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F. C. Lopes, P. A. Dinis, L. V. Duarte, P. P. Cunha

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The age and depositional environments of the lower Karoo Moatize Coalfield of Mozambique: insights into the postglacial history of central Gondwana

Idade e ambientes deposicionais do Karoo inferior da Bacia de Moatize em Moçambique: contributos para o conhecimento da história geológica pós-glacial no centro do continente Gondwana

P. Fernandes (1), J. Hancox (2), M. Mendes (3), Z. Pereira (3), G. Lopes (4), J. Marques (5), R. C. G. S. Jorge (6) and L. Albardeiro (7)

- (1) Centro de Investigação Marinha e Ambiental, (CIMA), Universidade do Algarve, Campus de Gambelas, 8005-139, Faro, Portugal, pfernandes@ualg.pt
 (2) Evolutionary Studies Institute, University of the Witwatersrand, PO Wits 2050, Johannesburg, South Africa.
 (3) Laboratório Nacional de Energia e Geologia (LNEG), Rua da Amieira, Apartado 1089, 4466-901, S. Mamede de Infesta, Portugal.
 (4) Plants, Photosynthesis and Soil Cluster, School of Biosciences, University of Sheffield, Alfred Denny Building, Western Bank, Sheffield S10 2TN, UK.
 (5) Gondwana Empreendimentos e Consultorias, Limitada, Rua 1.335, Bairro da COOP, Maputo, Moçambique.
 (6) Instituto Dom Luiz, Departamento de Geologia da Faculdade de Ciências, Universidade de Lisboa, Campo Grande, Edifício C6, Piso 4, 1749-016 Lisboa, Portugal.
 (7) Laboratório Nacional de Energia e Geologia (LNEG), Bairro da Val d'Oca. Ap. 14, 7601-909 Aljustrel, Portugal.

Sumário: Quatro sondagens realizadas na Bacia Carbonífera de Moatize (Moçambique) foram alvo de estudos palinoestratigráficos e paleoambientais, permitindo a determinação da idade da sucessão estratigráfica do Karoo inferior desta bacia. Os dados forneceram, também, conhecimentos sobre a idade das camadas de carvão, evolução dos ambientes sedimentares e condições paleoclimáticas nesta parte do Supercontinente Gondwana desde o final da glaciação do Paleozoico superior (Guadalupiano inferior) até à fronteira Pérmico-Triásico. Duas fases deposicionais foram reconhecidas relacionadas com importantes eventos tectónicos regionais. A primeira registou a mudança de um leque deltaico de deglaciação para ambientes de delta lacustre e a deposição das camadas de carvão Sousa Pinto e Chipanga em pântanos das margens de lagos durante o Roadiano-Wordiano. A segunda fase está relacionada com os sistemas fluviais de elevada carga sedimentar, e a deposição das camadas de carvão Bananeiras, Intermédia, Grande Falésia e André em planícies de inundação durante o Wordiano (Guadalupiano) ao Lopingiano.

Palavras-chave: palinologia, análise estratigráfica, camadas de carvão, Guadalupiano-Lopingiano, Karoo

Keywords: palynology, stratigraphic analysis, coal seams, Guadalupian-Lopingian, Karoo

The accumulation of extensive coal deposits is one of the main features of the lower Karoo sedimentary sequences deposited in the Gondwanan successions of south-central Africa, between the Late Palaeozoic Glaciation (LPG) and the end Permian extinction (EPE). The onset of a greenhouse climate mode follows the age of the LPG terminus. The sedimentary environments, and duration of the coal beds deposition, are still a matter of discussion, particularly in the Karoo-aged basins of Mozambique. The Mozambican coalfields outcrop extensively along the Zambezi Basin in Tete Province. They occur in three sub-basins: i) the Moatize - Minjova sub-basin, ii) the Sanângoè-Mefidéze sub-basin, and iii) the Chicôa-Mecúcoè sub-basin. The Lower Karoo Group in Mozambique comprehends three clastic units,

from oldest to youngest: the (glacial/deglacial) Vúzi, (coal-bearing) Moatize, and (sandstone-dominated) Matinde Formation. This work focuses exclusively on the Moatize Coalfield (MC), part of the Moatize – Minjova sub-basin, and is supported by the analysis of four stratigraphic boreholes. Based on palynological cluster analysis, it presents the relative ages of the lower Karoo stratigraphic succession, including the recognised coal seams. This analysis allowed the correlation of the entire coal-bearing stratigraphic sequence of the MC. In addition, interpretations of the sedimentary environments, together with the palynological record, provide critical information for establishing new considerations on the age and onset of the deglaciation events, the age of coal deposits, the sedimentary environment dynamics, the

palaeoclimatic evolution, and the overall geological evolution for this part of Gondwana during Permian times.

The main conclusions of this study were:

1) In the MC, the coal seams sequences are all younger than the base of the Roadian Stage (early Guadalupian Epoch), dating the beginning of the deglaciation phase in this basin;

2) The sedimentological analysis indicates that the deposition in the MC occurred in two different phases. The beginning of the deposition is related to major regional tectonic events. The older depositional phase records the evolution from an initial deglacial fan-delta to a lake-delta depositional environment. The climate change accompanying this phase is characterised by a warming trend that allowed the accumulation of terrestrial vegetation in wetlands and the formation of the Sousa Pinto and Chipanga seams, respectively. In the lake-delta depositional system, coals were formed in lake margin mires and swamps of the delta top, whereas inside the lake basin, fine-grained sediments accumulated as lake-floor mudstones and siltstones, while conglomerates and sandstones accumulated as mass flow deposits (debris flows) on the lake floor and lake slope.

3) The sedimentation in the first depositional phase was influenced by the early transtensional tectonism that created the initial accommodation space for sedimentation, and the end of the LPG age, whose ice melting may have influenced the lake levels. A uniformisation of the sedimentary environments may have occurred in the entire basin, with the development of lake margin swamps that extend laterally in shallow lakes. This phase is associated with the deposition of the Chipanga Seam, whose accumulation is estimated to be between 1.5 to 2.7 million years. The palynological age of the first depositional phase that hosts the Sousa Pinto and

Chipanga seams is Roadian-Wordian (lower to mid-Guadalupian).

4) The second depositional phase relates to fluvial environments only. The beginning of this depositional phase was linked to an important regional tectonic pulse that tilted the basin floor and uplifted the source terrain. This led to a reorganisation of the sedimentary environments with the formation of fluvial systems characterised by bedload rivers (braided?) and overbank floodplains. The separation of the different depositional settings of the fluvial system is proposed to be linked to the tectonic compartmentation of the basin floor by active normal faults. The braided channel belt was constrained to hanging wall blocks of normal faults in grabens and half-grabens, characterised by high tectonic subsidence rates. At the same time, the floodplain deposition occurred on the footwall blocks of the normal faults or in the highest part of the hanging wall ramp of half-grabens. The coeval deposition of coal-rich and sandstone-rich succession in different parts of the basin may explain the difficulty in identifying the stratigraphic limit between the coal-bearing Moatize and the sandstone-dominated Matinde formations. The deposition of coal intervals within the braided channel belt is attributed to channel lateral migration and the formation of swamps in the abandoned channels. In contrast, the accumulation of coals in the floodplains is associated with permanent wetlands and marshes formed by frequent floodings with well-established luxuriant vegetation. These waterlogged settings were only preserved in humid temperate to warm climatic conditions. Based on their palynological signatures, the age of the fluvial depositional phase that hosted the Bananeiras, Intermédia, Grande Falésia and André coal seams is Wordian (Guadalupian) to Lopingian.

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