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Field Excursion Guide-

NW Magondi Belt and Makuti Group, NW Zimbabwe

Selected roadside exposures between Karoi and Kariba
19 November 2015

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Introduction

The Magondi Belt is a Palaeoproterozoic mobile belt situated on the western flank of the Archaean Zimbabwe Craton, extending from NW Zimbabwe to NE Botswana. It consists of deformed rocks of the Palaeoproterozoic Magondi Supergroup, a 2.2-2.06 Ga metasedimentary succession with minor volcanic rocks (Master *et al*., 2010; 2013). On the eastern part of the belt, there are autochthonous units that are in unconformable contact with Archaean granite-greenstone rocks of the Zimbabwe Craton. In the north and northeast of the belt, Magondi Supergroup rocks apparently either overlie older basement gneisses and schists unconformably, or are found as infolds within such basement.

In the northern part of the Magondi Belt, the crystalline basement consists of a heterogeneous succession of paragneisses and orthogneisses, which vary from foliated granitic leucogneisses to biotite gneisses to migmatites. There are also intercalations of hornblende-diopside calc-silicate gneisses. Granitoids consisting of plugs of granodioritic and tonalitic gneisses intrude the various paragneiss units.

The paragneisses and their associated intrusive granitic orthogneisses and ortho-amphibolites record a major orogenic cycle, named the "Hurungwe Orogeny" (Master, 1991, 1996), that is imprecisely dated, but apparently predated the ca. 2.1 Ga Magondi Supergroup. The age constraints on this orogenic cycle are very poorly defined. The only dating of the paragneisses, by Loney (1969), indicates ages that span 2533 to 2276 Ma, i.e. Neoarchaean to Palaeoproterozoic. The Hurungwe orogenic cycle supposedly may have involved subduction of oceanic crust underneath the Zimbabwe Craton, with orogenic obduction of an accretionary wedge onto the western edge of the craton (Master, 1991, 1996).

New SIMS U-Pb zircon age data (Master *et al.,* 2015) show that many of the granitoids in the supposed pre-Magondi basement are actually post-Magondi intrusive rocks, which are part of an extensive magmatic arc formed on the western flank of the Archaean Zimbabwe Craton at between 2.06 and 1.96 Ga (Master *et al*., 2010; 2013). There is no indication from the new geochronological results, which are the best quality dates obtained from the NW Magondi Belt, for any pre-Magondi Palaeoproterozoic orogeny ("Hurungwe Orogeny") between 2.6 and 2.2 Ga. The new geochronological data are best interpreted as indicating that the Magondi Supergroup and its Archaean basement was intruded by an Andean-type magmatic arc in the west, and then affected by the Magondi Orogeny, through collision with an unknown continent to the west (Terra Incognita; Master *et al*., 2010). High temperature metamorphism in the Magondi Belt, which reached granulite facies in the west, was partly caused by heat input from the magmatic arc (Munyanyiwa & Maaskant, 1998). During the Pan-African (Neoproterozoic to Early Palaeozoic) Zambezi Orogeny, the Makuti Group was thrust over the NW Magondi Belt, and resulted in renewed deformation, metamorphism, and geochronological overprinting at about 546 Ma (which is recorded by lower intercept ages of discordant zircon rims from the Manchinchi Bay biotite gneiss near Siavonga, Zambia; Master *et al*., 2015).

In this short field excursion, we will examine roadside outcrops of the supposed pre-Magondi basement rocks, from which new geochronological results have been obtained (Master *et al.,* 2015), as well as outcrops of the Neoproterozoic Makuti Group (Broderick, 1976; Fey & Broderick, 1990).

Itinerary

Thursday 19 November 2015
Convoy of excursion vehicles to meet at Twin Rivers Motel, Karoi.
Depart from Twin Rivers Motel, Karoi at 08:45AM.

Stop1. Hurungwe Gneisses. Roadcut on Main National Road from Karoi to Chirundu.

Stop 2. Makuti Group amphibolites, calc silicate rocks and eclogite, Vuti Synform.

Stop 3. Makuti Group quartzo-feldspathic gneiss. Tight folding with strong axial rodded lineation. Road cut on Main National Road from Karoi to Chirundu about 7km before Makuti. *Take care when parking and crossing the road.*

Stop 4. Makuti Group. Road cuttings displaying boudinaged biotite gneiss and marble. Zambezi Escarpment, Makuti to Chirundu Main National Road. *Please park well off the main road, which is very busy with big trucks, and beware of vehicles when crossing the road. A wide truck pull-off exists opposite the marble exposures, but is on a road bend.*

Stop 5. Makuti Group quartzo-feldspathic gneiss. (Optional) Kaburi anticline. Cutting, Makuit-Kariba road. *This is an optional stop as vehicle parking may be difficult.*

Stop 6. Kariba Gneiss in contact with basal Karoo red mudstones. Nyanyana River Bridge, Makuti-Kariba road before the Kariba Airport.

Stop 7. Kariba porphyritic biotite granitoid gneiss, 12 km from Kariba town near Nyamunga Township.

Stop 8. Kariba sillimanite quartzite, Kariba Heights. *Parking will either discussed beforehand, as we will have to park and either ascend or descend the road leading down from the Heights.*

Stop 9. Kariba Dam Observation Point. (Optional) Contact between Kariba biotite gneiss and sillimanite quartzite. *Parking is restricted and the stop may have to be subject to individual visits at any convenient time whist in Kariba.*

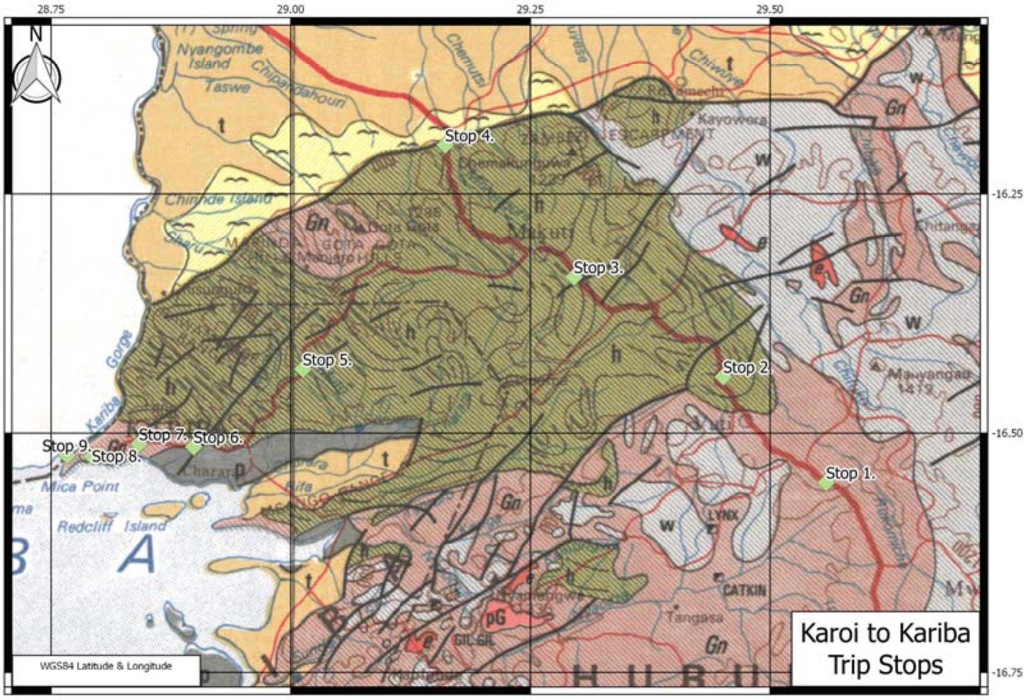

Figure 1: Stop locations in relation to the general geology, karoi to Chirundu road and Makuti to Kariba. *Zim. geol. Surv.,* 1:1m geological map.

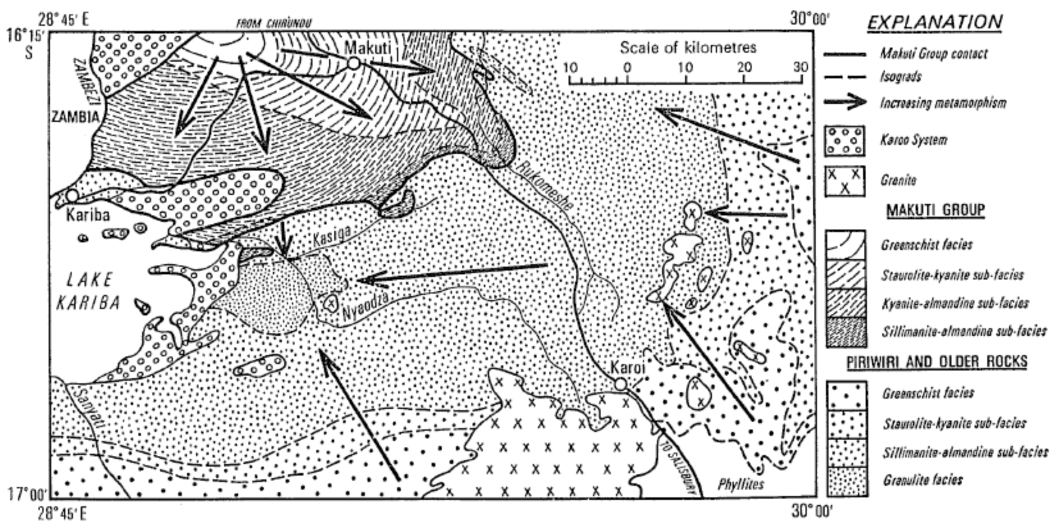

Figure 2: Regional metamorphism in the NW Magondi Belt ("Piriwiri and Older Rocks") and the Neoproterozoic Makuti Group (*after*Broderick, 1976). The field trip

route is from Karoi to Kariba, with a diversion to the Zambezi Escarpment beyond Makuti.

Field Stops

Note: latitude and longitudes are in WGS84

Stop 1.The Hurungwe Gneiss,*ZMB13/8B,* collected near 16°32’33.5”S, 29°32’47.5”E, on the Karoi-Chirundu road is a biotite garnet granitic gneiss, containing quartz, K-feldspar, plagioclase, biotite, garnet. Biotite schlieren 2-4 mm wide help to define a gneissic foliation in the rock. The zircons have yielded ages of **2020.7 ± 6.6 Ma**, which is regarded as the age of the intrusion (Master *et al.,* 2015). No inherited zircons were found in this sample.

Figure 3. The Hurungwe quartzo-feldspathic gneiss, dated at 2020.7 ± 6.6 Ma (Master *et al*., 2015).

Stop 2.Amphibolites with eclogite pods in the Makuti Group16°26'27.2"S 29°27'3.5"E

Within the Makuti Group there are garnet-clinopyroxene-hornblende gneisses (amphibolites) that contain lenses of eclogite having igneous (corona-textured) and metamorphic (garnet-omphacite) textural associations (Broderick, 1980, 1982; Dirks and Sithole, 1999). Dirks and Sithole (1999) found peak P-T conditions of metamorphism for the eclogites of c. 19 kb, 760 ± 25°C. The surrounding amphibolitic gneisses were metamorphosed under P-T conditions of 11 ± 1.5 kb, 730 ± 50°C. Whereas Dirks and Sithole (1999) supposed that the eclogitic metamorphism took place before 850 Ma, and may have been related to Rodinia formation at around 1 Ga, it was shown by John *et al.* (2003) that eclogites from the Zambezi Belt have an Sm–Nd isochron age of 595 ± 10 Ma. Furthermore, a phase of high-pressure whiteschist metamorphism yielded a U–Pb monazite age of 529 ± 2 Ma (John *et al.,* 2004), and similar ages have been found in the Lufilian Arc by Rainaud *et al.* (2005).

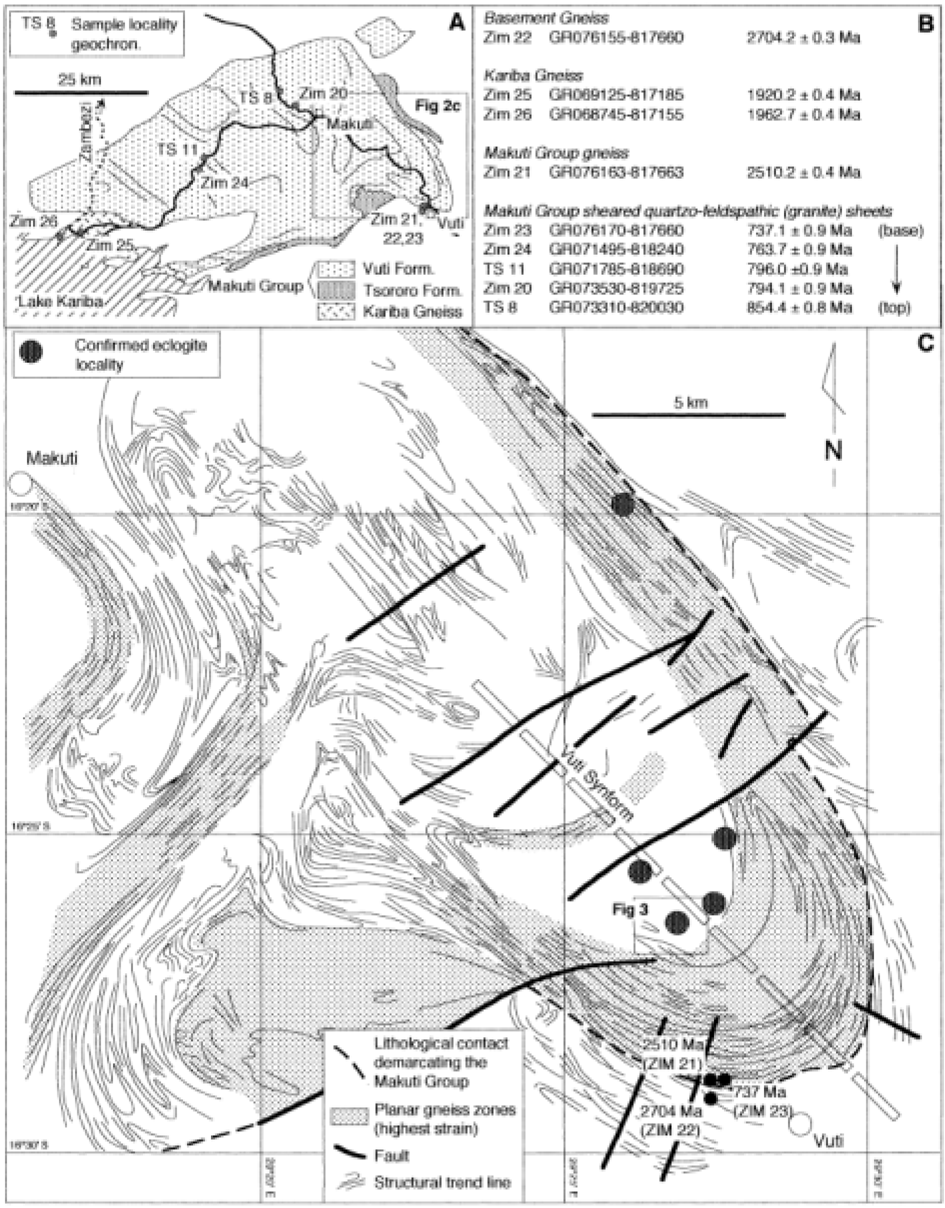

Figure 4. (a) Outline of the Makuti Group in NW Zimbabwe. The localities of the dated samples reported by Dirks *et al*. (1999) are shown. (b) Summary of Pb-Pb zircon evaporation ages reported by Dirks *et al*. (1999). (c). Structural trend map of the SE portion of the Makuti Group, derived from SPOT satellite imagery. Black circles represent known eclogite localities. After Dirks and Sithole (1999).

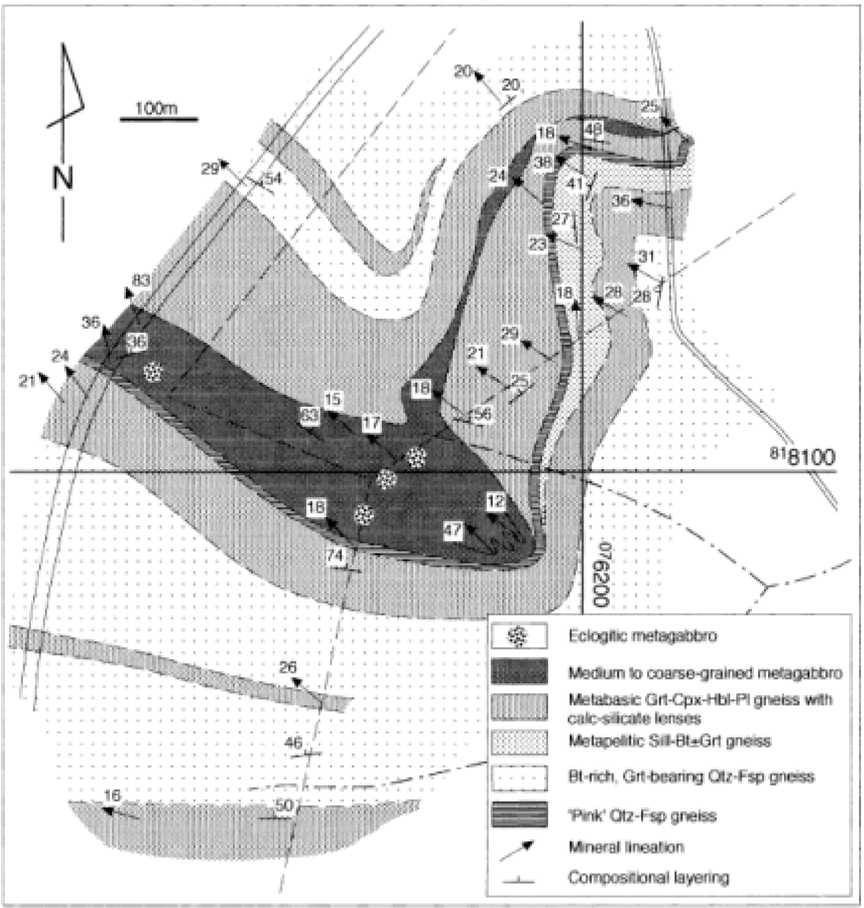

Figure 5. Detailed geological map of an eclogitic metagabbro lens in the hinge of a D2 fold structure within the Vuti synform (after Dirks and Sithole, 1999). The location of this map is shown on Figure 4.

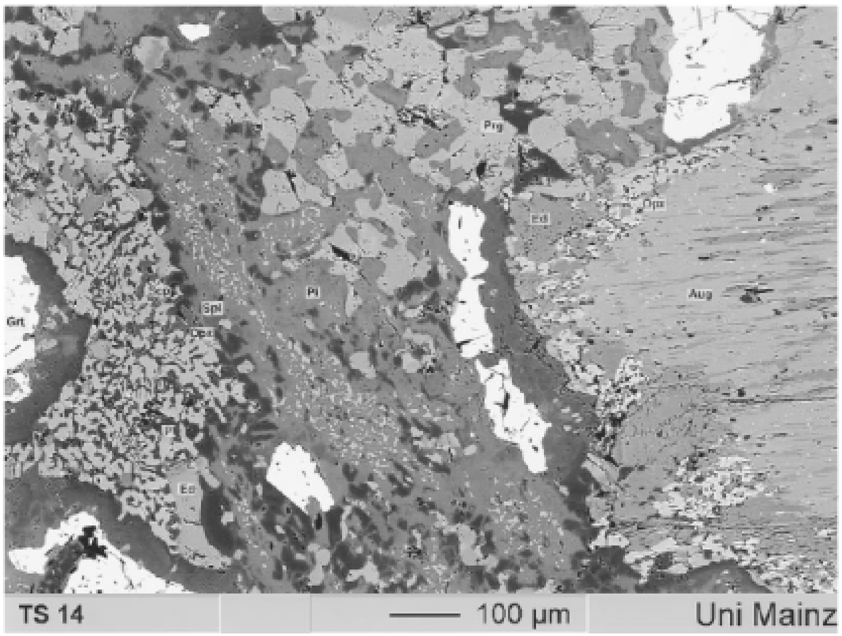

Figure 6. Composite electron backscatter image of symplectic textures preserved within eclogitic metagabbro sample TS14 (after Dirks and Sithole, 1999).

Stop 3.Makuti Group quartzo-feldspathic gneiss. 16°20'10.6"S 29°17'44.1"E

Tight to isoclinal folding with strong 13-16^{o} NW-plunging axial rod lineation indicating thrust translation within the Makuto Group lithological pile.

Figure 7: Folded Makuti Group gneiss displaying axial rod lineation.

Stop 4.Makuti Group paragneisses, exposed within the Zambezi Escarpment, Makuti to Chirundu main national road. 16°11'56.5"S, 29° 9'39.6"E

Exposures of paragneisses of the **Neoproterozoic Makuti Group** which are flat-lying, but highly deformed and metamorphosed. Good examples of boudinage can be seen in quartzo-feldspathic psammitic bends intercalated with politic and semi-pelitic schists. Brecciated dolomitic marbles can be seen close to the escarpment fault. Munyanyiwa *et al*. (1996) interpreted felsic gneisses (mapped as meta-arkoses by Broderick, 1976) and amphibolites from the Makuti Group as representing a bimodal rift sequence in an intraplate setting. This interpretation was disputed by Dirks *et al*. (1999), who regarded fine-grained felsic gneisses as representing sheared granitoids.

Figure 8: Google Earth image showing the location of the Zambezi Valley view point, the boudinaged biotite gneiss and marble in roadside cuttings.

Figure 9: Boudinaged biotite gneiss, Zambezi Valley Escarpment cuttings, Marongora.

Stop 5.Makuti Group quartzo-feldspathic gneiss 16°25'59.5"S, 29° 0'45.0"E

The Kaburi anticlinal fold structure with axis parallel to the NW regional trend, which can be traced over many tens of kilometres. The strongly deformed alternating lithologies comprising feldspathic gneiss, biotite gneiss, pelitic schist, quartzite, calc silicate rock and amphibolite are sometimes thrown into refolded interference paterns.

Figure 11: The Kaburi Anticline between Buffalo Bend and Rhino Nek, Kariba road. The situation has spiritual conotations, as seen from the clay pot placement.

Stop 6.Kariba biotite gneiss at the Nyanyana bridge foundation overlain by basal red mudstone of the Lower Karoo Group. 16°30'50.9"S, 28°53'55.5"E

The Nyanyana River bridge, crossed just prior to passing the turnoff to Kariba Airport, is founded on strongly foliated and folded biotite gneiss. The basal unit to the Karoo Supergroup, as in adjacent parts of Zambia, is a red mudstone with basal conglomerate in places. This mudstone is seen in direct contact with the Kariba gneiss both downstream of the bridge where they are overlain by a thick sequence of grey Madumabisa Mudstone beyond, and in the tributary upstream of the bridge. Large boulders of siliceous breccia from the Nyanyana Fault can be seen as boulders in the riverbed.

Figure 10 a and b: Folded Kariba biotite gneiss forming the foundation to the Nyanyana bridge, and the red mudstone of the basal Karoo in contact with the gneiss downstream of the bridge.

Stop 7. The **Kariba porphyritic biotite granitoid gneiss** (16°30’40.7”S, 28°50’30.3”E), some 12 km E of Kariba.

The **Kariba porphyritic biotite granitoid gneiss** (16°30’40.6”S, 28°50’30.3”E) is coarse-grained, with a weak gneissic fabric, and contains large K-feldspar phenocrysts, and numerous decimetric slab-like mafic xenoliths. It contains small garnets rimmed and replaced by biotite. The zircons dated have oscillatory zoning in the centre (of igneous origin), but the margins have been affected by metasomatic alteration zones, and in some cases have discrete overgrowth rims. The zircons have yielded ages of 1962.9 ± 8.5 Ma and 2.1-2.17 Ga. The age of intrusion is regarded as **1.963 Ga**, while the older zircons reflect inheritance from older crust (Master *et al.*, 2015).

The Kariba porphyritic biotite gneiss has been included within the Kariba Paragneiss (Broderick, 1976), together with some porphyroblastic biotite gneisses containing euhedral microcline and microperthite porphyroblasts, which are associated with small plugs of adamellite and granodiorite. The new SIMS U-Pb zircon age is slightly younger than the very imprecise recalculated WR Rb-Sr date of 2050 ± 32 Ma obtained by Loney (1969) for a metagranite intrusive into Kariba Parageisses. The new age of 1962.9 ± 8.5 Ma is indistinguishable, within error from the older of two ages of 1962.7 ± 0.4 Ma and 1920.2 ± 0.4 Ma, obtained on porphyritic garnetiferous granodiorite gneisses by Dirks *et al*. (1999).

Figure 11. Kariba porphyritic biotite gneiss, with mafic enclave, dated at 1.963 ± 8.5 Ga (Master *et al.,* 2015).

Stop 8. Kariba sillimanite quartzite, Kariba Heights.

The **Kariba sillimanite quartzite** Kariba Heights, Sample ZMB13/11.(16°31'26.5"S, 28°47'33.6"E) is an aluminous quartzite consisting mainly of quartz and sillimanite. The zircons have yielded concordant ages of 2.018 Ga, 2.172, 2.220 and 2.70 Ga (Master *et al*., 2015). The maximum age of the quartzite is 2.018 Ga, the age of the youngest concordant detrital zircon, while the other zircons reflect a provenance from older crust dated at 2.17, 2.22, and 2.70 Ga. Three youngest zircons have (discordant) ages between 1.955 and 1.963 Ga, reflecting possible resetting during intrusion of the 1.96 Ga granitoids.

The Kariba sillimanite quartzite is part of the Kariba Paragneiss succession which is a northern continuation of the Chipisa Paragneisses The Chipisa Paragneisses were dated by Loney (1969), and yielded a recalculated Rb-Sr WR age of 2443 ± 90 Ma. This imprecise result was interpreted by Master (1991, 1996) as indicating a Neoarchaean to Palaeoproterozoic age for the metamorphism that affected these rocks. The Kariba Paragneisses consist of foliated biotite paragneisses with calc-silicate bands and thin leucogneisses. The Kariba sillimanite quartzites occur interbedded within the Kariba Paragneisses, and are regarded as an arenaceous facies of the paragneiss. Loney (1969) obtained a (recalc. WR) Rb-Sr age of 2368 ± 92 Ma for the Kariba Paragneisses. Master (1991, 1996) considered this imprecise age as a minimum, metamorphic age, with the age of sedimentation of the protoliths being unknown, but most probably Neoarchaean or earliest Palaeo-proterozoic.

The new precise U-Pb zircon ages from the Kariba sillimanite quartzite indicate that the protoliths had a maximum sedimentary age of 2.018 Ga, and that they were metamorphosed at c. 1.96 Ga, during intrusion of the Kariba porphyritic granitoids. This means that the Kariba Paragneiss protolith was a sedimentary succession that was synchronous with the intrusion of the Andean arcs on the western edge of the Magondi Belt and Zimbabwe Craton.

Figure 12. Folded Kariba sillimanite quartzite from the Kariba Paragneiss, exposed in roadcutting at Kariba Heights. This quartzite has a maximum age of 2.018 Ga, which is the age of the youngest concordant detrital zircon (Master *et al*., 2015).

Stop 9.The Kariba Dam Observation Point. 16°31’23.3”S, 28°46’0.4”E

The steps ascending to the interpretive centre (beneath the crochet work) at the Observation Point, and those beyond, reveal banded Kariba Quartzite, with apparent biotite gneiss interleaved in either bedded or thrust relationship. It is in this situation where weathering is deep and where the dip corresponds with the hill slope, landslip took place threatening to disrupt the tailraces on the south bank. Extensive drainage, rock bolting and slope sculpture has aleviated this threat. The weathered contact on the south dam abutment was also associated with a highly weathered 'mica band', which was replaced by concrete buttresses to take the dam thrust – hence the south-bank car park.

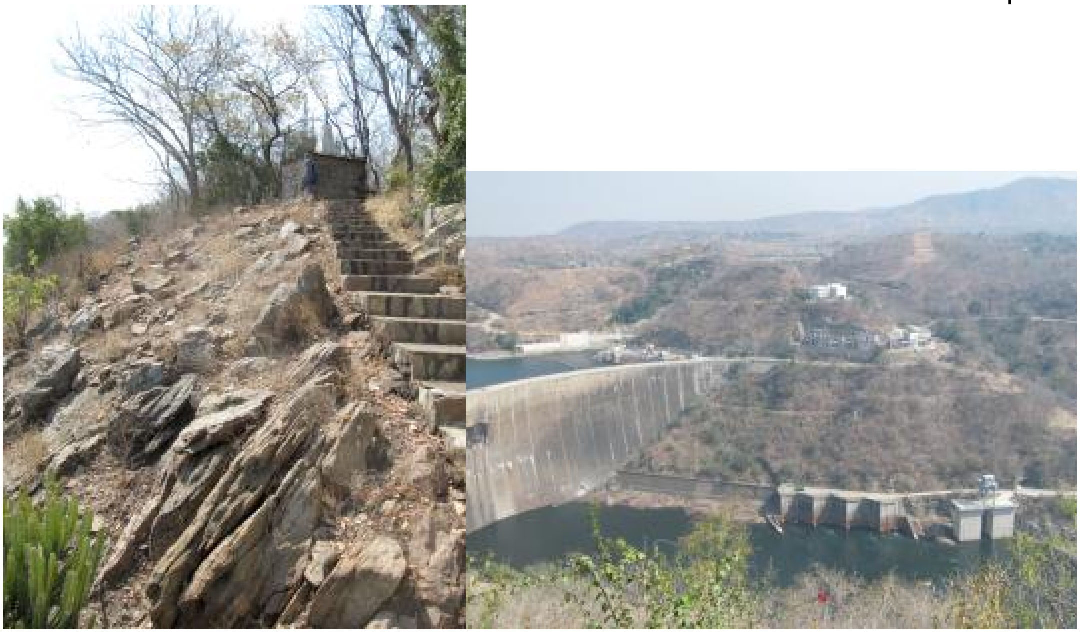

Figure 13 a and b: Banded Kariba Quartzite with weathered gneiss dipping downslope to the gorge, and view to the north-bank with new civil developments relating to the two new 180MW generators.

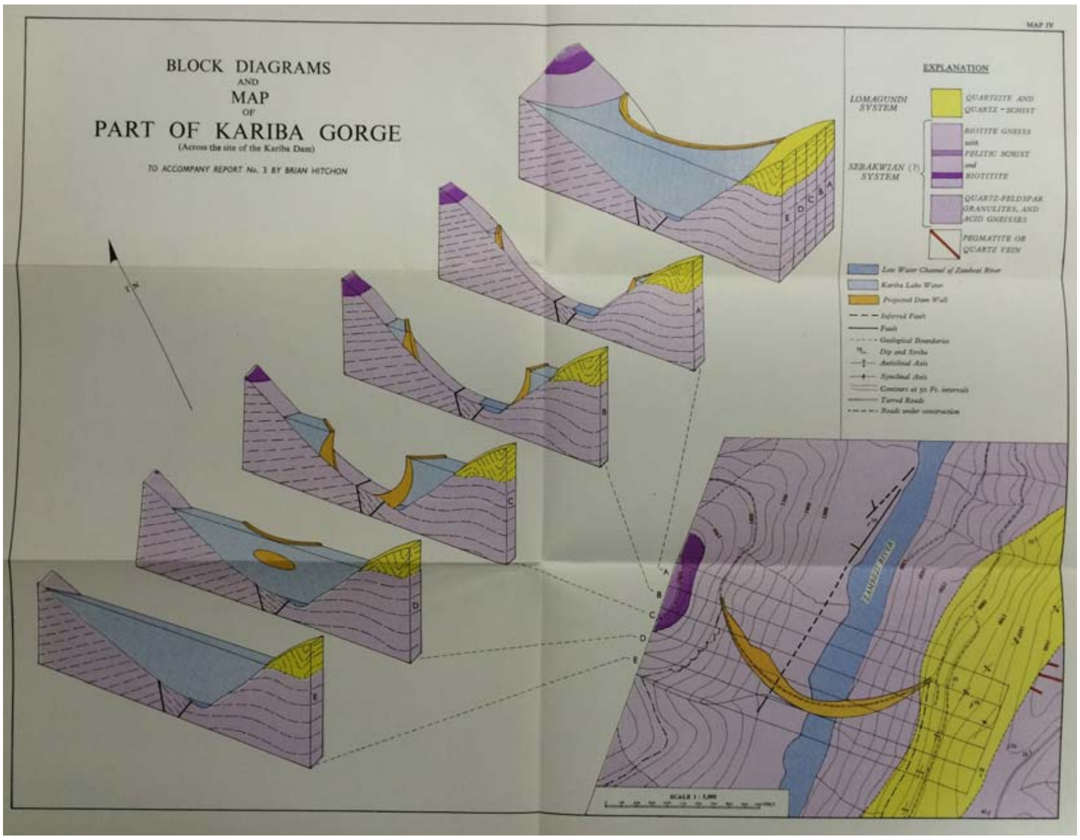

Figure 14: Geological plan and sections across the Kariba dam wall and abutments. Hitchon, 1958.

Other Points of Interest along the route

Way Point	UTM Zone 35k ARC1950 Easting	UTM Zone 35k ARC1950 Northing	Map	Location
Zim 22	761550	8176600	1629A4	Nyachimwe R Urungwe Gn, 2704.2±0.3 Ma
Zim21	761630	8176630	1629A4	Nyachimwe R 'Makuti' Gn, 2510.2±0.4 Ma
Zim23	761700	8176600	1629A4	Nyachimwe R Makuti Gn, 737.1+0.9 Ma
WP098	751773	8188865	1629A4	Folded Makuti Gneiss
Zim 20	735300	8197250	1629A1	NW Makuti, gneiss nr top, 794.1±0.9Ma
TS 8	733100	8200300	1629A1	NW Makuti, gneiss top, 854.4±0.8 Ma
WP102	730659	8208443	1629A1	Makuti marble, Zambezi Escarpment
WP126	739583	8195155	1629A3	Makuti Gneiss, Makuti Cuttings
WP125	723266	8194255	1629A3	Low grade Makuti metapelite - greenschist
WP124	720150	8190077	1629A3	Camp Hill cutting, Makuti Gneiss
WP123	720007	8188757	1629A3	Cutting near Razor Ridge
WP122	717949	8187594	1629A3	Folding, Kidney Hill
TS 11	717850	8186900	1629A3	Makuti Gneiss, Kidney Hill, 796.0+0.9Ma
Zim 24	714950	8182400	1629A3	Makuti Gneiss nr Kaburi, 763.7±0.9Ma
WP119	703951	8174107	1628D2	Glitterstone Quarry, Makuti muscovite quartzite

Age dates refer to Dirks *et al.*, 1999

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