

OPEN FILE PROGRESS REPORT ON EXPLORATION OF THE SOUTHERN KAROO BASIN THROUGH CIMERA-KARIN BOREHOLE KZF-1 IN THE TANKWA KAROO, WITZENBERG (CERES) DISTRICT

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ABSTRACT

CIMERA-KARIN drilled a borehole in the Tankwa Karoo in the Witzenberg (Ceres) district in order to explore the geology and in particular the shale gas potential of the southern Karoo Basin. What follows is an open file report to the community and all other interested parties on the progress made to date and initial results from the project. Borehole KZF-1 yielded a more complicated picture of the southern Karoo Basin than expected. Structural duplication and folding of portions of the basal Ecca Group was revealed. Also surprising was the groundwater intersected at depth. The greater part of the borehole was "dry" due to a number of cavities hit, which lead to water losses but at approximately 560 m and 660 m deep there was artisan flow from the brecciated shale, which produced notable good quality groundwater (i.e. slightly alkaline with low electric conductivity) compared to the groundwater from the shallow aquifers utilised by the farmers. Carbonaceous mudstones were collected for quantifying natural gas content. The Whitehill Formation yielded virtually no free natural gas, but generally contained significant volumes of residual methane. Background reference samples were collected spaced evenly throughout the core for mineralogical, geochemical, micro-paleontological and organic carbon characterization. This data will be available to participating scientists who have proposed to study specific aspects of the core.

INTRODUCTION

The Karoo Research Initiative (KARIN) is an

academic study of the geology of the Karoo Supergroup, with special reference to its shale gas potential, by Geoscientists from six of South Africa's leading universities, Keele University in the United Kingdom, and the Council for Geosciences (CGS) of South Africa. KARIN is incorporated under the DST-NRF Centre of Excellence for Integrated Mineral and Energy Resource Analysis (CIMERA). The principal aim of KARIN is to explore the southern Karoo Basin through the extraction of deep drill cores. The first of these boreholes (i.e., KZF-1) in the Tankwa Karoo near Ceres was successfully completed in August 2015, and is reported upon here.

The Karoo succession of rocks (i.e., Karoo Supergroup; Fig. 1) was deposited some 300 to 183 million years ago in the area now represented by the southern part of the African continent (Catuneanu et al., 2005; Johnson et al., 1996). The sedimentary succession attains a maximum cumulative thickness of 12 km along the southern margin of the Main Karoo Basin, a large erosional remnant of the Karoo

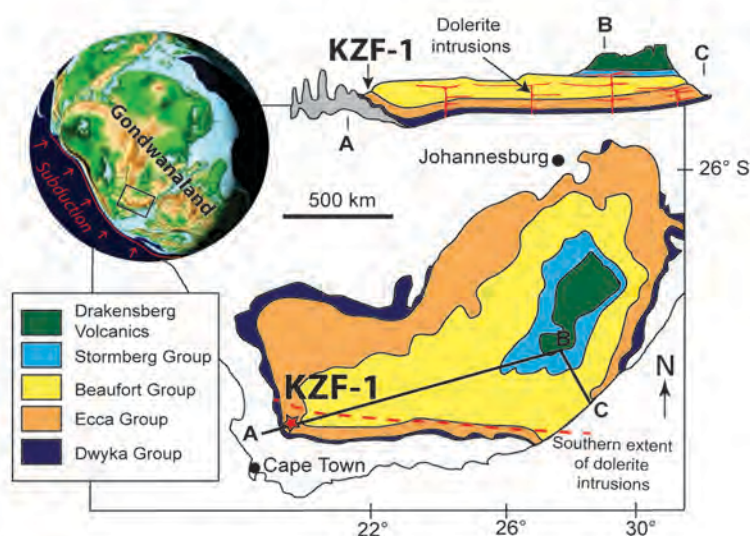


Fig. 1. Simplified geological map and cross section of the Karoo Basin of South Africa and its position within Gondwanaland. The position of borehole KZF-1 is indicated.

Supergroup that now covers approximately two-thirds of South Africa. Here the basin is bound by the Cape Fold Belt (**Fig. 2A**), a narrow zone of crustal shortening and thickening, now represented by the Cape Folded Mountain Belt, which developed in response to Late Paleozoic and Mesozoic subduction along this margin of Gondwanaland (Hansma et al., In Press; Tankard et al., 2009). The fill of the Main Karoo Basin thins dramatically northwards, to produce a highly asymmetrical basin, while the paleoenvironmental setting of the basin fill reflects changing climatic conditions as Gondwanaland drifted from high latitudes towards the equator (Johnson et al., 1996; Tankard et al., 2009). Sedimentary fill is glacial at the base (i.e., Dwyka Group) before it transitions through carbonaceous marine conditions, including deep water submarine fans in the south of the basin, into fluvial-deltaic conditions (i.e., Ecca Group). Terrestrial fluvio-lacustrine strata of the Beaufort Group follow, and ultimately the sedimentary basin fill became dominated by fluvial and aeolian sandstones (i.e., the Molteno, Elliot and Clarens formations of the Stormberg Group) deposited in an increasingly arid climate (Smith, 1990, 1993). Sedimentation in the basin was terminated at ca. 183 Ma ago with the emplacement and extrusion of the Karoo large igneous province or LIP, which includes the outpouring of at least 1400 m of basaltic lavas (i.e., Drakensberg Group) from a large feeder network of dolerite sills and dykes (Jourdan et al., 2005; Svensen et al., 2012). The Karoo Supergroup, and in particular the Ecca Group, contains all of the important coal deposits of South Africa (Hancox and Götz, 2014) as well as black carbonaceous shale that are a potential source of shale gas (Geel et al., 2013). The character of the Ecca Group varies considerably across the basin. It has been divided into several lithostratigraphic units in a number of representative type areas (Johnson, 2009). In the southwestern part of the basin the Ecca Group is represented from the base to its top by the Prince Albert, Whitehill, Collingham, Tierberg, Skoorsteenberg, Kookfontein and Waterford formations. The carbonaceous

Prince Albert and Whitehill formations in particular have been identified for their shale gas potential (e.g., Decker and Marot, 2012), but remains largely unquantified.

SCIENTIFIC OBJECTIVES

Drill core from boreholes planned by CIMERA-KARIN will allow for reconstructing the depositional history of the Karoo Basin, and the determination of the physical and petrochemical character of the rock succession. New data will assist in unraveling the deep structure of the basin and will elucidate the effect and distribution of dolerite intrusions on and within the succession.

Specific objectives of the initial phase of the project are:

- A) An increased understanding of the stratigraphy (litho- and chronostratigraphy) and structure of the southern Karoo Basin
- B) Studying of microfossil assemblages towards establishing a biostratigraphic framework for the Ecca Group
- C) Studying the total organic carbon content of rocks to gain insights into the thermal evolution of the Karoo Basin and the shale gas potential of the Ecca Group, and more specifically the Whitehill Formation
- D) Studying the paleomagnetic record towards establishing a magnetostratigraphic framework for the Karoo Basin
- E) Characterization of the hydrogeological conditions and water quality of the deep and shallow aquifer systems in the southern Karoo Basin to better understand the potential risks if there is interactions between the deep and shallow aquifer systems as a result of shale gas activities.

KARIN further generally aims to equip South African postgraduate students with the necessary high-level skills to pursue research, and ultimately careers, in relevant fields. Such

capacity building represents a fundamental shift to expand the expertise of South African graduates beyond the traditional national strengths, be these in the Karoo Basin or elsewhere.

DRILLING AND OPERATIONAL STRATEGY

The drill site for borehole KZF-1 (S32 50' 30.43" E19 49' 33.02"; **Fig. 1** and **Fig. 2**) was selected south of the southern limit of Karoo LIP dolerite occurrence near the lower contact of the Eccia Group with the Dwyka Group, and within a prominent bend in the strike of the Cape Fold Belt (i.e., the so-called Cape syntaxis). The Cape syntaxis is interpreted as a oroclinal bend in response to continued dextral shear during the Late Jurassic to Early Cretaceous periods (Johnston, 2000). The site is located on the farm Zandfontein 89.

Geoserve Exploration Drilling PTY LTD. was identified as the provider of choice following a thorough tender process. Drilling was preceded by extensive community engagement, the appointment of an Environmental Control Officer or ECO (Withers Environmental Consultants, Stellenbosch), setup of a detailed Environmental Management Plan (EMP) by the AGES group of Potchefstroom, and a baseline hydrogeological investigation into the shallow aquifer systems in a 10 km radius of the drill site in conjunction with the CGS and the Institute of Groundwater Studies (IGS) at the University of the Free State. The EMP, ECO reports and drilling progress reports by Geoserve are available as appendices 1-1 to 1-3 to the copy of this report on the CIMERA-KARIN website (<http://www.cimera.co.za/index.php/karin-feedback>).

Prior to drilling a shallow dipping simple layered geometry of stratigraphic units was expected, and predicted intersection depths were calculated based on a 4° easterly dip of

units that outcrop a couple of kilometers to the west of the drill site (based on unpublished 3219DD 1:50 000 scale geology map; attached as Appendix 2-1).

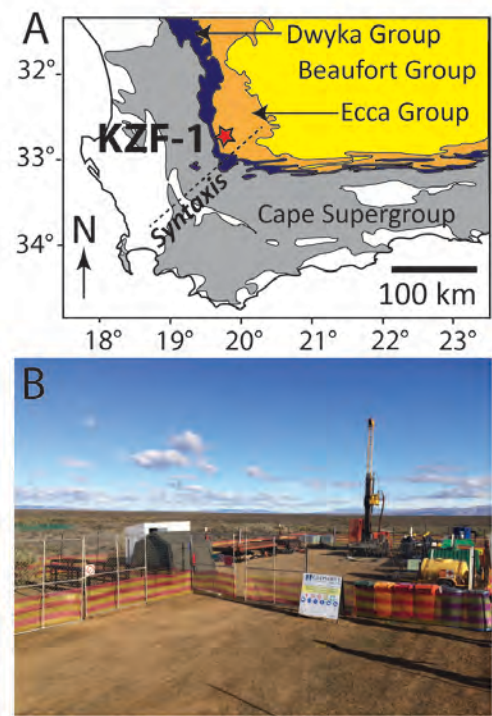


Fig. 2A. Regional geology of drill site KZF-1 within the zone of syntaxis of the Cape Fold Belt. **B.** Photograph of the drill site on Zandfontein 89.

The borehole was started at 85 mm diameter core (i.e., PQ) to approximately 60 m depth intersecting the shallow aquifer system utilised by the farmers. A 114 mm casing was installed and grouted into place and a gas diverter was installed, this effectively sealed off its shallow aquifer system from contamination by drilling chemicals and any interaction from deeper groundwaters of different water quality. The gas diverter was installed to handle any unexpected influx of natural gas. From this point the hole was drilled to produce 64 mm diameter core (i.e., HQ) up to the end of the hole at 671 m (**Fig. 3**). Soon after the shallow casing was installed a fracture zone in

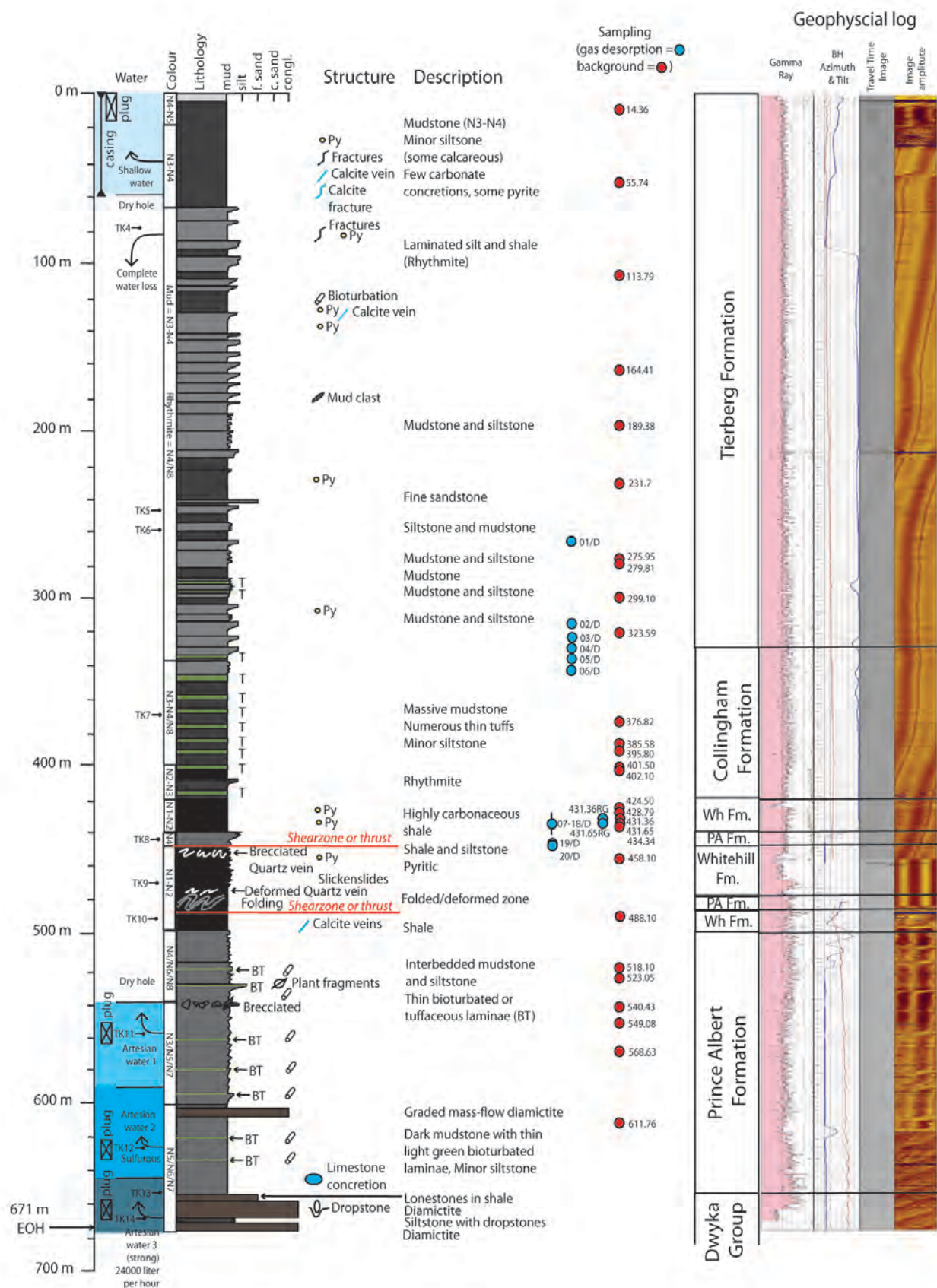


Fig. 3. Simplified graphic log of core from borehole KZF-1 showing intersected lithologies and their stratigraphic assignment, characteristics of the groundwater, sample positions for gas desorption studies and background information (see text for further explanation), as well as example geophysical logs.

massive black mudstone was intersected between 82 m and 83 m, which resulted in some core loss, as well as water loss. Attempts to seal off the fracture zone were only partially successful, and a higher percentage of drill mud had to be used for the remainder of the drilling. In general core recovery from the borehole was better than expected despite a number of unexpected fault zones intersected around 450 m and 480 m. Core was logged in detail on site by the geological manager (Aleck Birch) as well as a CGS scientist (Doug Cole).

After sealing off the shallow aquifer system the borehole was "dry" up to a depth of 560 m, where fresh, water artesian groundwater was intersected. (Fig. 3). Slightly sulfurous artesian water was intersected between 625 m and 626 m, and very strong artesian water was intersected near the end of the hole between 671 m and 668 m in association with the upper part of the Dwyka Group (Fig. 3). After geophysical surveys of the borehole by Weatherford and retrieval of deep groundwater samples, the various artesian aquifers and the borehole itself were sealed as per agreement, and a final site inspection after demobilization was completed by the environmental officer.

Core was transported to, and is curated at the National Core Library of the Council for Geoscience at Donkerhoek, east of Pretoria.

THE ECCA GROUP IN KZF-1

The various formations of the Ecca Group identified during logging of core are summarized in Fig. 3 and Fig. 4. Contrary to what was initially predicted, the borehole intersected structural duplication and folding of

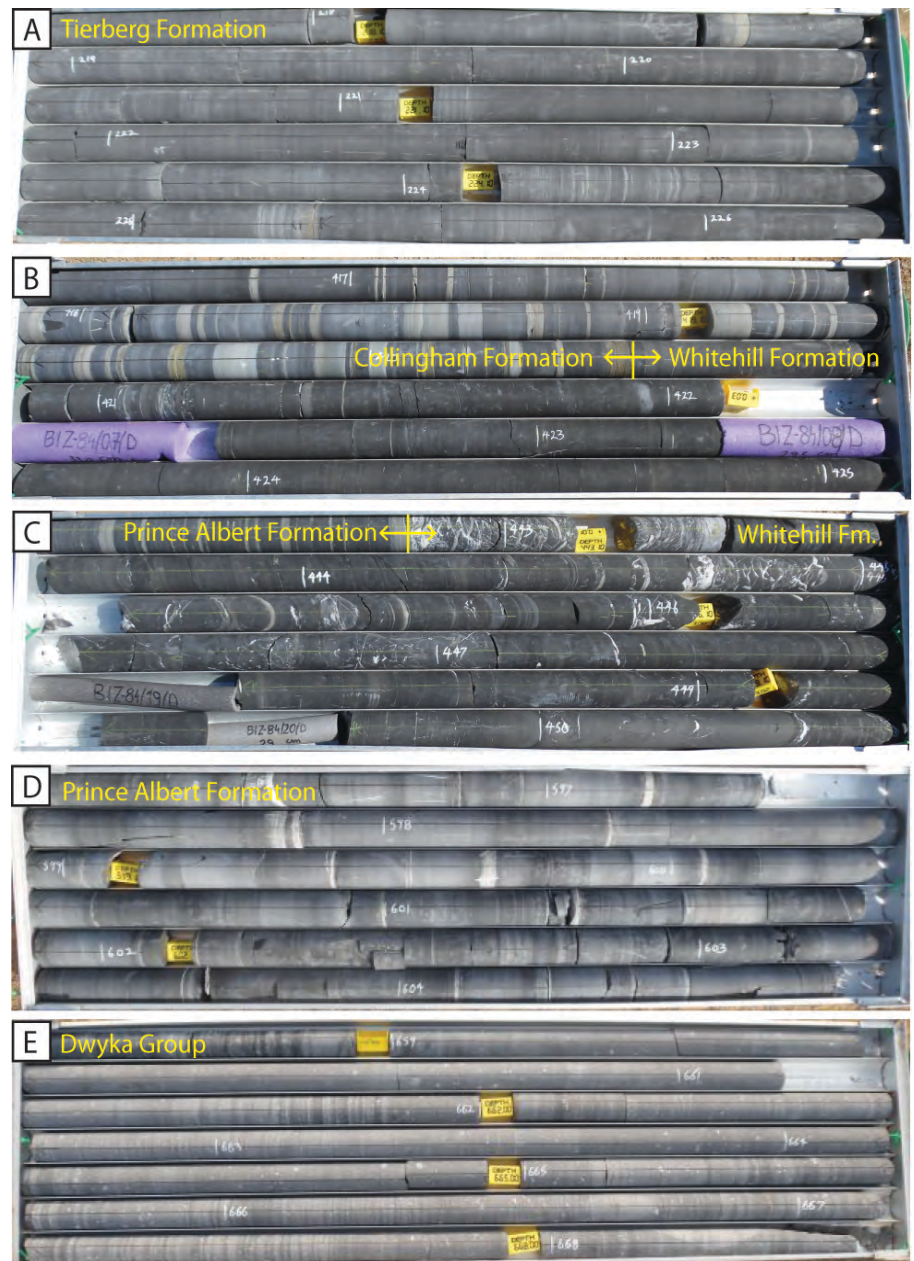


Fig. 4A. The Tierberg Formation. **B.** The Collingham Formation and its contact with the Whitehill Formation. Note the foam spacers where samples were removed for gas desorption studies. **C.** Duplicated intersection of the Whitehill Formation with a highly brecciated contact to the Prince Albert Formation. Note the foam spacers where samples were removed for gas desorption studies. **D.** The Prince Albert Formation, and **E.** the Dwyka Group

portions of the Whitehill and Prince Albert formations, and deeper intersection depths (Fig. 3). The top of the Whitehill Formation was intersected at 420 m, while the top of the Dwyka Group was intersected at 657 m. A slight higher dip (4.8 to 4.9°) and structural

duplication is responsible for the increased depths at which units were intersected.

Tierberg Formation

KZF-1 was started in the Tierberg Formation with a total thickness of 338.62 m of this succession of essentially dark grey mudstone with sparse siltstone beds and laminae and tuffaceous beds and laminae (**Fig. 4A**), which become predominant in the lower 50 m of the unit.

Collingham Formation

The Collingham Formation was recognized by the presence of numerous tuffaceous (i.e., ancient volcanic ash) beds and laminae and chert beds between 338.62 m to 420.46 m (i.e., a total thickness of 81.84 m) that make up the bulk of the intersection in core (**Fig. 4B**). The top of the Collingham Formation is characterized by several prominent siltstones that represent the Wilgehout River Member, but other members of the formation could not be identified in core due to the absence of the Matjiesfontein Chert Bed in the area. The total thickness of the formation is higher than the quoted maximum thickness of 70 m in Viljoen (1992).

Whitehill Formation

The Whitehill Formation was identified by the characteristic predominance of black mudstone (**Fig. 4B**), with a black streak on concrete and an abundance of pyrite. In contrast to other units of the Eccra Group, it lacks tuffaceous beds and laminae. A total thickness of around 21 m was expected based on regional boreholes from 1978 and surface geology. In borehole KZF-1 a thickness of 19.5 m was initially intersected (i.e., between 439.95 m and 420.46 m depth), but unexpected structural duplication (**Fig. 3**) resulted in further intersections between 443.30 m to 479.55 m (i.e., 36 m thickness) and between 489.15 m and 498.45 m (i.e., 9 m thickness). It is thus difficult to determine the true thickness of the Whitehill Formation given

the brecciated nature of contacts (**Fig. 4C**). The first 19.5 m intersection, however, is likely to represent the true thickness as it appears that it is the Prince Albert Formation, rather than the Collingham Formation, that is tectonically displaced with the Whitehill Formation.

Prince Albert Formation

The Prince Albert Formation grey mudstone with numerous siltstone and tuffaceous horizons (**Fig. 4D**) is easily distinguished from the characteristic black mudstone of the Whitehill Formation. An unduplicated thickness of 167.97 m is present in borehole KZF-1, which is comparable with expectations. The base of the formation is taken along the contact between a mudstone with isolated lonestones (a common occurrence for the lowermost mudstones of the Prince Albert Formation) and a diamictite intersected at 657.12 m depth.

Dwyka Group

A thickness of 13.88 m of the Dwyka Group mostly in the form of diamictite (**Fig. 4E**) was intersected before drilling was stopped.

INITIAL RESULTS AND FUTURE PLANS

Groundwater

In order to establish background information on the hydrogeology of the area surrounding the drillsite, a hydrocensus of the shallow aquifer groundwater in a 10 km radius around the drill site was undertaken. The 10 km radius was decided because the horizontal drill ability of a hydraulic fracturing rig is a maximum of 5 km. The data collected during the hydrocensus included static water levels, groundwater quality and aquifer parameters. A total of 48 groundwater samples from the area surrounding the KZF-1 site and 18 samples of deep water intersected in borehole KZF-1 were collected (**Table 1** and **Fig. 5**). Sample analysis (see **Table 2** for details of what was analysed) was still outstanding at the time of writing of this report, but pH, electrical

Table 1. Summary of groundwater samples and field measurements

Label	Sample ID	Site	Lat	Long	Elevation	Sample Date	Field pH	Field EC (µS/cm)	Field Temp. (°C)	Comments
1	Beukesfontein 1	Spring	-32.922	19.757	525.3	29/06/2015	8.5	1550	-	H ₂ S smell
2	Beukesfontein 2	Spring	-32.883	19.738	547.3	29/06/2015	7.8	710	-	-
3	Zandfontein 1	Windmill	-32.835	19.813	520.9	19/08/2015	7.9	1483	21.8	
4	Zandfontein 2	Windmill	-32.843	19.830	522.5	29/06/2015	8.1	1020	-	-
5	Zandfontein 3	Closed borehole (not in use)	-32.835	19.825	513.0	29/06/2015	7.8	1640	-	Used for drilling water
6	Zandfontein 4	Abandoned open borehole	-32.847	19.841	524.9	29/06/2015	7.3	1730	-	-
7	De Vloeren 1	Closed borehole (not in use)	-32.857	19.799	516.7	29/06/2015	7.1	4139	-	H ₂ S smell
8	De Vloeren 2	Windmill	-32.859	19.798	518.3	29/06/2015	7.9	2260	-	-
9	De Vloeren 3	Windmill	-32.858	19.792	513.8	29/06/2015	7.5	7100	-	-
10	De Vloeren 4	Windmill	-32.872	19.781	515.4	29/06/2015	7.3	7010	-	-
11	De Vloeren 5	Windmill	-32.869	19.801	520.6	29/06/2015	-	-	-	-
12	De Vloeren 6	Closed borehole (not in use)	-32.888	19.838	545.5	29/06/2015	7.1	4830	-	-
13	De Vloeren 7	Closed borehole (not in use)	-32.906	19.809	532.3	29/06/2015	7.5	4200	-	H ₂ S smell
14	De Vloeren 8	Solarpump	-32.904	19.805	531.9	29/06/2015	7.3	3210	-	-
15	De Vloeren 9	Windmill	-32.901	19.804	529.8	29/06/2015	7.5	4290	-	-
16	De Vloeren 10	Abandoned open borehole	-32.906	19.792	524.9	29/06/2015	7.5	7590	-	-
17	De Vloeren 11	Closed borehole (not in use)	-32.911	19.786	533.8	29/06/2015	6.5	7050	-	-
18	De Vloeren 12	Abandoned open borehole	-32.914	19.778	548.4	29/06/2015	6.9	6910	-	-
19	Driedam 1	Reservoir	-32.811	19.766	491.9	29/06/2015	8.1	4460	-	-
20	Rietfontein 1	Spring	-32.865	19.888	534.7	30/06/2015	8.0	3110	-	-
21	Rietfontein 2	Spring	-32.865	19.887	535.1	30/06/2015	8.6	1740	-	-
22	Rietfontein 3	Solarpump	-32.863	19.890	538.9	30/06/2015	8.9	1860	-	-
23	Rietfontein 4	Abandoned open borehole	-32.834	19.927	554.1	30/06/2015	7.9	3410	-	-
24	Driefontein 1	Windmill	-32.847	19.869	523.2	30/06/2015	8.7	1030	-	-
25	Driefontein 2	Spring	-32.846	19.869	522.3	30/06/2015	8.1	1260	-	-

Table continued on the next page.

conductivity and temperature were measured for a select number of samples in the field.

Apart from the water table levels and chemistry of the groundwater, slug tests were also conducted on five existing boreholes in the shallow aquifer system. (Table 3). A slug test is a controlled field test to estimate the preliminary hydraulic properties of the aquifer. Slug tests are primarily used to determine whether it is time and cost effective to conduct more comprehensive tests on a borehole in order to determine sustainability or more

accurate aquifer parameters, especially when borehole information is absent e.g. borehole construction, geological logs, blow yield and water strikes.

In terms of pH, all samples from borehole KFZ-1 are generally elevated (i.e., more alkaline) relative to the shallow groundwater in the surrounding area, while the electrical conductivity, and therefore the amount of dissolved salts in the samples from borehole KFZ-1 is significantly lower than for those from the surrounding shallow boreholes.

Table 1. Summary of groundwater samples and field measurements (continued)

Label	Sample ID	Site	Lat	Long	Elevation	Sample Date	Field pH	Field EC (µS/cm)	Field Temp. (°C)	Comments
26	Soutpans-koppies 1	Solarpump	-32.911	19.855	546.1	30/06/2015	7.7	4000	-	-
27	Soutpans-koppies 2	Windmill	-32.916	19.824	540.6	30/06/2015	7.7	1790	-	-
28	Soutpans-koppies 3	Solarpump	-32.916	19.824	539.4	30/06/2015	7.7	2790	-	-
29	Soutpans-koppies 4	Solarpump	-32.915	19.817	537.9	30/06/2015	7.5	7330	-	-
30	Soutpans-koppies 5	Abandoned open borehole	-32.937	19.798	544.7	30/06/2015	7.0	4280	-	-
31	Soutpans-koppies 6	Solarpump	-32.933	19.783	550.5	30/06/2015	7.2	4780	-	-
32	TK1	KZF-1	-32.842	19.743	-	18/08/2015	9.2	626	20	Sample collected at surface from the 559m fracture
33	TK2	KZF-1	-32.842	19.743	-	19/08/2015	8.8	635	16.4	Sample collected at surface from the 559 m fracture
34	TK4	KZF-1	-32.842	19.743	-	20/08/2015	8.9	731	25.8	83.4 m depth sample by Weatherford
35	TK5	KZF-1	-32.842	19.743	-	20/08/2015	8.4	666	26.4	249.5 m depth sample by Weatherford
36	TK6	KZF-1	-32.842	19.743	-	21/08/2015	8.7	641	29	260.3 m depth sample by Weatherford
37	TK7	KZF-1	-32.842	19.743	-	21/08/2015	8.8	654	29.7	369 m depth sample by Weatherford
38	TK8	KZF-1	-32.842	19.743	-	21/08/2015	8.81	652	30	441.8 m depth sample by Weatherford
39	TK9	KZF-1	-32.842	19.743	-	21/08/2015	8.93	662	31	470.3 m depth sample by Weatherford
40	TK10	KZF-1	-32.842	19.743	-	21/08/2015	8.82	649	31	491 m depth sample by Weatherford
41	TK1	KZF-1	-32.842	19.743	-	25/08/2015	-	-	-	Sample collected at surface when fracture hit at 558 m
42	TK15	KZF-1	-32.842	19.743	-	25/08/2015	-	-	-	Sample collected at surface at depth of 634.5 m
43	TK16	KZF-1	-32.842	19.743	-	25/08/2015	-	-	-	Sample collected at surface at drill depth of 637.5 m
44	EOH	KZF-1	-32.842	19.743	-	25/08/2015	-	-	-	Sample collected at surface at drill depth of 671 m
45	TK11	KZF-1	-32.842	19.743	-	28/08/2015	8.4	496	33.7	559.65 m depth sample by Weatherford
46	TK12	KZF-1	-32.842	19.743	-	28/08/2015	8.4	468	34.6	625.5 m depth sample by Weatherford
47	TK13	KZF-1	-32.842	19.743	-	28/08/2015	8.3	467	36.6	654.4 m depth sample by Weatherford
48	TK14	KZF-1	-32.842	19.743	-	28/08/2015	8.3	478	34.4	671 m depth sample by Weatherford

The water in borehole KZF-1 is therefore less saline and less acidic than shallow aquifers groundwater. The source of this mineralization will be identified from the stable isotopes and chemical analyses still outstanding.

Borehole KZF-1 intersected several aquifers. Shallow aquifer system was encountered before about 60 m depth, and was not sampled due to installation of a grouted casing to this depth. After shallow aquifer system was intersected the borehole was dry up to around 550 m. Hereafter three artesian inflows were encountered at 558 m (fresh), 625.5 m (sulfurous), and 671 m

(fresh). Groundwater samples were collected *in situ* at various depths in the borehole and from surface as the drilling progressed to various depths (**Table 1; Fig. 3**). Deep artesian water at 671 m registered a temperature of 34.4°C and a flow rate of 6.67 l/s. It is probable that deep artesian water is utilizing fault zones. Such a fault is expressed at the surface some 9 km southwest of KZF-1 as a NNW-SSE trending fault breccia with abundant quartz veins and steeply dipping beds in the Collingham Formation.



Fig. 5. Locality of various shallow groundwater samples (see **Table 1**) relative to the drillsite KZF-1. The red line represents a prominent lineament and probably a fault.

Table 2. Chemical elements and parameters analyzed for groundwater chemistry characterization

Determinant	Determinant
pH	NO ₂ (N)(Nitrite as N)
EC	Br (Bromine)
Ca (Calcium)	NO ₃ (N)(Nitrate as N)
Mg (Magnesium)	PO ₄ (Phosphate)
Na (Sodium)	SO ₄ (Sulphate)
K(Potassium)	Ca Hard.
PAIk	Mg Hard.
MAIk	Tot. Hard.
F (Fluorine)	TDS (sum)
Cl (Chlorine)	Li (Lithium)
B (Boron)	Mn (Manganese)
Si (Silicon)	Mo(Molybdenum)
Al (Aluminium)	Ni (Nickel)
As (Arsenic)	Pb (Lead)
Ba (Barium)	Sb (Antimony)
Cd (Cadmium)	Se(Selenium)
Co (Cobalt)	V (Vanadium)
Cr (Chromium)	Zn (Zinc)
Cu (Copper)	Sr (Strontium)
Fe (Iron)	U (Uranium)

Desorbed and residual gas

Gas is generated during the maturation of organic matter in carbonaceous mudstone. The majority of this gas is typically sorbed, or attached to the surface of mudstone particles.

Upon a reduction in pressure (e.g., during drilling and core retrieval) some of the gas will desorb from the

mudstone and escape via fractures or cleats in the mudstone. This is termed desorbed gas. Gas that remains trapped in the mudstone is referred to as residual gas, and is only released during complete fracturing of the mudstone, which is achieved in the laboratory by milling. The volume of gas that desorbed from mudstones was measured over a period of time (Appendix 3-1). The daily rate of desorption and total volume of gas that was desorbed was negligible and ranged from 0.000 to 0.047 ml.g⁻¹.day⁻¹.

Table 3. List of boreholes that were slug tested

Farm name	Date
Zandfontein 3	29/06/2015
Zandfontein 4	29/06/2015
De Vloeren 1	29/06/2015
De Vloeren 7	29/06/2015
De Vloeren 10	29/06/2015
De Vloeren 11	29/06/2015
De Vloeren 12	29/06/2015
Rietfontein 4	30/06/2015
Soutpans-koppies 1	30/06/2015
Soutpans-koppies 5	30/06/2015

Of the twenty samples, nine samples of the Whitehill Formation were sent to the laboratories of Geokrak in Cracow, where three of these were analysed for residual gas content and composition (Table 4). Two additional samples of the Whitehill Formation were analysed for residual gas content by Latona Consulting in Johannesburg and found to contain comparable amounts of residual gas to the samples listed in Table 4. The majority of gas in the Whitehill Formation is residual, and is of particular interest given its methane content and significant volume (Table 4).

Table 4. Residual gas content and composition

Sample	Content $\text{m}^3 \cdot \text{t}^{-1}$ (STP)	N ₂	CO ₂	CH ₄	C ₂ H ₆	C ₃ H ₈
BIZ-84/08/D	0.24	7.59	22.70	68.89	0.80	0.02
BIZ-84/14/D	0.17	7.90	22.17	68.78	1.13	0.02
BIZ-84/20/D	0.56	3.45	10.24	85.83	0.48	0.004

Background reference samples

A series of 28 core samples were collected from KFZ-1 in Donkerhoek (Fig. 3) to provide a background reference dataset available to KARIN researchers. Current analyses focus on X-ray diffraction for establishing the mineralogical composition and Kübler index (a measure of thermal maturity), standard optical petrography for describing mineralogy and textures, vitrinite reflectance for establishing thermal maturity, RockEval pyrolysis for determining the nature and maturity of organic matter, and determination of organic carbon content and sulfur isotope signatures. Samples have been prepared, and have been shipped to various laboratories for analyses.

A systematic sampling of carbonaceous shales has been undertaken to quantify the micropaleontological assemblage of the succession (i.e., pollen and spores). Analysis of these samples is currently under way at Keele University in the United Kingdom.

Proposals and scientists taking part in KARIN

Proposals have been received by the various KARIN scientists (Table 5) to study the retrieved core under the following themes:

- 1) Stratigraphy, palaeoclimate and basin analysis
- 2) Magnetostratigraphy and rockmagnetics
- 3) Petrophysics and geomechanics
- 4) Karoo sills and dykes
- 5) Environment and water
- 6) Geophysics

Table 5. KARIN scientists

Institution	Scientists
University of Johannesburg	Prof. N.J. Beukes (Director of CIMERA) Prof. M.O. de Kock (South African scientific manager of KARIN) Prof. B. Cairncross, Prof. N. Wagner Dr. H.S. van Niekerk, Dr. C. Vorster Ms L. Bowden
Keele University (UK)	Prof. A.E. Götz (Scientific manager of KARIN)
University of Pretoria	Prof. W. Altermann Prof. J.L. van Rooy Dr N. Lenhardt
University of the Witwatersrand	Prof. L. Latypov Dr. M. Manzi Dr S. Webb Ms S. Scheiber
University of Cape Town	Dr. E. Bordy Ms C. Geel
University of the Free State	Dr. F.D. Fourie Mr. F. de Lange
Council for Geoscience	Dr. D. Cole Dr. J. Neveling Dr. L. Mare Dr. M. Grobbelaar Dr. L. Chevallier Ms. K. Robey Ms. D. Black

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APPENDICES

Appendices refer to website copy of this report at:

<http://www.cimera.co.za/index.php/karin-feedback>

1-1 [EMP: Drilling of Exploration Borehole 2015/06/18](#)

1-2 **ECO Checks Withers-KZF:**

1-2.1 [ECO-Checklist 1](#)

1-2.2 [ECO-Checklist 2](#)

1-2.3 [ECO-Checklist 3](#)

1-3 [GEOSERVE Internal Report - Cimera Karin Interim report FINAL](#)

2-1 Unpublished 3219DD 1:50000 scale geology map

3-1 Final desorption report KZF-01