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GEOCHRONOLOGY OF THE NCHANGA GRANITE, AND CONSTRAINTS ON THE MAXIMUM AGE OF THE KATANGA SUPERGROUP, ZAMBIAN COPPERBELT

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by

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ABSTRACT

The age of the Neoproterozoic Katanga Supergroup, which hosts the stratiform Cu-Co deposits of the Central African Copperbelt, has not been well constrained. The Nchanga Granite, the youngest pre-Katangan intrusion in the Copperbelt basement, is non-conformably overlain by sedimentary rocks of the Katanga Supergroup, a relationship that is well exposed in the open pit at Nchanga mine, Zambia. Previous attempts at dating the Nchanga Granite using the K-Ar and Rb-Sr systems have given only younger Pan-African ages, reflecting resetting during regional metamorphism. Magmatic zircons extracted from this granite have been analysed by ion-microprobe and have yielded an age of 883 ± 10 Ma. Detrital zircons obtained from coarse-clastic sediments in the lower part of the Roan Group (at the base of the Katanga Supergroup), immediately above the non-conformity, cluster into 2 age populations, one at *c.* 880 Ma and the other at between 1800 and 2000 Ma. The Nchanga Granite age provides a reliable maximum estimate of the beginning of deposition of the Katanga Supergroup, or more specifically, of Roan Group deposition. The presence of Nchanga Granite-aged zircon detritus in the lower Roan sediments also indicates that sedimentation in the Central African Copperbelt did not commence until the Nchanga Granite had been exhumed and eroded. Our new maximum age for the Katanga Supergroup precludes its previous correlation with the *c.* 950 Ma Mbuji Mayi Group, and reinforces the likelihood of correlations with similar sequences in the Damara and West Congolian orogenic belts.

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GEOCHRONOLOGY OF THE NCHANGA GRANITE, AND CONSTRAINTS ON THE MAXIMUM AGE OF THE KATANGA SUPERGROUP, ZAMBIAN COPPERBELT

INTRODUCTION

The Katanga Supergroup is the host of the major stratiform sediment-hosted Cu-Co deposits, as well as numerous other deposits of Cu, Pb, Zn, U, Au, Fe, etc., which constitute the Central African Copperbelt in Zambia and the Democratic Republic of Congo (Robert, 1956; Mendelsohn, 1961). In spite of its great economic significance there are few age data relevant to the deposition of the Katanga Supergroup. The latter sequence was previously considered to have been deposited in late Mesoproterozoic times (Cahen *et al*., 1968, 1975, 1984), but this study shows unequivocally that it is much younger, with sedimentation having been initiated in the Neoproterozoic.

REGIONAL GEOLOGICAL SETTING

In the Central African Copperbelt, the oldest pre-Katangan basement consists of a Palaeoproterozoic magmatic arc sequence, the Lufubu Metamorphic Complex, comprising the Lufubu Schists and intrusive granitoids and gneisses, dated at between 1994 and 1873 Ma (Rainaud *et al*., 2005). The magmatic arc rocks, together with metasedimentary rocks of the flanking Ubendian Belt, were deformed and metamorphosed in the *c.* 2.0–1.8 Ga Ubendian Orogeny (Master, 1990; Lenoir *et al*., 1994). In the Zambian Copperbelt, the magmatic arc rocks are overlain unconformably by quartzitic and metapelitic metasediments of the Muva Group, which were deposited after 1941 Ma, based on the ages of detrital zircons (Rainaud *et al*., 2003). The Nchanga Granite is the youngest intrusion in the pre-Katangan basement (Garlick and Brummer, 1951; Garlick, 1973), and it is nonconformably overlain by the Katangan Sequence, which consists of metasediments traditionally divided into the Roan and Lower and Upper Kundelungu Supergroups (Cailteux *et al*., 1994; Francois, 1995). Distribution of the Nchanga Granite in the Zambian Copperbelt relative to Katangan sequences is illustrated in Figure 1.

More recently, Wendorff (2001, 2003) and Master *et al*. (2005) have proposed a new lithostratigraphic scheme in which the Katanga Supergroup is subdivided into the Roan, Nguba and Kundelungu Groups, with two additional lithotectonic units, the Fungurume and Plateau Groups, which were deposited syntectonically in a foreland basin during deformation of the earlier Katangan groups during the Pan-African Lufilian Orogeny.

Rocks of the Katanga Supergroup were deformed and metamorphosed during the Lufilian (*c*. 600-512 Ma) Orogeny (Cosi *et al*., 1992; Porada and Berhorst, 2000; Rainaud *et al*., 2002, 2005; John *et al*., 2003, 2004), while supposedly correlative lithologies in the Zambezi Belt were also deformed and metamorphosed during the Lusakan (*c*. 840 Ma) Orogeny (Hanson *et al*., 1994). The depositional age and duration of the Roan Group has been very poorly constrained, with the available data suggesting a range between *c*. 1200 and 870 Ma (Cahen *et al*., 1984). Kampunzu and Cailteux (1999) suggested a maximum age of 980 Ma for the Katanga Supergroup, based on the presence in basal Katangan conglomerates of pebbles of *c.* 980 Ma Kibaran tin granites (Madi, 1985), as well as of detrital cassiterite in lowermost Roan sediments (Jedwab, 1997). The minimum age of the entire Katanga Supergroup was established by Cahen (1973) at 620 Ma, based on U-Pb dating of post-Kundelungu uraninite veins. However, more recent dating of detrital muscovites from the Kundelungu Plateau give a maximum age of 573 ± 5 Ma for the uppermost Katangan sediments of the Plateau Group, which were deposited in a foreland basin during the Lufilian Orogeny (Master *et al*., 2005).

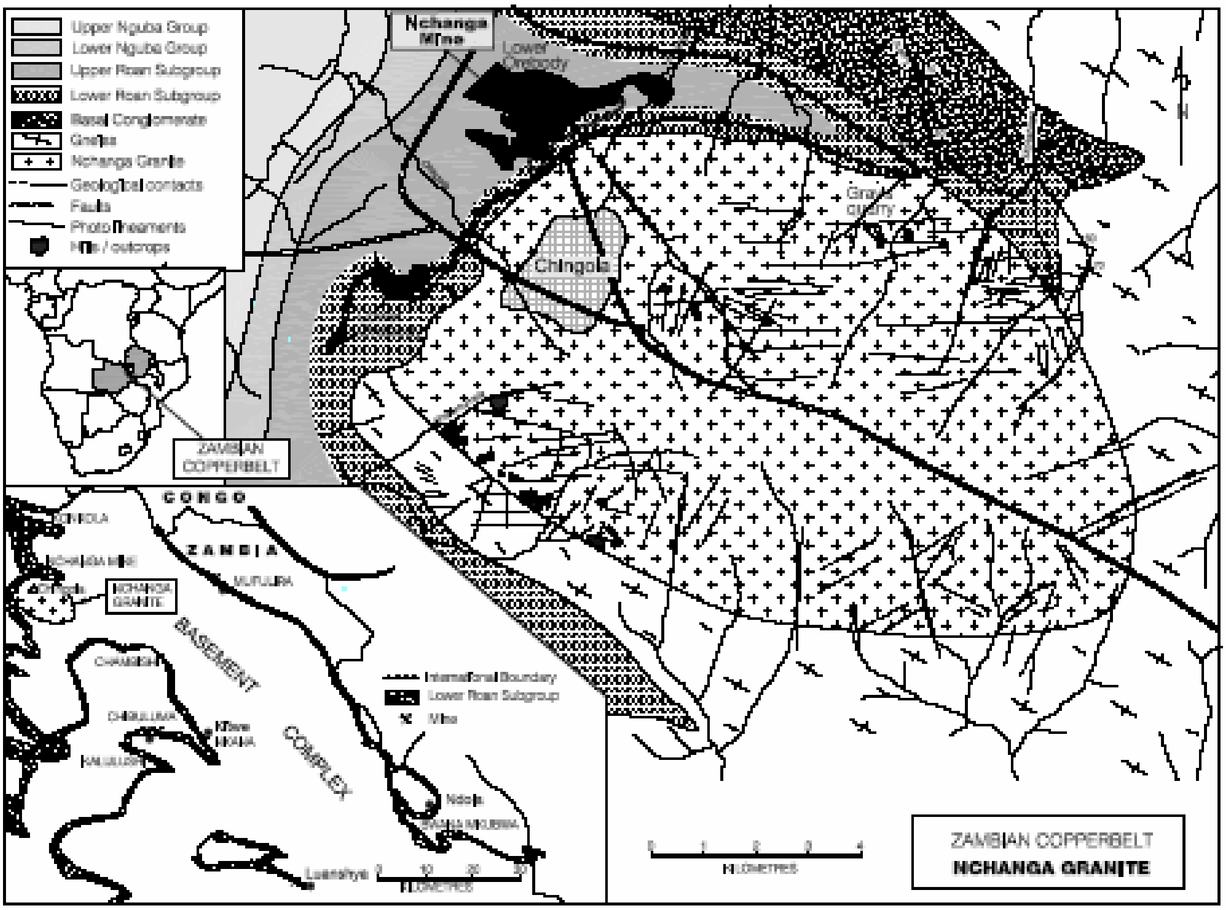

Figure 1. *Location and distribution of the Nchanga Granite in the Zambian Copperbelt (after Garlick, 1973).*

ANALYTICAL PROCEDURES

In this study a population of zircons was obtained from the Nchanga Granite (pink variety), which was sampled in borehole P322, drilled in the underground section of Nchanga Mine, where it is nonconformably overlain by coarse clastic sediments of the lower Roan Group (Table 1). Suites of detrital zircons were extracted from crossbedded Roan arkoses and sandstones sampled at 6 and 23 metres above the contact with the Nchanga Granite in the same borehole (P322) drilled at Nchanga Mine from which the granite sample was obtained (Table 1). The separation of zircons was performed at the Hugh Allsopp Laboratory, University of the Witwatersrand, Johannesburg, using conventional techniques. The separated zircons were examined and characterised using cathodoluminescence imagery. All zircons were analysed randomly. U-Pb analyses were performed on the Sensitive High Resolution Ion Microprobe (SHRIMP II) at the Research School of Earth Sciences, Australian National University. The SHRIMP analytical procedure used in this study is similar to that described by Claoué-Long *et al.* (1995). Age calculations and plotting were carried out using Isoplot/Ex (Ludwig, 2000) and all ages are quoted with errors at the 1σ level. The zircons show typically magmatic features such as oscillatory zoning and euhedral outlines, with no cores.

Table 1. Log of borehole P322, drilled underground at Nchanga Mine, showing sampling for geochronology

Depth (m)	Description
0-18.0	Shales interbedded with arkose
18.0-18.5	Feldspathic sandstones with trough cross-bedding containing magnetite-rich heavy mineral layers on foresets (up to 5 mm thick); becoming arkosic downwards. ***Sample 1*** (Fig. 4b)
18.5-26.0	Coarse-grained arkose with subrounded to rounded granitic pebbles. Kaolinisation of feldspar laths. Some chlorite observed.
26.0-41.5	Arkose. ***Sample 2 @ 35 m*** (Fig. 4a)
41.5-45.0	Massive Nchanga Granite. ***Sample 3*** (Fig. 2) End of hole.

NCHANGA GRANITE

The youngest intrusion in the pre-Katangan basement is the Nchanga Granite, which is an unfoliated, coarse-grained, peraluminous biotitic alkali granite with A-type geochemical characteristics (Cahen *et al*., 1970b; Tembo *et al*., 2000). The Nchanga Granite has red and grey varieties (O'Meara, 1959; in McKinnon and Smit, 1961), and is cut by thin aplite dykes, which are regarded as the final phase of a composite intrusion. A maximum age limit on the Katanga Supergroup would be the age of the Nchanga Granite, which has provided detritus in the form of granitic pebbles and zircons in the overlying Roan sediments (Binda, 1972; Garlick, 1973; Fleischer *et al*., 1976).

Many previous attempts at dating the Nchanga Granite have yielded unsatisfactory results. An age of 490 ± 20 Ma based on K-Ar dating of biotite probably reflects resetting during the Lufilian Orogeny (Snelling *et al*., 1964). Whole rock Rb-Sr dating gave an age of 604 ± 40 Ma, while Rb-Sr dating of whole rock powders and mineral separates from the Nchanga Granite gave isochron ages of *c*. 500 to 455 Ma, again reflecting a younger resetting event, possibly during the waning stages of the Lufilian Orogeny (Snelling *et al*., 1964; Drysdall and Garrard, 1964; Armstrong *et al*., 1999). The first attempt at U-Pb dating of zircons from the Nchanga Granite was made by Cahen *et al*. (1970b), who obtained two discordant multi-grain zircon fractions with very different $^{207}Pb/^{206}Pb$ ages of 710 Ma and 551 Ma. Using the assumption that these zircons contained common lead with the isotopic composition of Copperbelt galena leads, Cahen *et al*. (1970b) obtained a model age of *c*. 600 Ma for the Nchanga Granite. Further interpretations of the discordant zircons ages of Cahen *et al*. (1970b), led Cahen (1975) to propose a possible upper intercept concordia age of 960 Ma (recalculated by Cahen *et al*., 1984, as 954 Ma). Cahen *et al*. (1984) quoted unpublished data from Binda, which indicated an imprecise Pb-Pb age of 1100–1200 Ma for the Nchanga Granite. Palaeomagnetic results from the grey and pink varieties of the Nchanga Granite were interpreted geochronologically by comparison with the Neoproterozoic polar wander path for southern Africa (Thomson and Sweeney, 1995). The Nchanga Grey Granite gave an age of 1200-1100 Ma, while the Nchanga Pink Granite gave an age of between 700 and 600 Ma (Thomson and Sweeney, 1995). However, palaeomagnetic results similar to those from both varieties of Nchanga Granite were also obtained from the overlying Roan Group sediments (Thomson and Sweeney, 1995), hence the age interpretations cannot be correct, and the palaeomagnetic poles represent some kind of magnetic overprint whose significance is unclear.

A hand-picked suite of 13 magmatic zircons (free of fractures and inclusions) was analysed and the results are listed in Table 2 and plotted on a concordia diagram in Figure 2. The analyses plot in a single cluster and no xenocrysts were detected in the present sample set. The weighted mean $^{207}Pb/^{206}Pb$ age of all analysed zircons yields an age of 883 ± 10 Ma with MSWD = 0.12. This is interpreted as the emplacement age of this phase of the Nchanga Granite.

Table 2. Analytical data for zircons from the Nchanga Granite (sample 3)

Grain .Spot	% $^{206}Pb_c$	ppm U	ppm Th	$^{232}Th/^{238}U$	ppm $^{206}Pb^*$	(1) $^{206}Pb/^{238}U$ Age		(1) $^{207}Pb/^{206}Pb$ Age		% Dis-cor-dant	(1) $^{207}Pb^*/^{206}Pb^*$	±%	(1) $^{207}Pb^*/^{235}U$	±%	(1) $^{206}Pb^*/^{238}U$	±%	err corr
1.1	0.03	606	401	0.68	74.0	856.6	± 5.1	889	± 13	4	0.06868	0.62	1.346	0.89	0.14212	0.64	.714
2.1	0.10	503	301	0.62	62.1	864.9	± 5.4	875	± 17	1	0.06821	0.83	1.350	1.1	0.14359	0.66	.623
3.1	0.11	181	153	0.87	22.2	858.0	± 6.9	877	± 29	2	0.06829	1.4	1.340	1.7	0.1424	0.86	.520
4.1	0.06	523	336	0.66	65.9	882.8	± 5.6	881	± 17	0	0.06840	0.82	1.384	1.1	0.14677	0.68	.638
5.1	0.39	50	61	1.27	6.00	840	±12	868	± 65	3	0.0680	3.2	1.305	3.5	0.1393	1.5	.436
6.1	0.10	250	243	1.01	31.3	876.3	± 6.3	877	± 21	0	0.06828	1.0	1.371	1.3	0.1456	0.76	.603
7.1	0.23	1040	607	0.60	125	843.7	± 4.8	876	± 20	4	0.06823	0.98	1.316	1.1	0.13983	0.60	.526
7.2	0.06	880	475	0.56	103	821.6	± 4.8	876	± 15	6	0.06824	0.72	1.279	0.96	0.13593	0.63	.655
8.1	0.09	301	198	0.68	36.8	856.9	± 6.0	883	± 21	3	0.06847	10	1.342	1.3	0.1422	0.75	.601
9.1	0.30	99	62	0.65	11.7	828.7	± 8.4	894	± 43	7	0.0689	2.1	1.302	2.3	0.1372	1.1	.463
10.1	0.26	516	359	0.72	62.4	846.0	± 5.3	896	± 22	6	0.06890	1.1	1.332	1.2	0.14023	0.67	.534
11.1	0.05	1172	561	0.49	147	875.6	± 4.8	886	± 11	1	0.06858	0.53	1.376	0.79	0.14548	0.59	.746
13.1	1.12	802	450	0.58	96.8	838.4	± 5.0	885	± 58	5	0.0685	2.8	1.312	2.9	0.13889	0.64	.222

Errors are 1-sigma; Pb_c and Pb^* indicate the common and radiogenic portions, respectively.

Error in Standard calibration was 0.34% (not included in above errors but required when comparing data from different mount

(1) Common Pb corrected using measured ^{204}Pb.

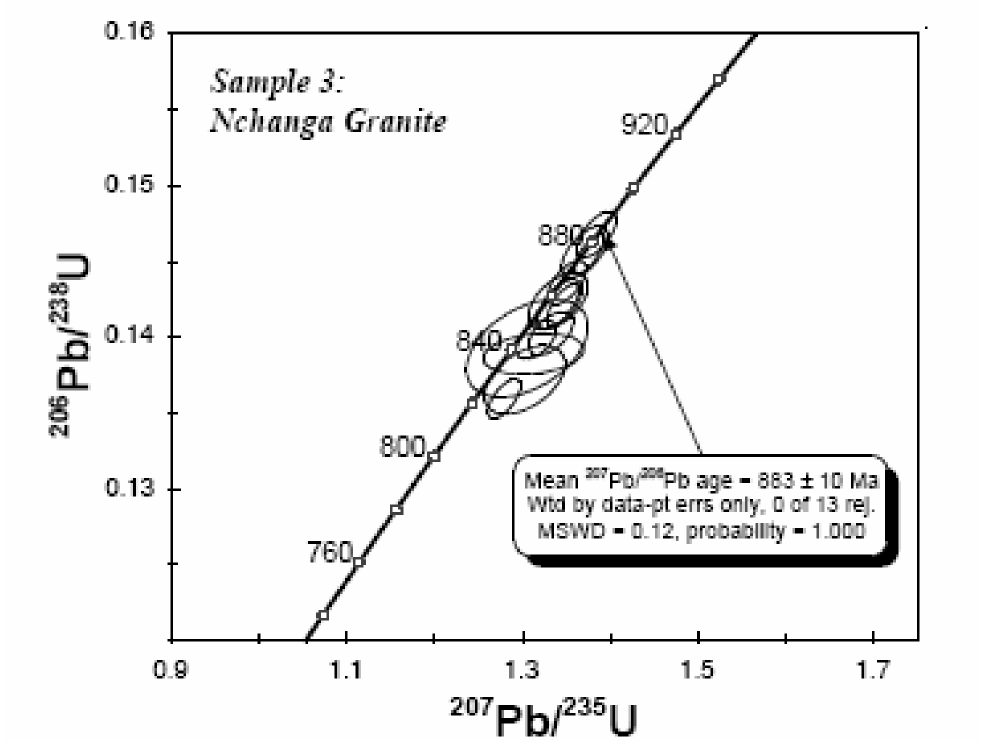

Figure 2. *Concordia plot of zircons analysed from the Nchanga Granite.*

KATANGA SUPERGROUP- LOWER ROAN GROUP SEDIMENTS

Conglomeratic and arkosic sediments of the siliciclastic unit in the lower Roan Group at Nchanga Mine nonconformably overlie the Nchanga Granite, a relationship that is well exposed in the Nchanga open pit (Fig. 3). Previous studies have indicated that there are pebbles and zircons from the Nchanga Granite in basal Roan conglomerates, suggesting that the lower Roan sediments are derived by erosion of a proximal basement that included the Nchanga Granite (Binda, 1972; Garlick, 1973). Despite the overwhelming field evidence for an unconformable contact between the Nchanga Granite and the Roan sediments, there have been attempts to argue that the granite was intrusive into Roan sediments. Such attempts (e.g., by Gysin, 1960), were based on the intersection of supposed dykes of granite within the Roan sediments. However, it was shown by Garlick (1973) and by Fleischer *et al*. (1976) that these supposed dykes were exfoliated slabs of granite near the unconformity surface, or large boulders of granite intersected in drill core, and mistaken for dykes.

Figure 3. *Nonconformity between Nchanga Granite (below dashed line) and Roan Group conglomerate containing large boulders of Nchanga Granite (above the hammer head and dashed line), overlain by coarse-grained arkose. Exposure in the Nchanga open pit.*

U-Pb SHRIMP dating of these lower Roan Group detrital zircons, from both the arkose and the feldspathic sandstone (samples 2 and 1 respectively), using the same procedures as those applicable to the Nchanga Granite, reveals two distinct age populations (Table 3 and Fig. 4a,b), one at between 2000 to 1800 Ma (corresponding to the range of ages in the adjacent Palaeoproterozoic

Lufubu Metamorphic Complex basement; Rainaud *et al.*, 2005), and the other at around 880 Ma (corresponding to the age of the Nchanga Granite presented above). This demonstrates that the Nchanga Granite provided detritus to the Lower Roan, and had been unroofed by the time deposition in the Katangan basin commenced. It sets an unequivocal lower limit of 880 Ma for the age of the Katanga Supergroup. The poorly sorted, coarse clastic, lower Roan sediments were derived from a proximal provenance that comprised both the 880 Ma Nchanga Granite as well as the Palaeoproterozoic Lufubu basement.

INTRUSIVE DYKES IN LOWER ROAN GROUP SEDIMENTS

At least three intrusive rocks cut lower Roan Group sediments exposed in the Nchanga open pit. Felsic dykes cut meta-arkoses in borehole NOP-589 and also intrude schistose siliciclastic metasediments in borehole NOP-681. These dykes contain zircons, but SHRIMP U-Pb analysis indicates that all are xenocrystic and derived from the local basement. Additional analyses of rutile and sphene from these dykes are the object of a current study that will further constrain the minimum ages of both the Roan Group as well as the stratiform Cu-Co mineralization within it (Robb *et al.*, in prep.).

DISCUSSION

The 883 ± 10 Ma age of the Nchanga Granite sets a considerably younger new maximum age for the Katanga Supergroup. This age is indistinguishable from the 879 ± 16 Ma age of the Kafue Rhyolite, which is at the base of supposed Katangan-equivalent supracrustals of the Zambezi Belt (Hanson *et al.*, 1994). This event suggests that felsic magmatism occurred just prior to, or during, the early rifting stages of Katangan basin formation (Armstrong *et al.*, 1999). This view would best be compatible with a scenario in which the Katangan rifts were limited in extent and formed in response to the rifting of a composite terrane consisting of both the Kalahari and Congo Cratons (e.g., Master, 1990, 1993; Hanson, 2003). Recently published data on MORB-type eclogites in the Zambezi Belt (John *et al.*, 2003), however, give an age of *c.* 590 Ma for eclogite formation at high pressures (up to 23 kb), and suggest the presence of a wide ocean basin (>1000 km), which closed by subduction of oceanic crust to depths of >90 km, prior to exhumation. Furthermore, high-pressure talc-kyanite white schists from the Lufilian Arc and the Zambezi Belt record metamorphic ages on monazite of *c.* 530 Ma (John *et al.*, 2004). The Zambezi Belt could, therefore, be interpreted as a collisional suture between two widely separated cratons (the Congo and Kalahari), so that rocks such as the Nchanga Granite on the Congo Craton cannot be genetically related to similar aged units in the Zambezi Belt, which were on the northern edge of the Kalahari Craton. Furthermore, the interpretation of the Zambezi Belt supracrustals, which include the Makuti Group of NW Zimbabwe, as a bimodal rift sequence (Munyanyiwa *et al.*, 1997), has been questioned by Dirks *et al.* (1999) who showed that rocks described as “meta-arkoses” (Broderick, 1976) and “meta-rhyolites” (Munyanyiwa *et al.*, 1997) are, in fact, sheared granites. The age of the Nchanga Granite is similar to, but slightly older than, those of the Lusaka Granite (842 ± 33 Ma; recalculated from Barr *et al.*, 1978), the Ngoma Gneiss in the Zambezi Belt (820 ± 7 Ma; Hanson *et al.*, 1988), and a megacrystic granite dated at 852 ± 11 Ma in the Tsumkwe area near the southern edge of the Congo Craton (Hoal *et al.*, 2000). Our preferred interpretation, therefore, is that the granitoids and felsic volcanics of the Zambezi Belt in SW Zambia were probably on an entirely different crustal fragment or continent at this time and should not be correlated with the Nchanga Granite. The latter remains the only known granitic intrusion of Neoproterozoic age in the Copperbelt region.

The felsic dykes at Nchanga contain xenocrystic zircons sourced from the Proterozoic basement of the Central African Copperbelt (Rainaud *et al.*, 2005). These dykes cut across Roan Group sediments and probably represent the feeders to sills (Tembo *et al.*, 1999) and extrusive lavas higher in the Katangan succession, such as the 760 ± 5 Ma Lwavu volcanics in western Zambia

Table 3. Analytical data for detrital zircons from lower Roan Group sediments (samples 1 and 2) overlying the Nchanga Granite

Grain.Spot	% $^{206}Pb_c$	ppm U	ppm Th	^{232}Th $/^{238}U$	ppm $^{206}Pb^*$	(1) ^{206}Pb $/^{238}U$ Age		(1) ^{207}Pb $/^{206}Pb$ Age		% Dis-cor-dant	(1) $^{207}Pb^*$ $/^{206}Pb^*$	±%	(1) $^{207}Pb^*$ $/^{235}U$	±%	(1) $^{206}Pb^*$ $/^{238}U$	±%	err corr
1.1	0.18	183	228	1.29	56.2	1,971	±15	1,964	± 21	0	0.1205	1.2	5.945	1.5	0.3577	0.88	.601
2.1	0.53	435	379	0.90	109	1,643.8	± 8.6	1,808	± 22	9	0.1105	1.2	4.425	1.3	0.2905	0.60	.443
4.1	0.00	297	533	1.86	90.9	1,967	±15	1,957	± 12	-1	0.12008	0.66	5.906	1.1	0.3567	0.87	.799
5.1	0.16	384	214	0.57	106	1,788.6	± 9.4	1,959	± 13	9	0.12022	0.72	5.300	0.94	0.3198	0.60	.645
5.2	0.21	307	150	0.50	89.6	1,881	±11	1,924	± 16	2	0.1179	0.90	5.508	1.1	0.3389	0.67	.595
6.1	0.19	145	134	0.96	43.7	1,933	±19	1,952	± 29	1	0.1197	1.6	5.77	2.0	0.3497	1.2	.576
7.1	2.50	285	417	1.51	45.5	1,074.2	± 9.2	1,995	± 64	46	0.1226	3.6	3.07	3.7	0.1813	0.93	.250
8.1	0.08	97	117	1.24	28.6	1,892	±19	1,975	± 21	4	0.1213	1.2	5.704	1.7	0.3411	1.2	.692
9.1	0.00	73	78	1.11	21.1	1,870	±22	1,911	± 23	2	0.1170	1.3	5.43	1.9	0.3365	1.4	.730
10.1	0.00	225	276	1.27	24.8	778.7	± 7.8	859	± 28	9	0.06768	1.4	1.198	1.7	0.1284	1.1	.615
11.1	0.21	193	174	0.93	58.5	1,948	±14	1,954	± 17	0	0.1198	0.96	5.830	1.3	0.3528	0.81	.643
12.1	0.19	87	102	1.22	9.49	771	±13	847	± 58	9	0.0673	2.8	1.179	3.3	0.1271	1.8	.532
13.1	0.16	67	95	1.47	19.1	1,844	±23	1,865	± 39	1	0.1141	2.2	5.21	2.6	0.3311	1.4	.550
14.1	3.14	783	1038	1.37	137	1,157.8	± 6.1	1,676	± 83	31	0.1028	4.5	2.79	4.5	0.1967	0.57	.126
15.1	1.90	103	108	1.08	13.1	868	±13	859	±230	-1	0.0677	11	1.35	11	0.1442	1.6	.146
16.1	0.17	438	351	0.83	117	1,739.3	± 8.6	1,811	± 15	4	0.11073	0.84	4.729	1.0	0.3097	0.57	.557
17.1	--	227	328	1.49	27.8	858.0	± 7.2	876	± 44	2	0.0682	2.1	1.340	2.3	0.1424	0.90	.390
18.1	0.00	68	75	1.15	19.7	1,872	±23	1,900	± 24	1	0.1163	1.4	5.40	2.0	0.3369	1.4	.718
19.1	0.34	96	110	1.19	27.0	1,829	±23	1,858	± 36	2	0.1136	2.0	5.14	2.5	0.3280	1.4	.590
20.1	0.78	78	98	1.30	22.9	1,890	±26	1,921	± 45	2	0.1177	2.5	5.53	2.9	0.3407	1.6	.530
21.1	0.15	89	106	1.23	25.5	1,850	±23	1,890	± 29	2	0.1157	1.6	5.30	2.2	0.3324	1.4	.657
22.1	0.05	240	172	0.74	73.5	1,963	±17	1,960	± 15	0	0.1202	0.86	5.902	1.3	0.3560	1.0	.768
23.1	0.64	115	87	0.78	32.8	1,845	±21	1,902	± 36	3	0.1164	2.0	5.32	2.4	0.3313	1.3	.560
24.1	0.87	250	302	1.25	63.0	1,644	±15	1,965	± 29	16	0.1206	1.6	4.829	1.9	0.2905	1.0	.532
25.1	1.12	251	432	1.78	57.6	1,510	±14	1,838	± 39	18	0.1124	2.1	4.091	2.4	0.2640	1.1	.444
26.1	0.19	128	137	1.11	37.3	1,882	±20	1,860	± 21	-1	0.1138	1.2	5.316	1.7	0.3389	1.3	.730
27.1	1.22	165	134	0.84	19.0	801	±10	841	±130	5	0.0671	6.1	1.225	6.3	0.1323	1.4	.219
28.1	3.96	261	425	1.68	24.2	636	±13	884	±210	28	0.0685	9.9	0.980	10	0.1038	2.1	.206
29.1	0.08	254	107	0.44	75.6	1,916	±17	1,949	± 15	2	0.11949	0.83	5.702	1.3	0.3461	1.0	.773
30.1	0.30	131	87	0.69	41.5	2,025	±23	1,978	± 26	-2	0.1215	1.4	6.18	2.0	0.3690	1.3	.682
31.1	0.05	66	40	0.63	19.8	1,936	±27	1,994	± 27	3	0.1226	1.5	5.92	2.2	0.3503	1.6	.731
33.1	0.57	286	217	0.78	71.0	1,628	±14	1,966	± 26	17	0.1207	1.5	4.781	1.8	0.2873	1.0	.567
34.1	0.03	144	143	1.02	35.0	1,604	±27	1,881	± 37	15	0.1151	2.0	4.48	2.8	0.2826	1.9	.684
35.1	0.42	114	128	1.16	31.7	1,796	±21	1,847	± 32	3	0.1129	1.8	5.00	2.2	0.3212	1.3	.594
36.1	0.13	273	161	0.61	85.1	1,992	±17	1,964	± 14	-1	0.12052	0.79	6.016	1.3	0.3621	0.97	.774
37.1	4.14	825	1090	1.37	154	1,220.8	± 9.5	1,885	± 84	35	0.1153	4.6	3.31	4.7	0.2085	0.85	.181
38.1	0.50	230	332	1.49	65.0	1,826	±17	1,945	± 25	6	0.1193	1.4	5.385	1.8	0.3275	1.1	.597
39.1	1.53	114	120	1.08	26.1	1,495	±19	1,790	± 69	16	0.1094	3.8	3.94	4.0	0.2610	1.4	.347
40.1	0.82	112	117	1.08	13.7	851	±12	936	±100	9	0.0702	4.9	1.367	5.1	0.1412	1.5	.299
41.1	0.68	419	1210	2.98	38.4	649.5	± 9.4	662	±170	2	0.0617	7.9	0.901	8.1	0.1060	1.5	.189
42.1	0.38	247	167	0.70	72.9	1,897	±16	1,922	± 21	1	0.1177	1.2	5.556	1.5	0.3422	0.97	.645
43.1	0.26	109	78	0.74	31.3	1,850	±21	1,990	± 25	7	0.1223	1.4	5.61	1.9	0.3325	1.3	.681
44.1	0.18	252	293	1.20	75.0	1,915	±16	1,927	± 17	1	0.1181	0.97	5.633	1.4	0.3460	0.98	.709
45.1	4.15	776	2086	2.78	73.8	650.9	± 5.6	857	±170	24	0.0676	8.2	0.990	8.2	0.10624	0.90	.109
Sample 1: Roan sandstone																	
1.1	0.22	566	320	0.59	157	1,802	±15	1,834	± 12	2	0.11210	0.66	4.985	1.1	0.3225	0.93	.815
2.1	0.02	189	184	1.01	54.6	1,874	±18	1,846	± 15	-2	0.11287	0.83	5.250	1.4	0.3374	1.1	.793
3.1	3.08	776	884	1.18	160	1,349	±12	1,794	±100	25	0.1097	5.6	3.52	5.7	0.2328	1.0	.179
4.1	0.11	74	64	0.89	22.8	1,979	±23	1,951	± 17	-1	0.1196	0.96	5.928	1.7	0.3593	1.4	.819
5.1	0.48	81	71	0.90	23.8	1,889	±22	1,957	± 29	3	0.1200	1.7	5.64	2.1	0.3406	1.3	.623
6.1	0.11	184	91	0.51	55.6	1,937	±24	1,958	±12	1	0.12011	0.69	5.805	1.6	0.3505	1.4	.899

7.1	0.27	124	334	2.80	32.4	1,714	±23	1,875	±19	9	0.1147	1.1	4.819	1.9	0.3047	1.5	.813
8.1	0.37	85	109	1.34	25.3	1,917	±26	1,963	±24	2	0.1205	1.3	5.75	2.1	0.3464	1.6	.766
9.1	0.58	58	50	0.89	17.2	1,896	±28	1,965	±35	4	0.1206	2.0	5.68	2.6	0.3419	1.7	.657
10.1	--	181	135	0.77	53.5	1,912	±23	1,980	±12	3	0.12162	0.65	5.788	1.5	0.3452	1.4	.905
11.1	0.22	505	95	0.20	164	2,066	±23	1,966.0	± 8.4	-5	0.12067	0.46	6.286	1.4	0.3779	1.3	.940
12.1	0.08	299	378	1.31	94.0	2,009	±23	1,993.1	± 9.2	-1	0.12251	0.52	6.176	1.4	0.3656	1.3	.932
13.1	0.12	752	262	0.36	213	1,834	±20	1,944.0	± 6.2	6	0.11919	0.34	5.407	1.3	0.3291	1.3	.965
14.1	0.15	114	240	2.17	34.0	1,911	±25	1,959	±18	2	0.1202	0.99	5.72	1.8	0.3452	1.5	.836
15.1	0.20	62	90	1.50	17.9	1,858	±27	1,901	±25	2	0.1163	1.4	5.36	2.2	0.3341	1.7	.769
16.1	0.39	416	250	0.62	107	1,678	±19	1,970	±14	15	0.12093	0.74	4.958	1.5	0.2974	1.3	.861
17.1	0.11	270	248	0.95	77.1	1,846	±35	1,970	±17	6	0.1209	0.95	5.53	2.4	0.3315	2.2	.918
18.1	0.12	182	180	1.02	52.4	1,862	±36	1,862	±18	0	0.1138	10	5.26	2.4	0.3349	2.2	.911
19.1	0.07	499	233	0.48	150	1,936	±35	1,956.5	± 9.6	1	0.12002	0.54	5.80	2.1	0.3502	2.1	.968
20.1	0.01	1448	362	0.26	409	1,834	±32	1,960.0	± 5.7	6	0.12026	0.32	5.46	2.0	0.3291	2.0	.988
21.1	0.33	28	48	1.75	7.98	1,827	±53	2,018	±71	9	0.1243	4.0	5.61	5.2	0.328	3.4	.642
21.2	0.07	316	163	0.53	94.5	1,925	±35	1,970	±13	2	0.12094	0.71	5.80	2.2	0.3480	2.1	.948
22.1	2.50	327	200	0.63	94.4	1,825	±34	1,896	±55	4	0.1160	3.1	5.23	3.8	0.3272	2.1	.571
23.1	0.09	178	182	1.05	51.1	1,854	±36	1,947	±16	5	0.1194	0.88	5.48	2.4	0.3332	2.3	.931
24.1	0.37	144	165	1.18	33.1	1,522	±32	1,840	±30	17	0.1125	1.7	4.13	2.9	0.2664	2.4	.819
25.1	0.11	452	261	0.60	124	1,787	±33	1,871	±12	4	0.11441	0.66	5.04	2.2	0.3195	2.1	.954
26.1	--	178	151	0.88	50.9	1,856	±36	1,902	±17	2	0.1164	0.92	5.36	2.4	0.3337	2.3	.926
27.1	--	309	364	1.22	89.7	1,879	±35	1,984	±11	5	0.12187	0.63	5.69	2.2	0.3384	2.1	.959
28.1	1.65	675	241	0.37	116	1,153	±22	1,699	±42	32	0.1042	2.3	2.814	3.1	0.1959	2.1	.669
28.2	0.11	161	184	1.18	50.5	2,003	±39	1,869	±17	-7	0.1143	0.94	5.74	2.4	0.3644	2.2	.922

Errors are 1-sigma; Pb_c and Pb^* indicate the common and radiogenic portions, respectively.

(1) Common Pb corrected using measured ^{204}Pb.

(Key *et al.*, 2001). These volcanics are located within the Mwashya Subgroup, which stratigraphically overlies the Roan Group. Additional evidence for magmatic activity at this period is present in the form of the gabbroic intrusions within Katangan carbonate sediments of the Solwezi area, NW Zambia, which have yielded ages of 745 ± 7.8 Ma and 752.6 ± 8.6 Ma (Barron *et al.*, 2003). These ages collectively constrain deposition of the Roan and Mwashya sediments to the interval between 880 and 760 Ma. Cahen *et al.* (1970a, 1984) reported the ages of two metamorphic microcline veins cutting the Roan Group at Luanshya and Musoshi, as being 840 ± 42 Ma, hence setting a younger limit to the age of the Roan Group. However, we regard these Rb/Sr model ages to be unreliable, hence 880 Ma remains the most reliable maximum age of the Katanga Supergroup. This new maximum age precludes a suggested correlation of the Katangan with the older (948 ± 15 Ma) Bushimay or Mbuji Mayi Supergroup in the Congo (Cahen *et al*., 1984), but reinforces the likelihood of correlations with similar sequences within the Damaran and West Congolian orogenic belts (Miller, 1983; Tack *et al*., 2001).

Whereas previously they were thought to reflect diachronous basin development spanning several hundred million years (Porada, 1989), the Katanga and Damara Supergroups are now regarded as part of a single episode of rifting and passive margin formation, followed by later subduction and continental collision, on the southern margin of the greater Congo Craton (Master, 2004; Rainaud *et al*., 2005). The mafic lavas and gabbroic intrusions in the Mwashya Subgroup, which range in age between 760 ± 5 Ma and 745 ± 7.8 Ma, have the same range of ages as felsic volcanics and intrusive syenites from the Damara Supergroup, in the Summas Mountains of northern Namibia (Hoffman *et al*., 1996). In the Summas Mountains, the basal Damaran rocks consist of a continental succession of feldspathic sandstones and conglomerates of the Nosib Group, which record continental rifting in the southern margin of the Congo Craton (Hoffmann, 1994). The Nosib Group is overlain here by the Ugab Subgroup, a mixed association of syn- to post-extensional carbonates and terrigenous sedimentary rocks (Miller, 1980). In the Damara Supergroup, a felsic ash-flow tuff

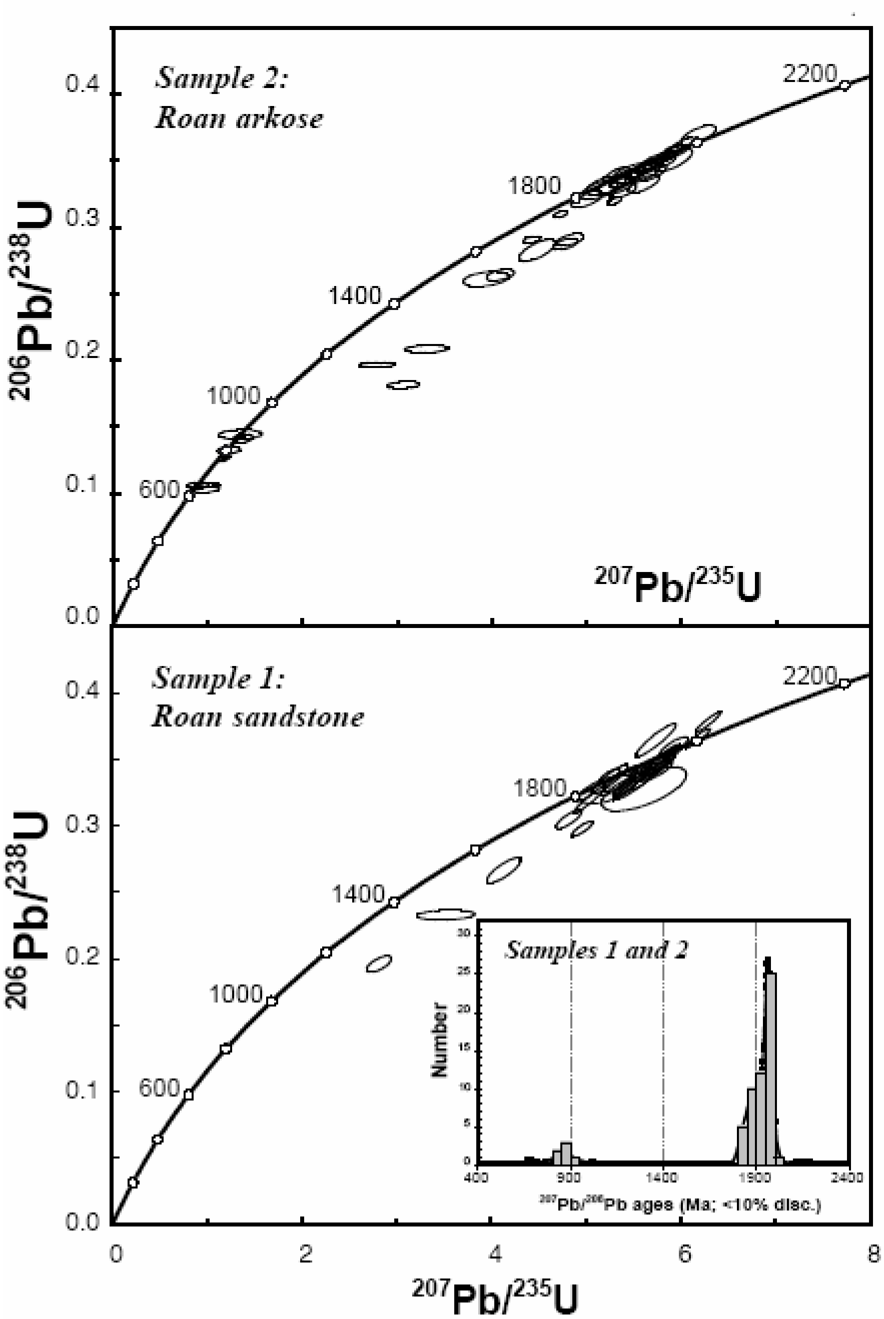

Figure 4. *Concordia Plot of zircons analysed from lower Roan Group sediments overlying the Nchanga Granite. (a) Sample 2 – arkose at 35m depth in borehole P322; (b) Sample 1 – feldspathic sandstone at 18m depth in borehole P322.*

from the Naauwpoort Formation of the upper Nosib Group and a rhyolite from the lower Ugab Subgroup have yielded indistinguishable U-Pb zircon ages of 746 ± 2 and 747 ± 2 Ma, respectively (Hoffman *et al*., 1996). The Oas quartz syenite, which intrudes the lower Nosib Group, has been dated at 756 ± 2 Ma (Hoffman *et al*., 1996) and, hence, the lowermost Nosib Group, at the base of the Damara Supergroup, is older than this. Because the pre-Damaran basement in the southern Congo Craton is of Palaeoproterozoic (*c*. 2000 to 1800 Ma) age (Tegtmeyer and Kröner, 1985), the age of the lowermost Damaran sediments is not well constrained. The age equivalence of intrusive and extrusive rocks in the Mwashya Subgroup, and of the intrusive and extrusive Damaran rocks of the Summas Mountains suggests a correlation between the Mwashya Subgroup and the Naauwpoort Group and lower Ugab Subgroups. This also suggests a correlation between the pre-Mwashya Roan Group, and the lowermost Nosib Group. The maximum age of 880 Ma for the

Roan Group obtained in this paper may also, therefore, represent a maximum age for the Nosib Group at the base of the Damara Supergroup.

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