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Palynological records of the Permian Ecca Group (South Africa): Utilizing climatic icehouse–greenhouse signals for cross basin correlations

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ABSTRACT

The Permian formations of the South African Karoo Basin play a crucial role in understanding Gondwana's climate history during this time of major global changes. In this paper we present two data sets, one from the coal-bearing Vryheid Formation (Witbank Basin) and one from the Whitehill and Upper Prince Albert formations of the DP 1/78 core (NE Karoo).

Our main goal was to study the vegetation changes during this period of global warming and test if the climatic signals could be used to correlate the basinal Ecca group facies with the fluvio-deltaic coal-bearing strata of the Witbank Basin. The palynological record of the No. 2 Coal Seam of the Vryheid Formation indicates a cold climate, fern wetland community, characteristic of lowland alluvial plains, and an upland conifer community in the lower part of the coal seam. Up section, these communities are replaced by a cool-temperate cycad-like lowland vegetation and gymnospermous upland flora. The data set of the DP 1/78 core is interpreted to represent a cool to warm temperate climate represented by a high amount of Gangamopteris and Glossopteris elements.

Both data sets are very different in their composition, which can be explained by the differences in depositional environment; however, our findings reveal a different age of the studied assemblages and thus also suggest that both data sets represent different stages in the transition from icehouse to greenhouse during Permian times. As the stratigraphic correlation between the Main Karroo Basin and the peripheral basins is still under discussion, this paper provides new data to underpin the stratigraphic placement of the Whitehill Formation relative to the coal-bearing Vryheid Formation.

1. Introduction

Our knowledge of the Permian palynology of the South African Karoo Basin is based on a fundamental research carried out in the 1970s and 1980s by Anderson (1977) and Falcon (see 1989 and references therein). No recent works address high-resolution palynostratigraphy of the Permian–Triassic coal-bearing formations in the South African Karoo, whereas new palynostratigraphic zonation schemes were established in other parts of southern Africa (D'Engelbronner, 1996; Nyambe and Utting, 1997; Stephenson and McLean, 1999; Modie and Le Hérissé, 2009). In general, Gondwanan land plant communities changed rapidly during Permian times due to the dramatic climate change subsequent to the melting of the Dwyka ice. This prominent change in vegetation, displayed in palynomorph assemblages, enables a high-resolution correlation.

From this background, it seems imperative to study the palynological record of the Permian succession in much more detail with respect to establish a high-resolution stratigraphic framework and climate history of the Karoo. Here, we report on new palynological data from the No. 2 Coal Seam of the northern Witbank coal field and a core (DP 1/78) drilled in the northeastern part of the Main Karoo Basin with the aim of using climatic signals for basin-wide correlation.

2. Geological setting

The Late Carboniferous to Middle Jurassic Karoo Basin covers approximately one third (i.e. 700 000 km^2) of South Africa (Johnson et al., 2006), extending into Lesotho and in parts of Swaziland and Mozambique (Cole, 1992, Catuneanu et al., 2005). A total thickness of 12 km sediment infill is reached within the southeastern part of the Main Karoo Basin. This sedimentary succession, known as the Karoo Supergroup, is subdivided into the Dwyka Group (Late Carboniferous (Pennsylvanian) to Early Permian (Artinskian); Visser, 1996), the Ecca Group of Permian age, the Permian–Triassic Beaufort Group (Johnson et al., 2006), and the Stormberg Group (Late Triassic to Early Jurassic;

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Catuneanu et al., 1998, Catuneanu et al., 2005). The Karoo succession is capped by 1.4 km of basaltic lavas of the Drakensberg Group and intruded mafic dyke swarms (Veevers et al., 1994; Johnson et al., 1996).

The Karoo Basin forms part of a major series of Gondwanan foreland basins, including the Paraná Basin in South America, the Beacon Basin in Antarctica, and the Bowen Basin in Australia (De Wit and Ransome, 1992; Veevers et al., 1994; Catuneanu et al., 1998; Catuneanu and Elango, 2001; Catuneanu and Bowker, 2002). These basins formed mainly as a result of collision and terrain accretion tectonics along the southern edge margin of Gondwana (De Wit and Ransome, 1992; Veevers et al., 1994). Recent interpretations of the basin evolution and tectonic setting of the Karoo range from a retro-arc foreland basin (Johnson et al., 2006), a transtensional foreland system created by subsidence and tilting in a strike-slip regime (Tankard et al., 2009) to a thin-skinned fold belt that developed from collisional tectonics and distant subduction to the south (Lindeque et al., 2011).

The Karoo Basin hosts important coal resources of South Africa (Johnson et al., 1997; Cairncross, 2001). The Witbank coal field comprises the basin's northeastern and most economic coal deposits (Snyman, 1998) with 5 coal seams (coal seams 1–5 in ascending order) that belong stratigraphically to the Vryheid Formation. One of the most important coal seams of the Witbank coal field, the No. 2 Coal Seam, represents postglacial fluvio-deltaic deposits of the Lower Ecca Group, pointing to a highly proximal setting of the northern basin margin (Falcon, 1989). Further south in the Main Karoo Basin organic-rich shales of the Whitehill Formation have been regarded as time-equivalent to the coal-bearing Vryheid Formation (Viljoen, 1994; Johnson et al., 1996, 1997).

3. Material and methods

During a field campaign in 2011, we sampled an 8 m thick succession of the No. 2 Coal Seam exposed in the Inyanda Coal Mine south of Witbank (Fig. 1) to study palynofacies and palynostratigraphy. Lithologies of 22 samples include fine- to medium-grained sandstones, organic-rich siltstones and coals. We also present here data from the DP 1/78 core (Fig. 1) that was sampled during a data gathering campaign by Shell Exploration & Production. In total, 11 samples of a black shale interval have been analysed.

For palynofacies analysis samples were prepared using standard palynological processing techniques, including HCl (33%) and HF (73%) treatment for dissolution of carbonates and silicates, and saturated $ZnCl_2$ solution ($D \approx 2.2$ g/ml) for density separation. Residues were sieved at a 15 μm mesh size. Slides have been mounted in Eukitt, a commercial, resin-based mounting medium.

Sedimentary organic matter is grouped into sporomorphs, fresh water algae, acritarchs, degraded organic matter, amorphous organic matter and phytoclasts. The phytoclast group has been subdivided into opaque and translucent particles. Equidimensional and needle-shaped phytoclasts have been counted separately. The relative percentage of these components is based on counting at least 300 particles per slide.

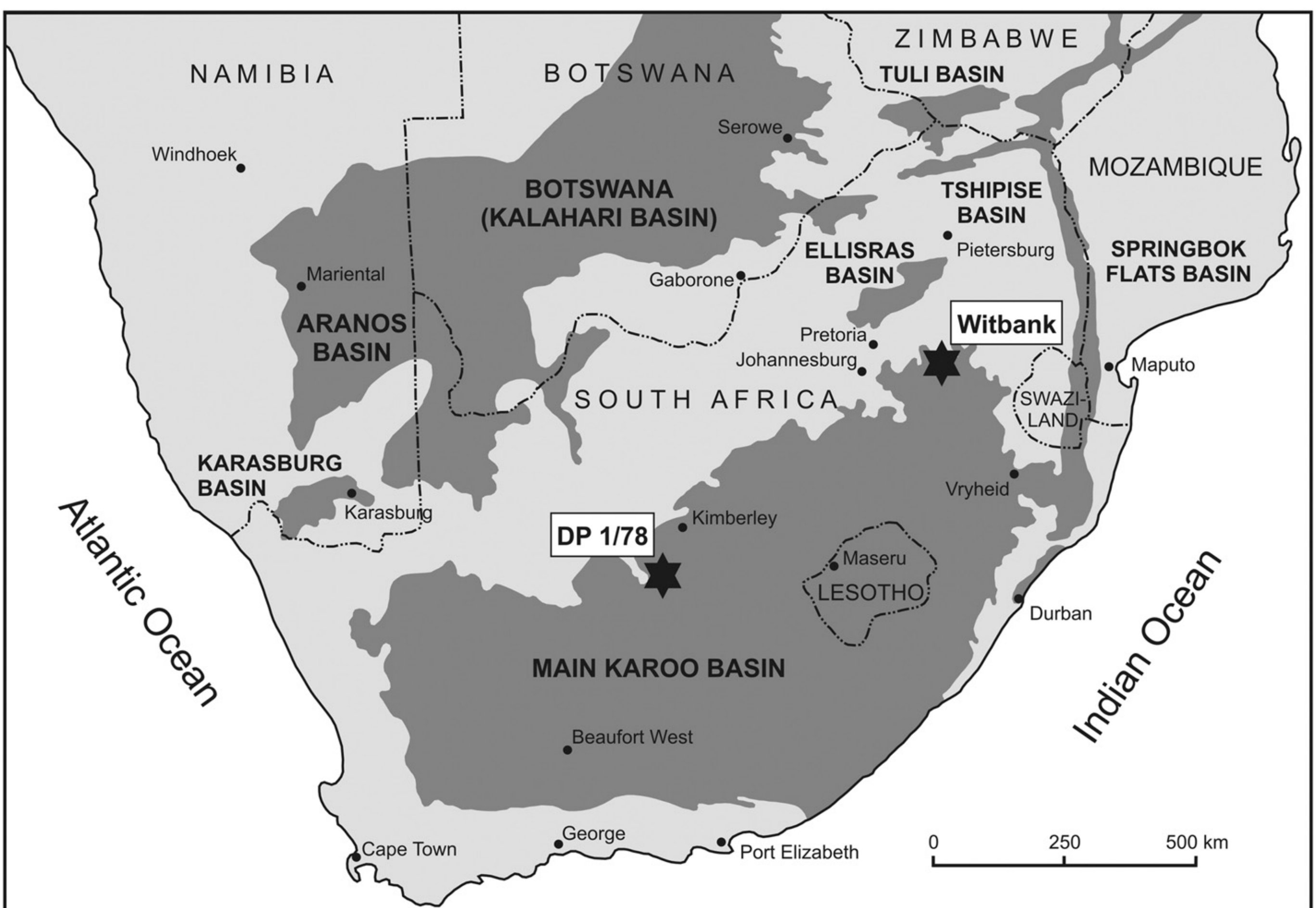

Fig. 1. Location of the studied well section (DP 1/78) and the No. 2 Coal Seam exposed in the Inyanda mine (Witbank). Map modified from Johnson et al. (2006).