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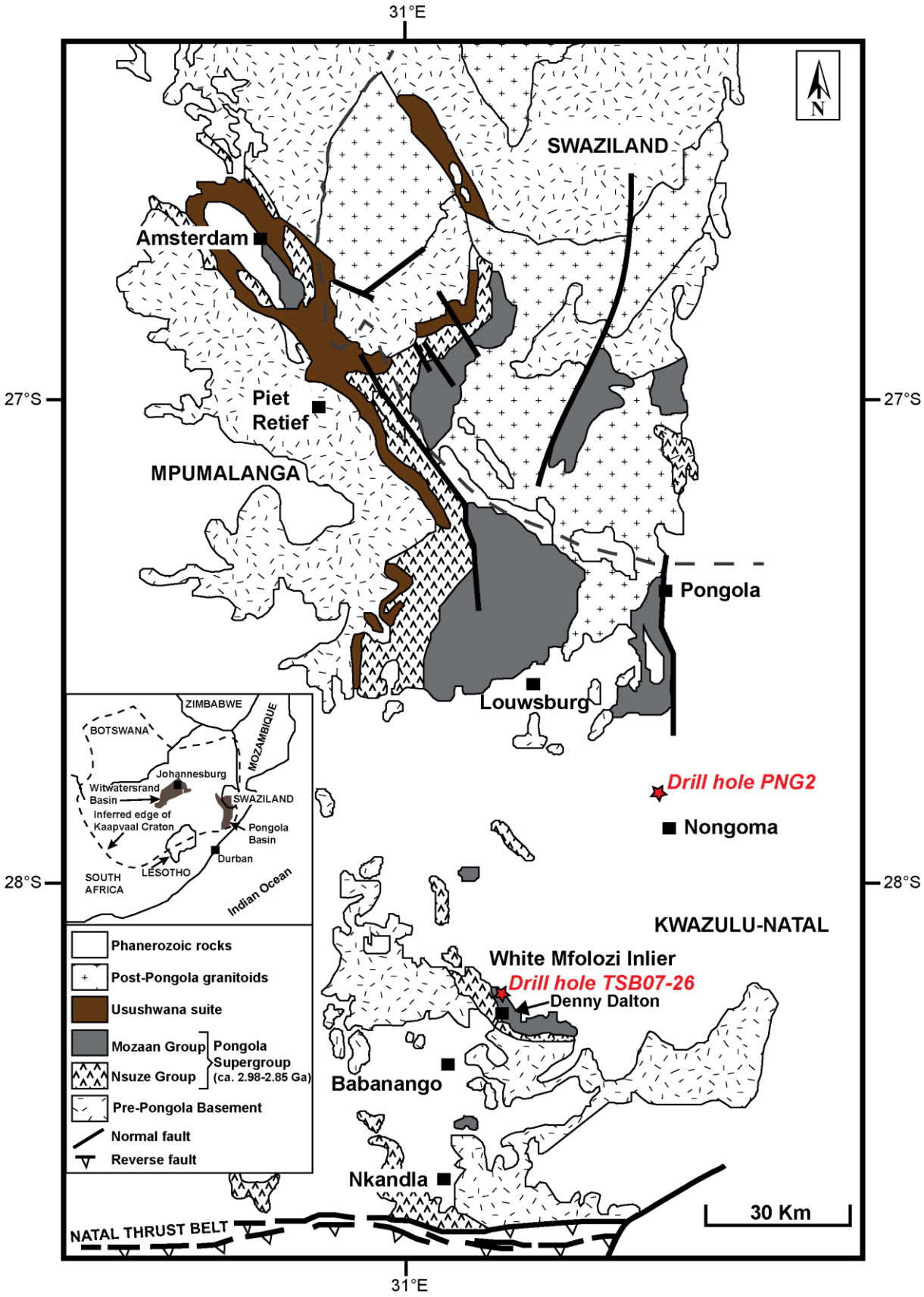

Fig. S1. Geological map of the area where the Pongola Supergroup outcrops (modified from ref. 1).

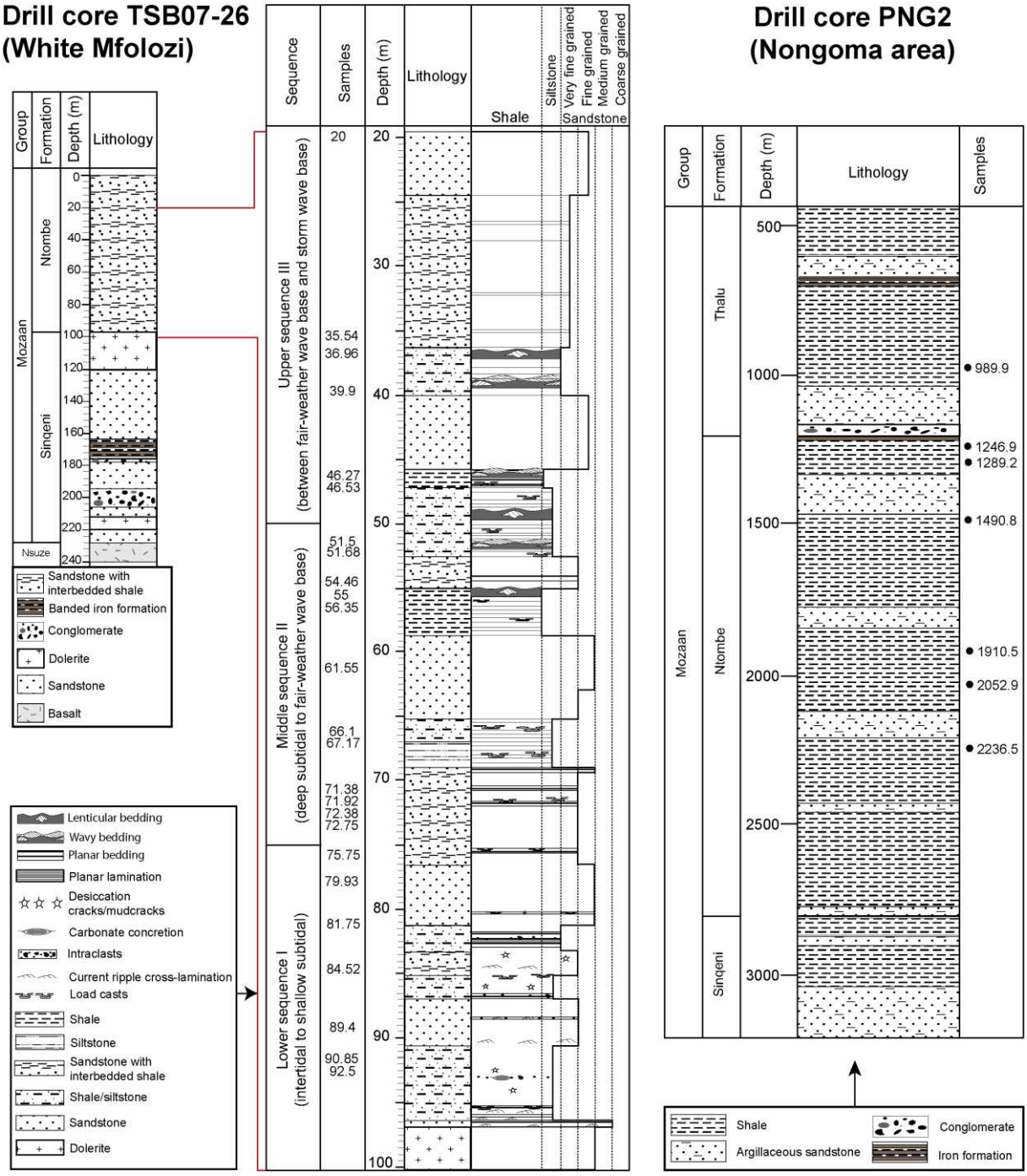

Fig. S2. Stratigraphic columns for the drill cores TSB07-26 and PNG2 of the Mozaan Group and a detailed lithological log of the studied section of the Ntombe Formation in the White Mfolozi Inlier (modified from refs. 5, 12).

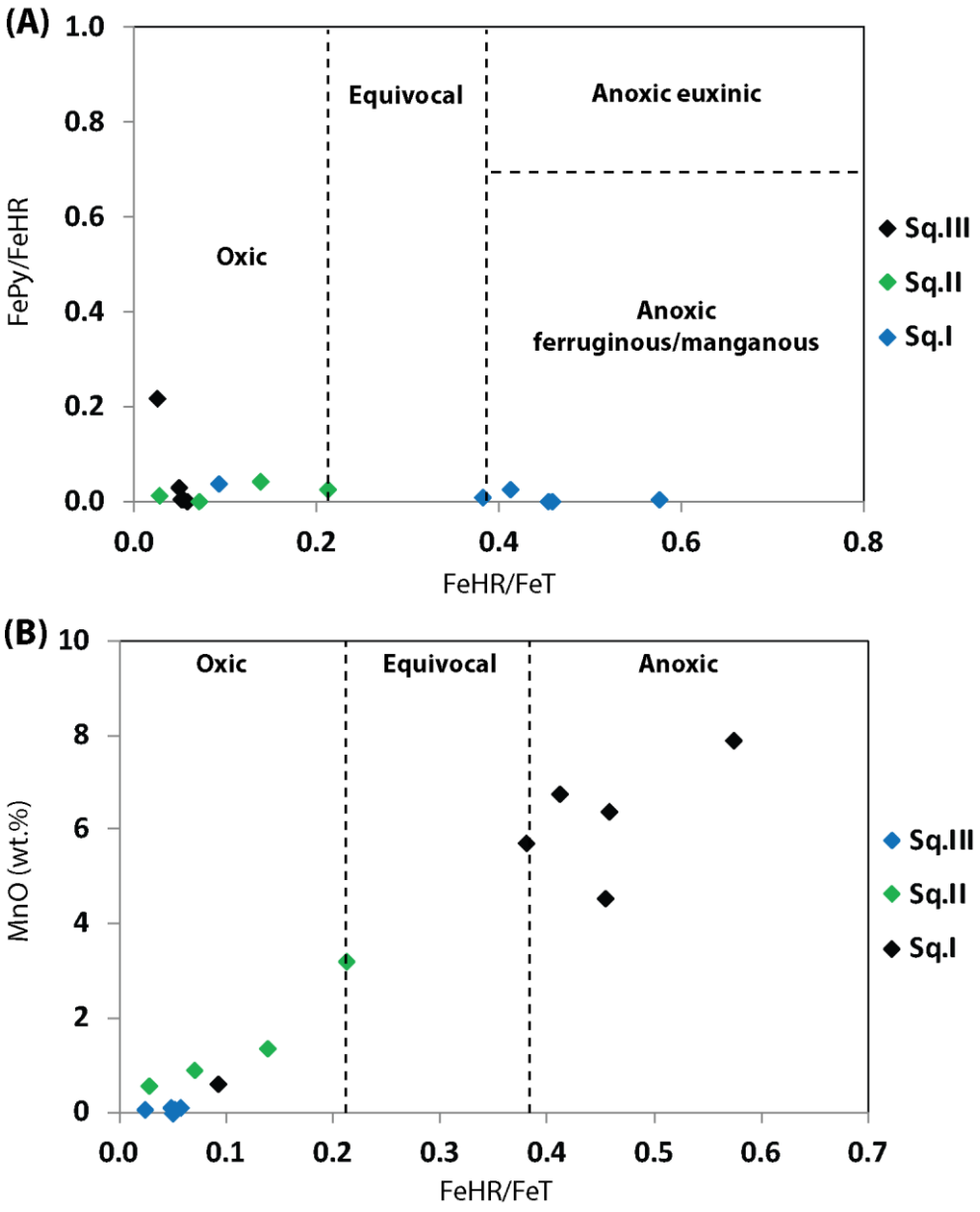

Fig. S3. Iron speciation data for the Mozaan Group (Ntombe Formation) in the White Mfolozi Inlier where the three sequences described in this study are developed. FeHR/FeT ratios are above 0.38 for most samples from the sequence I, while the data for samples stratigraphically higher in the section (sequences II and III) are below 0.22. FePy/FeHR ratios for all analyzed shales from the White Mfolozi Inlier do not indicate euxinic conditions. FeHR/FeT vs. MnO (wt.%) plot shows positive co-variation, suggesting coupled aqueous Mn and Fe supply to the mildly oxic, shallow-water column. FeHR (highly reactive iron content); FeT (total iron content); FePy (iron concentration in pyrite); Sq. I (sequence I); Sq. II (sequence II); Sq. III (sequence III).

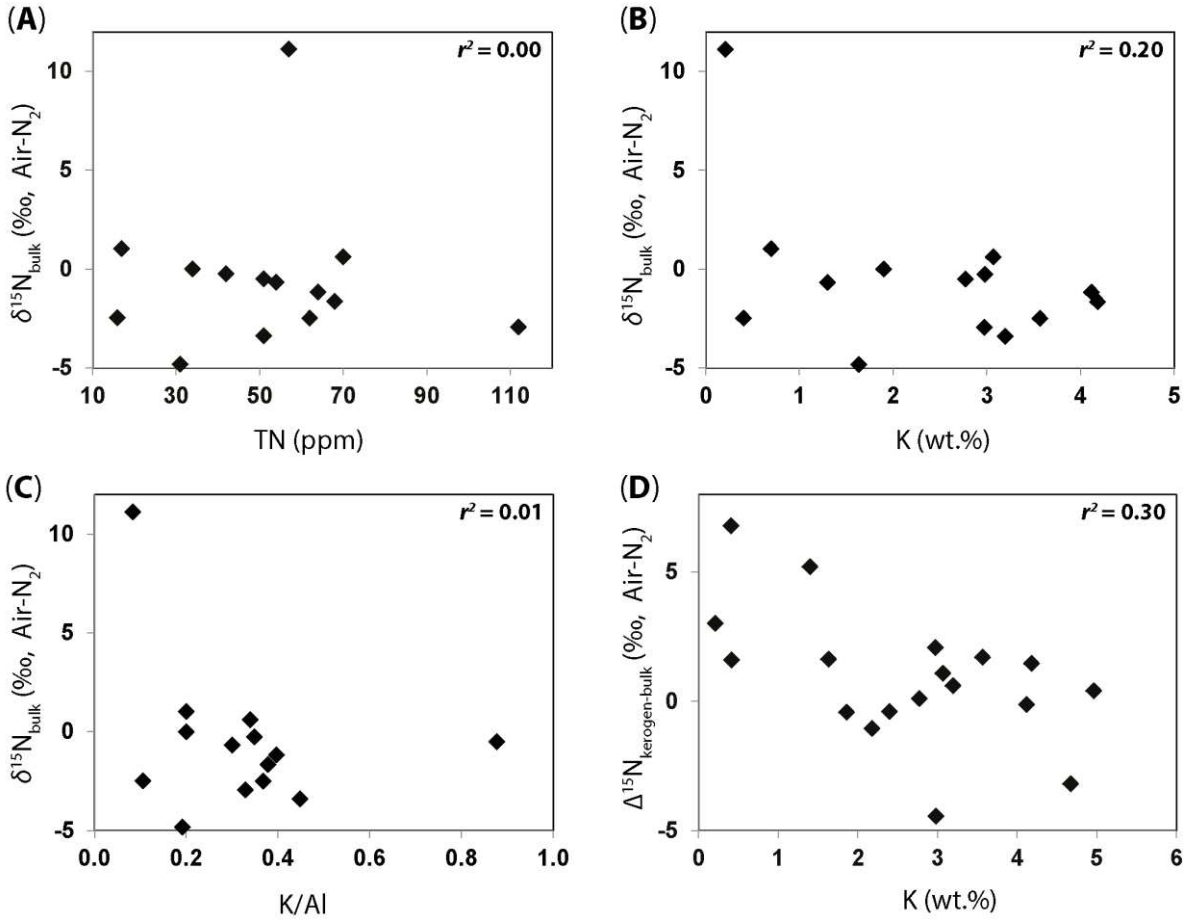

Fig. S4. Geochemical data for bulk shale samples from the Mozaan Group showing no obvious co-variation among N, K, and C concentrations, K/Al and N isotope data. (**A**) TN vs. $\delta^{15}N$ of bulk sediment ($\delta^{15}N_{bulk}$); (**B**) K concentration vs. $\delta^{15}N_{bulk}$; (**C**) K/Al vs. $\delta^{15}N_{bulk}$; (**D**) K concentration vs. the difference between $\delta^{15}N_{ker}$ and $\delta^{15}N_{bulk}$ ($\Delta^{15}N_{ker\text{-}bulk}$).

Table S1: Concentrations of major and trace elements as well as water-column redox proxies (e.g., Fe speciation) for the Mozaan Group. Sequences are defined based on water-depth indicators and geochemical data.

Drill core and sampled areas	Sequence	Sample depth	Mn	Fe	Al	P	Mo	U	Fe_{Carb}	Fe_{Ox}	Fe_{Mag}	Fe_{Py}	Fe_{HR}/Fe_T	Fe_{Py}/Fe_{HR}	Fe/Al	Mn/Fe	P/Al	U/Al	Mo/Al	Mo
		(m)	(wt.%)	(wt.%)	(wt.%)	(ppm)	(ppm)	(ppm)							0.43**	0.01**	87*	0.35*	0.19*	EF
TSB07-26 (White Mfolozi Inlier)	Sequence III	**20**	0.1	5.7	10.4	218	0.33	3.25	0.05	0.17	0.08	0	0.05	0	0.55	0.02	20.96	0.31	0.03	0.17
		35.54	0	6.5	11	218	1.8	-	0.08	0.02	0.04	0.04	0.03	0.22	0.59	0	19.82	-	0.16	0.86
		36.96	0	6.7	9.7	218	-	-	-	-	-	-	-	-	0.7	0	22.47	-	-	-
		39.9	0	5.5	11.8	218	-	-	0.08	0.14	0.07	0	0.05	0	0.47	0	18.47	-	-	-
		46.27	0.1	7.2	11	218	-	-	0.14	0.15	0.13	0	0.06	0	0.66	0.01	19.82	-	-	-
		46.53	0.1	11.2	8.5	214	0.37	2.21	-	-	-	-	-	-	1.3	0.01	25.18	0.26	0.04	0.23
	Sequence II	**51.5**	0.1	4.9	9.1	305	-	-	0.1	0.06	0.07	0.01	0.05	0.03	0.53	0.02	33.52	-	-	-
		51.68	0.1	6.2	8.6	-	-	-	-	-	-	-	-	-	0.7	0.02	-	-	-	-
		54.46	0.7	7.9	6.9	nd	0.41	-	0.43	0.04	0.09	0	0.07	0	1.15	0.09	-	-	0.06	0.31
		55	0.4	12	9.6	392	-	-	0.19	0.03	0.1	0	0.03	0.01	1.25	0.03	40.83	-	-	-
		56.35	2.5	13.9	5.8	218	0.62	1.2	2.24	0.11	0.53	0.08	0.21	0.03	2.39	0.18	37.59	0.21	0.11	0.56
		61.55	1.1	7.8	11.2	392	0.99	-	0.25	0.61	0.19	0.05	0.14	0.04	0.7	0.14	35.00	-	0.09	0.47
	Sequence I	**66.1**	3.5	13.9	3.9	96	1.14	1.3	5.09	0.17	1.03	0	0.45	0	3.6	0.25	24.62	0.33	0.29	1.54
		67.17	1.3	8	7.1	252	2.02	1.73	-	-	-	-	-	-	1.1	0.16	35.49	0.24	0.28	1.50
		71.38	4.4	16.6	5.6	93	0.63	2.18	4.91	0.16	1.21	0.05	0.38	0.01	2.97	0.27	16.61	0.39	0.11	0.59
		72.38	5.2	20.5	4.4	120	-	-	5.89	0.19	2.15	0.22	0.41	0.03	4.62	0.25	27.27	-	-	-
		72.75	4.9	16.6	4.8	120	1.03	2.14	6.02	0.18	1.41	0	0.46	0	3.47	0.3	25.00	0.45	0.21	1.13
		79.93	0.5	12.7	8.8	227	-	1.56	0.71	0.07	0.36	0.05	0.09	0.04	1.44	0.04	25.80	0.18	-	-
		81.75	2.2	10.2	7.9	218	-	-	-	-	-	-	-	-	1.3	0.22	27.59	-	-	-
		89.4	3.9	8.7	6.1	125	-	2.42	-	-	-	-	-	-	1.4	0.45	20.49	0.40	-	-
		90.85	3.5	9	3.2	nd	0.92	-	-	-	-	-	-	-	2.9	0.39	-	-	0.29	1.51
		92.5	4.4	11.3	6.1	nd	-	-	-	-	-	-	-	-	1.9	0.39	-	-	-	-
PNG2 (Nongoma area)	Distal equivalent	**989.9**	0.3	18.2	4.4	244	0.76	1.39	-	-	-	-	-	-	4.17	0.02	55.45	0.32	0.17	0.91
		1054.5	0.3	24.9	2.5	279	-	-	-	-	-	-	-	-	9.86	0.01	111.60	-	-	-
		1246.9	0.1	8.1	9	nd	1.76	2.71	-	-	-	-	-	-	0.9	0.01	-	0.30	0.20	1.03
		1289.2	0.3	17.9	5.2	-	-	-	-	-	-	-	-	-	3.43	0.02	-	-	-	-
		1490.8	0.2	23.1	3.7	344	0.45	0.72	-	-	-	-	-	-	6.18	0.01	92.97	0.19	0.12	0.64
		1910.5	0.1	8.2	9	nd	1.77	1.91	-	-	-	-	-	-	0.91	0.01	-	0.21	0.20	1.04
		2052.9	0.1	11.8	7.8	-	-	-	-	-	-	-	-	-	1.5	0.01	-	-	-	-
		2236.5	0.2	12.4	7.8	nd	1.17	-	-	-	-	-	-	-	1.58	0.02	-	-	0.15	0.79

FeMag: magnetite-associated iron; FeCarb: carbonate-associated iron; FeOx: ferric iron (oxyhydr)oxide-associated iron; FePy: pyrite-associated iron; FeHR: highly-reactive iron; FeT: total iron; (0.43**; 0.01**): average ratios for shales of the Pongola Supergroup (ref. 6); (87*; 0.35*; 0.19*): average ratios for the upper crust (ref. 7); -: not measured; nd: not detected.

Table S2: Carbon and nitrogen data for the Mozaan Group. Sequences are defined based on water-depth indicators and geochemical data ($\delta^{13}C_{TOC}$ and TOC data are from ref. 12 in SI).

Drill core and sampled areas	Sequence	Sample Depth (m)	TOC (wt.%)	TN (ppm)	C/N_T	$\delta^{13}C_{TOC}$ (‰, VPDB)	$\delta^{15}N_{bulk}$ (‰, Air-N_2)	C/N_{ker}	$\delta^{13}C_{ker}$ (‰, VPDB)	$\delta^{15}N_{ker}$ (‰, Air-N_2)	$\Delta^{15}N$ (bulk-ker)
TSB07-26 (White Mfolozi Inlier)	Sequence III	**20.00**	0.25	16	13	–36.0	–1.2	32	–38.0	–1.3	0.1
		35.54	0.38	150	25	–37.4	–1.7	52	–38.0	–0.2	1.5
		36.96	0.35	136	26	–38.1	–2.5	40	–37.9	–0.8	1.7
		39.90	0.40	137	29	–37.7	-	83	–37.2	0.4	0.4
		46.53	0.28	87	32	–32.2	–4.8	54	–31.4	–3.2	1.6
	Sequence II	**51.68**	0.25	109	23	-	–0.3	41	–30.6	–4.7	4.4
		56.35	0.45	76	59	–31.7	-	113	–30.3	1.6	1.6
		61.55	0.63	-	-	–29.3	-	96	–29.6	–3.2	3.2
	Sequence I	**66.10**	0.37	74	50	–28.8	–2.5	206	–28.8	4.3	6.8
		67.17	0.22	51	43	–29.2	–3.4	78	–27.8	–2.8	0.6
		71.38	0.01	30	3	–27.4	-	137	–27.9	5.2	-
		72.38	0.01	17	6	–27.5	1.0	56	–27.3	3.0	2.0
		75.75	0.26	73	37	–28.2	–0.7	39	–27.8	0.2	0.9
		79.93	0.19	-	-	–27.8	-	47	–27.3	–0.4	-
		84.52	0.34	69	49	–26.3	0.7	26	–30.4	1.8	1.1
		90.85	0.40	67	60	–25.7	–0.5	103	–25.8	–0.4	0.1
PNG2 (Nongoma area)	Distal equivalent	**989.90**	0.27	76	35	–31.7	35.3	47	–30.6	2.2	33.1
		1054.50	0.21	57	37	–30.5	11.1	44	–29.7	14.1	3.0
		1246.90	0.30	70	43	–31.2	0.6	61	–30.9	1.7	1.1
		1910.50	0.64	112	57	–32.9	–2.9	248	–31.7	–0.9	2.0
		2052.90	0.31	-	-	–33.4	-	49	–37.3	–0.4	-
		2236.50	0.13	-	-	-	-	26	–37.0	–1.1	-

TOC: total organic carbon content in bulk rock; TN: total nitrogen content in bulk rock; bulk: bulk rock; ker: kerogen; C/N_T: C/N molar ratio in bulk rock; C/N_{ker}: C/N molar ratio in kerogen; $\Delta^{15}N$ (bulk-ker): offset between $\delta^{15}N_{bulk}$ and $\delta^{15}N_{ker}$; -: not measured.