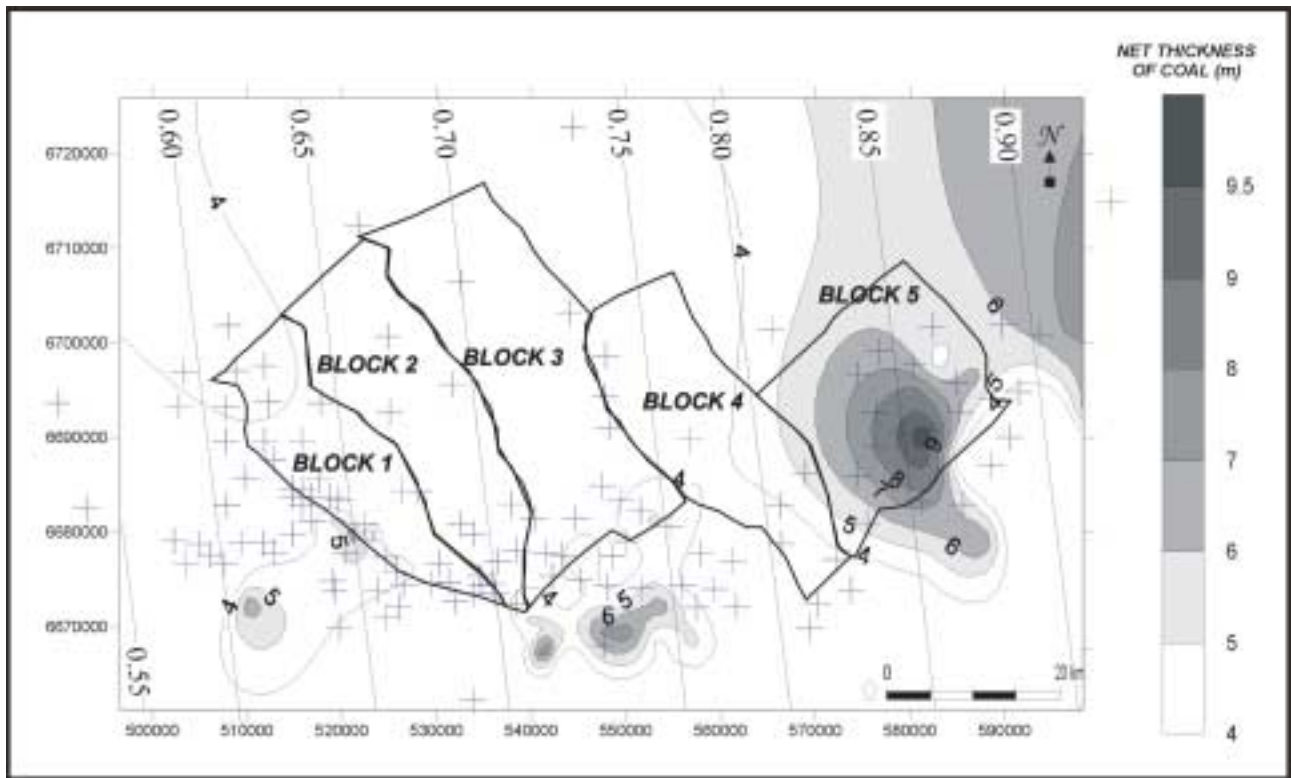


Figure 3. Position of major structural units as defined by 3D modeling (Blocks 1 to 5), coal isopach maps for net coal thickness greater than 4 m, and vitrinite iso-rank lines (0.55 to 0.90 %) indicating rank increase from west to east.

3. Methane Adsorption Isotherms

Methane Isotherm experiments carried out on a number of coal seam samples indicate: a) in samples with similar vitrinite and mineral matter contents, the highest values of methane adsorption correspond to the highest reflectivity; b) in samples of similar rank (reflectivity) and vitrinite content the highest value of methane adsorption correspond to the lowest mineral matter content; c) in samples with similar rank (reflectivity) and mineral matter content the highest methane adsorption correspond to the highest vitrinite content (Kalkreuth et al., 2000).

4. 3D Modeling

Geometrical modeling of the basin geology – and especially the coal bearing sequences - is based on borehole data and on soft data i.e. the conceptual model of the depositional environment and tectonic setting. To accomplish this task, the geoscientific 3D modeling package SurpacVision by Surpac Software International (Pty.) Ltd. of Perth, Western Australia was used. SurpacVision uses triangulated irregular networks (TINs) as a representation scheme for surfaces as well as for solids.

As it is impossible to correlate the large number of thin seams it was necessary to conceive a novel approach to investigate the coal-bearing layers within parasequences defined by sequence stratigraphic methods. Therefore our final geological model will consist of the top of the basement and of 6 parasequences. Within the coal bearing parasequences we consider the cumulative thickness of coal layers for estimating the coal gas potential. In a first conceptual geometrical model, emphasis was laid on the question if tectonic blocks of sufficient size for future economic gas production are existing. The Santa Terezinha Coalfield is characterized by NW-dipping strata, which are separated into 5 mega-blocks by a number of nearly vertical, NW-SE-strike faults (see Fig. 4). Blocks 1 and 2 are excluded from further analysis because it can be expected that most seam gas has migrated to the surface, related to the relatively low overburden in this area. Blocks 3, 4 and 5 are the most favorable areas in terms of CBM potential.

The following step will be the geometrical modeling of coal-bearing strata in these blocks. A detailed spatial analysis of all relevant boreholes shows that these blocks are not as homogeneous as expected. Missing sequence stratigraphic events in some boreholes and minor vertical movements within these blocks reveal significant internal variation of the spatial distribution of coal seams. As an example a more detailed geometrical model of Block 5 is given. Even though, the drillhole spacing is relatively large, it was possible to infer the basement paleotopography. A 3D-view of the basement structures is given in Fig. 5a. The top of parasequence 1, which unconformably overlies the basement is shown in Fig. 5b. The drowning of the Precambrian landscape is easily recognizable by the shape of the subcrops. The evaluation of the drillhole logs revealed that the top of this parasequence has been subjected to erosional processes. Fig. 5c depicts the top of parasequence 2. This parasequence was not only affected by erosion but also by the intrusion of a basaltic sill in the north-eastern portion of the block.

In the final model, all faults, areas of reduced thickness as well as sills have to be regarded as vital criteria to delineate exclusion areas for CBM test wells. In the remaining parts of the blocks which are offering sufficient geometrical continuity, the coal quality parameters must be analysed for predicting CBM potential. The final favorability map will be the intersection of geometrically and coal quality related homogeneous subareas in each block.

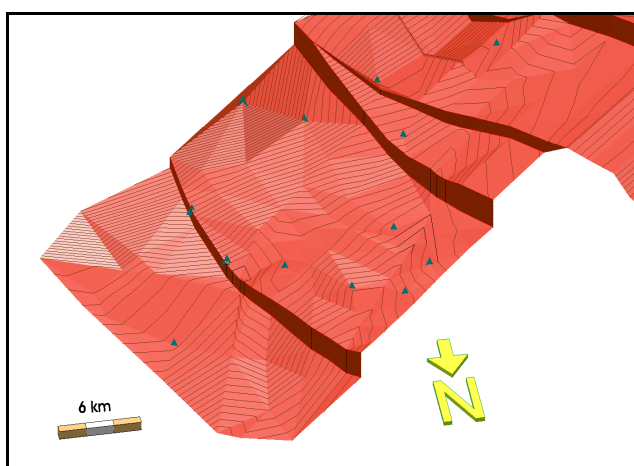
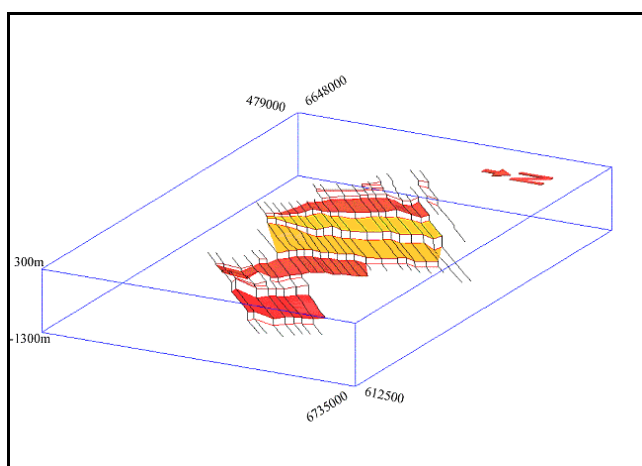


Fig. 4: 3D view of mega-blocks defined by almost vertical dipping major faults (view from NE, vertical exaggeration 15 times).

Fig. 5a: 3D view of the top of the basement with drillhole intercepts (triangles) and 10m contours (vertical exaggeration 10x).

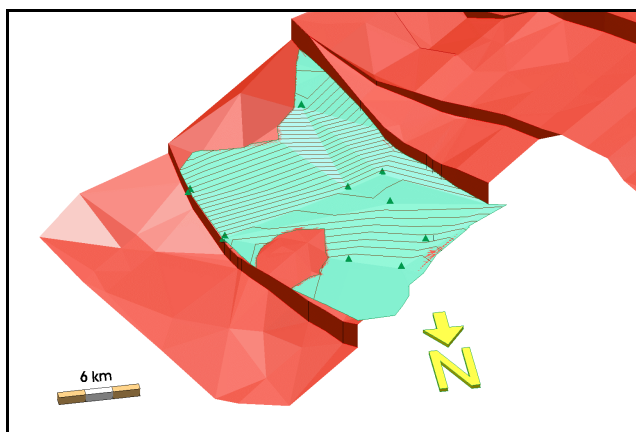


Fig. 5b: 3D view of the top of parasequence 1 in block #5 with drillhole intercepts (triangles) and 10m contours (vertical exaggeration 10x).

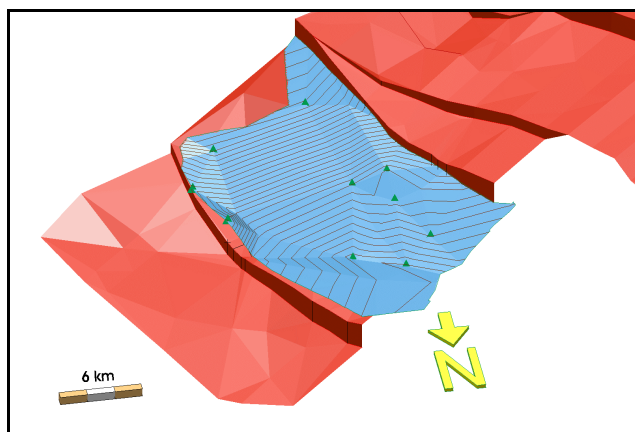


Fig. 5c: 3D view of the top of parasequence 2 in block #5 with drillhole intercepts (triangles) and 10m contours (vertical exaggeration 10x).

5. Conclusions

Coal distribution and coal rank make Blocks 4 and 5 the prime targets for CBM exploration in the study area. The depth range of the coal zones in these blocks are between 463 – 902 m, and estimated CBM contents are in the order of 4-5 cm³/g of coal. CBM critical parameters for the various blocks are given in Tables 1 and 2.

Table 1. CBM evaluation parameters for blocks 1 to 5

Block	Area (km ²)	Rr (%)	Rmax (%)	T _{coal} (m)	T _{total} (m)	d _u (m)	d _l (m)	CBM (cm ³ /g)
1	288	0.64	0.99	3.76	5.28	197	397	2.13
2	403	0.66	0.80	3.92	6.49	230	343	2.67
3	574	0.73	0.95	3.80	5.19	305	461	3.14
4	366	0.76	0.92	3.13	4.15	463	625	4.28
5	309	0.84	1.03	5.65	6.77	610	902	5.43

Area = area of each block (given by the geometric model)

Rr (%) = mean random vitrinite reflectance

Rmax (%) = highest vitrinite reflectance recorded

T_{coal} = mean of net total coal seam thickness

T_{total} = mean of total coal seam thickness

d_u = top of coal zone

d_l = base of coal zone

CBM (cm³/g) = CBM content estimated from empirical formulas

Table 2. Coal seam characteristics for selected boreholes from blocks 3, 4 and 5, considered to be favourable for CBM exploration

Block #	Bore-hole	Depth NN (m)	Total Thickness of Coal Seams (m)	Net Coal Thickness (m)	No of coal zones	Seams > 0.50 m	Max.Seam Thickness (m)	Mean Rrandom (%)	Ash (wt.%)
3	TG-28	263-327	9.42	7.55	12	8	2.88	0.72	--
3	TG-49	370-385	5.57	3.89	12	3	1.59	0.69	52.8
3	TG-88	280-308	10.65	8.24	11	6	3.50	0.72	--
4	TG230	526-551	5.78	4.71	9	3	3.00	0.83	46.3
5	TG-95	865-907	8.15	6.42	16	3	2.91	0.84	45.1
5	TG227	785-907	8.75	8.75	13	6	1.10	0.85	--

6. Acknowledgements

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7. References

- ARAÚJO, C., CORRÊA DA SILVA, Z., RODRIGUES, R. Petrographic and geochemical study of coals from the Santa Terezinha Coalfield, Rio Grande do Sul, Brazil. *Revista Latino-Americana de Geoquímica Orgânica*, v. 1, n. 1, p. 28-45, 1995
- HOLZ, M. The Eo-Permian coal seams of the Paraná basin in southernmost Brazil: An analysis of the depositional conditions using sequence stratigraphic concepts. *Int. Journal of Coal Geology*, v. 36, n. 1-2, p. 141-163, 1998.
- KALKREUTH, W., HOLZ, M. The coalbed methane potential of the Santa Terezinha Coalfield, Rio Grande do Sul, Brazil. *Revista Brasileira de Geociências*, v. 30, n. 2, p. 342-345, 2000
- KALKREUTH, W., HOLZ, M., BURGER, H., LEMOS DE SOUSA, M., RODRIGUEZ, C., SÜFFERT, T. The coalbed methane potential of Permian coals in the Paraná Basin of Brazil. 31st Int. Geol. Congress, Rio de Janeiro, Brazil, Aug. 6-17, 2000, Abstracts Volume, CD ROM, 1p., 2000
- KERN, M. Avaliação do Potencial gerador de metano das Jazidas de Chico Lomã e Santa Terezinha, Nordeste do Rio Grande do Sul. Dissertação de Mestre em Geociências, Universidade Federal do Rio Grande do Sul, pp. 181, 2002