[PS]Comparing and Contrasting the Onshore and Offshore Components of the Gamtoos Basin from Petrography, Lithostratigraphy and Facies Analysis, South Coast of South Africa*

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Abstract

The Gamtoos Basin is one of the five Outeniqua sub-basins on the south coast of South Africa known for its hydrocarbon potentials. The basin is one of the only two on the south coast present both onshore and offshore with a thickness of up-to 4 km. The study area is located within the main Outeniqua Basin on the south coast of Southern Africa between Port Elizabeth and Jeffreys Bay. The basin follows a southeast to northwest trend between the following coordinates; longitude 33°44'5.54"S to 34°55'36.16"S and latitude 24°35'31.20"E to 25°45'21.18"E.

The basin is bound by the following: Gamtoos Fault (east), St. Francis Arch (west) and Port Recife Arch (east and west). Offshore, the basin is situated in the Indian Ocean southwest of Port Elizabeth whereas onshore it is situated north-west of Port Elizabeth in the Eastern Cape Province within the following local towns: Loerieheuwel, Hankey and Patensie. The basin is smaller onshore in comparison to its larger offshore component.

The onshore geology is divided into lithologies of the Uitanhage Group, which comprises the late Jurassic to early Cretaceous Enon Formation and the Early to mid-Cretaceous Kirkwood Formation. The Enon Formation comprises massive red-grey conglomerate units at the base overlaid by alternating layers of red, grey and white sandstones, siltstones and mudstones of up-to 0.48 km in thickness. The overlaying Kirkwood Formation comprises red-white alternating layers of sandstones, siltstones and mudstones at the base and massive grey-red layers of conglomerates at the top adding up-to 2.2 km in thickness.

The following facies were encountered across the entire basin: dark grey thin bedded and laminated sandstones, light grey massive bedded sandstones, light grey wavy laminated sandstones, light grey to white massive bedded mudstones and red to grey convolute bedded sandstones. The following facies were observed onshore: red massive bedded mudstones, red wavy laminated mudstones, red tabular cross-bedded sandstones, grey lenticular sandstones, dark grey massive bedded conglomerates, light grey massive bedded conglomerates and red massive bedded conglomerates. The following facies were observed offshore: grey intraclastic sandstones, dark grey massive bedded mudstones, grey bioturbated sandstones, grey bioclastic sandstones and grey fine-grained pelletic mudstones.

Petrographic analyses of both onshore and offshore samples revealed the presence of organic intraclasts from the following rock types: fine-grained siltstones, fine-grained mudstones, lithic arenites, quartz arenites, quartz wackes and pelletic wackes. It also showed the presence of asphalt from fine-grained siltstones, grey intraclastic sandstones, grey thinly bedded and laminated sandstones and grey massive sandstone facies (occasionally). Asphalt, organic carbon rich micro-fractures, coal lenses, macroscopic organic carbon rich intraclasts, glauconite and bioturbation were only observed offshore. Red lithologies, massive conglomerates, load casts and lenticular sandstones were only observed onshore.

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Introduction

The Gamtoos Basin is one of the five Outeniqua sub-basins on the south coast of South Africa known for its hydrocarbon potentials. It is one of the only two on the south coast present both onshore and offshore with a thickness of approximately 4 km. The basin is bound by the following structures: Gamtoos Fault (east), St. Francis Arch (west) and Port Recife Arch (east). Onshore the geology is divided into lithologies of the Uitanhage Group comprising the Upper-Jurassic to Lower-Cretaceous Enon Formation and the Lower to mid-Cretaceous Kirkwood Formation.

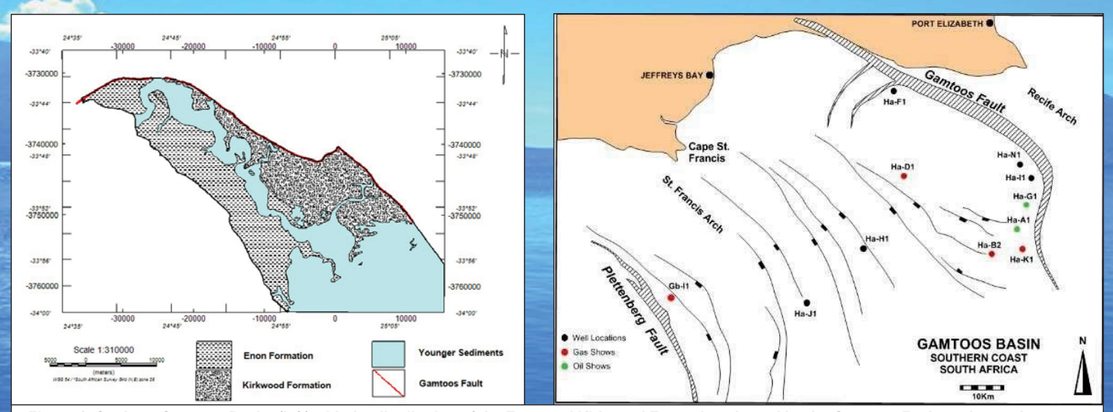

Figure 1. Onshore Gamtoos Basin (left) with the distribution of the Enon and Kirkwood Formations bound by the Gamtoos Fault on the north eastern edge. Offshore Gamtoos Basin (right) bound by the Gamtoos Fault and Recife Arch east and St. Francis Arch west. The basin is located on the south coast of South Africa between Port Elizabeth and Jeffreys Bay. Source: Davids et al; 2017.

Methodology

The following methods were used to analyse the Gamtoos Basin onshore and offshore for the distribution of organic matter: petrography, facies analysis and lithostratigraphy. This was achieved through borehole core logging offshore, macroscopic analysis of outcrops onshore and analysis of thin sections for mineral compositions, rock types and type of organic matter present.

Results

The Enon Formation comprises massive red-grey conglomerate (Cgl) units at the base overlain by alternating layers of red, grey and white sandstones (Sd) and mudstones (Md) of up to 0.48 km in thickness. The overlying Kirkwood Formation comprises red-white alternating layers of sandstones, siltstones and mudstones at the base overlaid by massive grey-red layers of conglomerates adding up to 2.2 km in thickness.

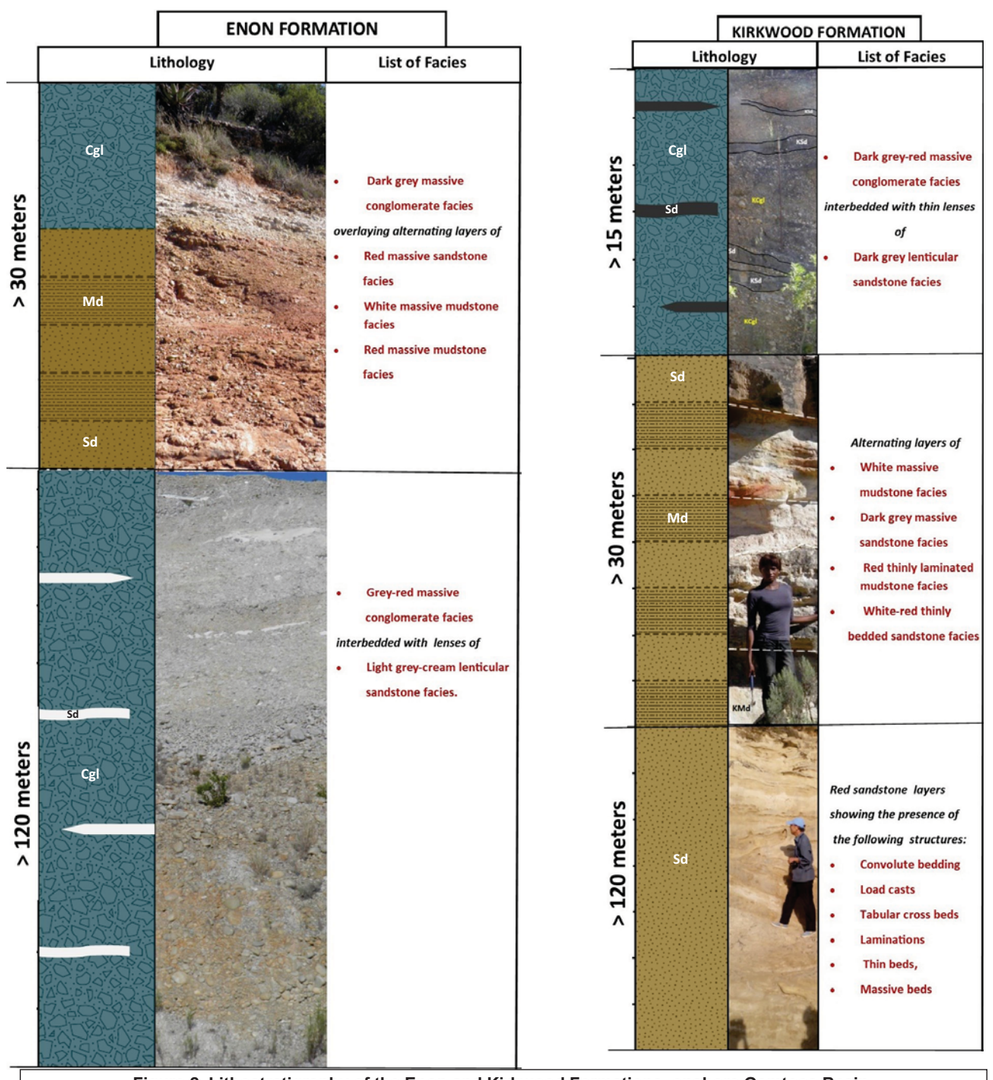

Figure 2. Lithostratigraphy of the Enon and Kirkwood Formations, onshore Gamtoos Basin.

Figure 3. Different types of conglomerate facies observed across the onshore Gamtoos Basin. Photos A and B = white lenticular sandstone facies(A1) interbedded with massive conglomerate facies from both the Kirkwood and Enon Formations. Photos C and E = red massive conglomerate facies from both Enon and Kirkwood Formations. Photo E = light grey massive conglomerate facies of the Enon Formation whereas photo F = dark grey massive conglomerate facies of the Kirkwood Formation.

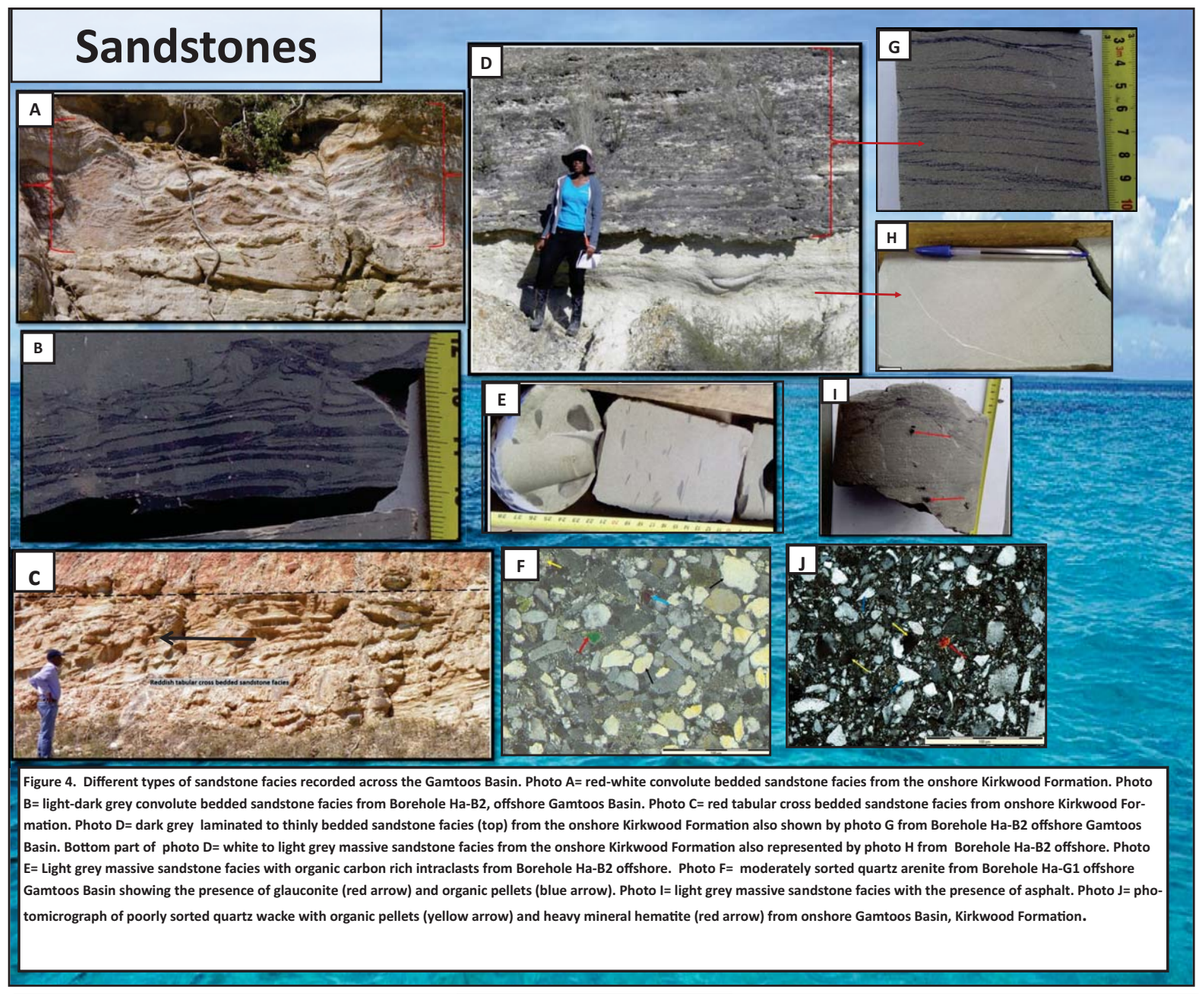

Figure 4. Different types of sandstone facies recorded across the Gamtoos Basin. Photo A= red-white convolute bedded sandstone facies from the onshore Kirkwood Formation. Photo B= light-dark grey convolute bedded sandstone facies from Borehole Ha-B2, offshore Gamtoos Basin. Photo C= red tabular cross bedded sandstone facies from onshore Kirkwood Formation. Photo D= dark grey laminated to thinly bedded sandstone facies (top) from the onshore Kirkwood Formation also shown by photo G from Borehole Ha-B2 offshore Gamtoos Basin. Bottom part of photo D= white to light grey massive sandstone facies from the onshore Kirkwood Formation also represented by photo H from Borehole Ha-B2 offshore. Photo E= Light grey massive sandstone facies with organic carbon rich intraclasts from Borehole Ha-B2 offshore. Photo F= moderately sorted quartz arenite from Borehole Ha-G1 offshore Gamtoos Basin showing the presence of glauconite (red arrow) and organic pellets (blue arrow). Photo I= light grey massive sandstone facies with the presence of asphalt. Photo J= photomicrograph of poorly sorted quartz wacke with organic pellets (yellow arrow) and heavy mineral hematite (red arrow) from onshore Gamtoos Basin, Kirkwood Formation.

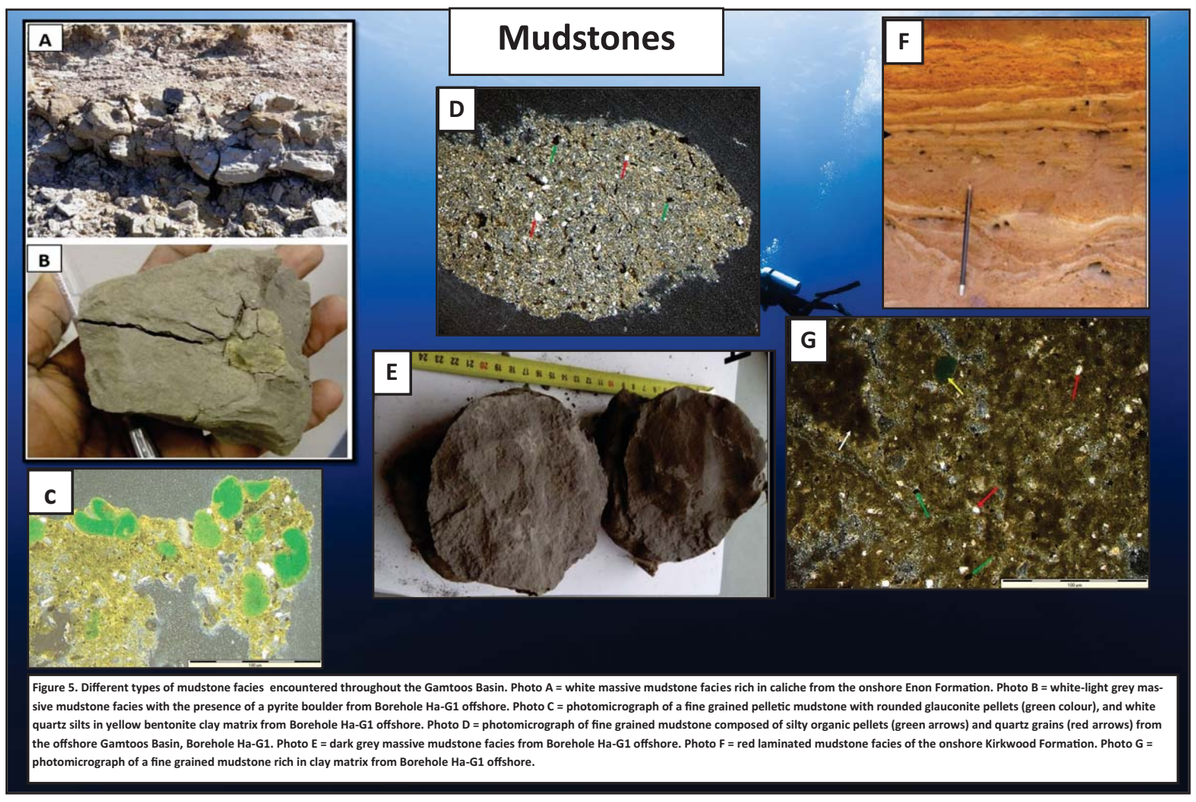

Figure 5. Different types of mudstone facies encountered throughout the Gamtoos Basin. Photo A = white massive mudstone facies rich in caliche from the onshore Enon Formation. Photo B = white-light grey massive mudstone facies with the presence of a pyrite boulder from Borehole Ha-G1 offshore. Photo C = photomicrograph of a fine grained pelletic mudstone with rounded glauconite pellets (green colour), and white quartz silts in yellow bentonite clay matrix from Borehole Ha-G1 offshore. Photo D = photomicrograph of fine grained mudstone composed of silty organic pellets (green arrows) and quartz grains (red arrows) from the offshore Gamtoos Basin, Borehole Ha-G1. Photo E = dark grey massive mudstone facies from Borehole Ha-G1 offshore. Photo F = red laminated mudstone facies of the onshore Kirkwood Formation. Photo G = photomicrograph of a fine grained mudstone rich in clay matrix from Borehole Ha-G1 offshore.

Discussion

The following facies were encountered across the entire basin: dark grey thin bedded and laminated sandstones, light grey massive bedded sandstones, light grey wavy laminated sandstones, light grey to white massive bedded mudstones and red to grey convolute bedded sandstones. The following facies were recorded onshore: red massive bedded mudstones, red wavy laminated mudstones, red tabular cross-bedded sandstones, dark grey lenticular bedded sandstones, white-light grey lenticular bedded sandstones, dark grey massive bedded conglomerates, light grey massive bedded conglomerates and red massive bedded conglomerates. The following facies were recorded offshore: light grey intraclastic sandstones, dark grey massive bedded mudstones, grey bioturbated sandstones, grey bioclastic sandstones and grey fine grained pelletic mudstones. The deposition of the Enon Formation conglomerates and sandstones is associated with faulting of the Cape Supergroup basement which resulted in high energy braided alluvial fan deposits. The Kirkwood Formation is represented by fluvial depositional environments although other parts of the formation in the Algoa Basin showed evidence of estuarine and shallow marine deposits. The presence of trough and planar cross beds indicates low sinuosity deposits while thicker cross bedded sandstones are an indication of migrating channel floor dune deposits

Petrographic analyses of both onshore and offshore samples revealed the presence of organic intraclasts from the following rock types: fine grained siltstones, fine grained mudstones, lithic arenites, quartz arenites, quartz wackes and pelletic wackes. It also showed the presence of asphalt from fine grained siltstones, grey intraclastic sandstones, grey thinly bedded and laminated sandstones and grey massive sandstone facies (occasionally). Asphalt, organic carbon rich micro-fractures, coal lenses, macroscopic organic carbon rich intraclasts, glauconite and bioturbation were only observed offshore. Red lithologies, massive conglomerates, load casts and lenticular sandstones were only observed onshore.

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Acknowledgements

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