

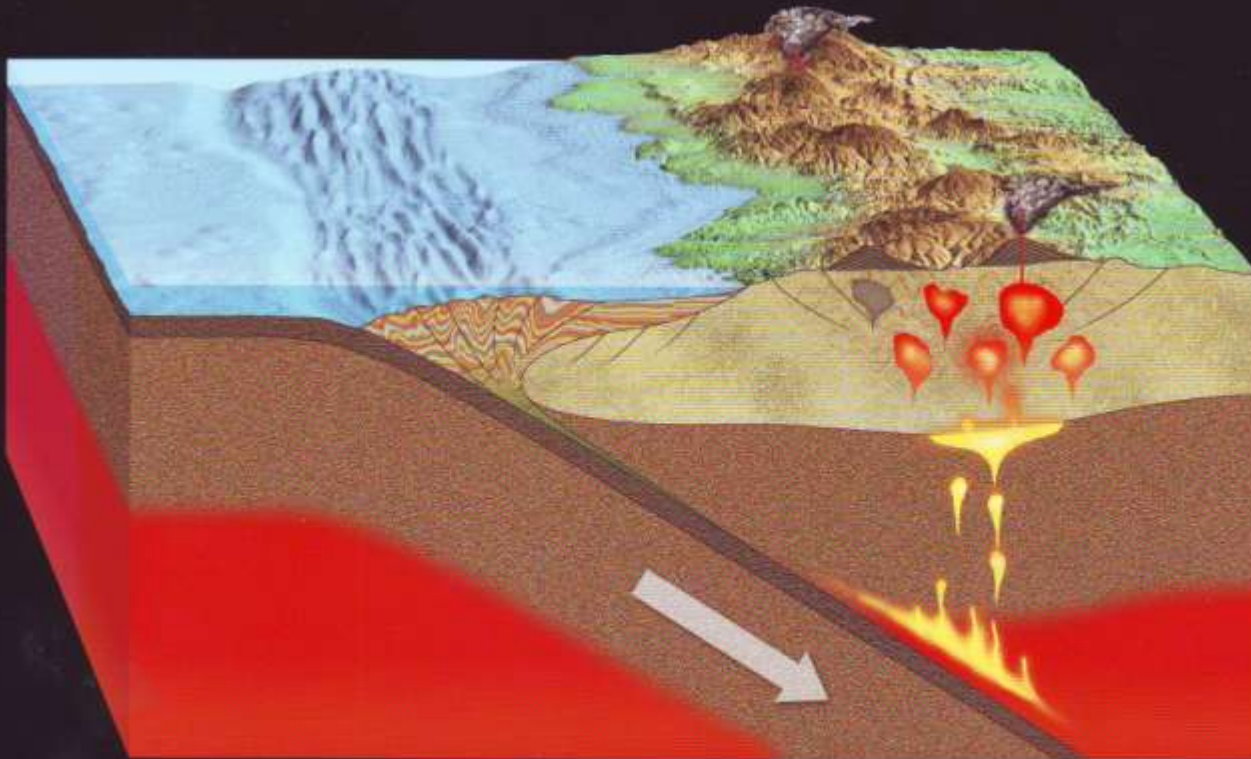
The Source and History of the Sand River Gneisses, Limpopo Belt, South Africa

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When Did Plate Tectonics Begin on Planet Earth?

edited by Kent C. Condie and Victoria Pease



- Did the Sand River Gneisses form by slab melting or melting of the overlying mantle wedge?

- TTG and adakite

- Review its post-emplacment history

Geochemical investigations
on high-grade metamorphic rocks from
the Central Zone of the Limpopo Belt,
South Africa and implications
on Archaean crustal evolution

Diplomarbeit

Roland E. B. Seubert
2009

Institute for Geology



Julius Maximilian University
Würzburg

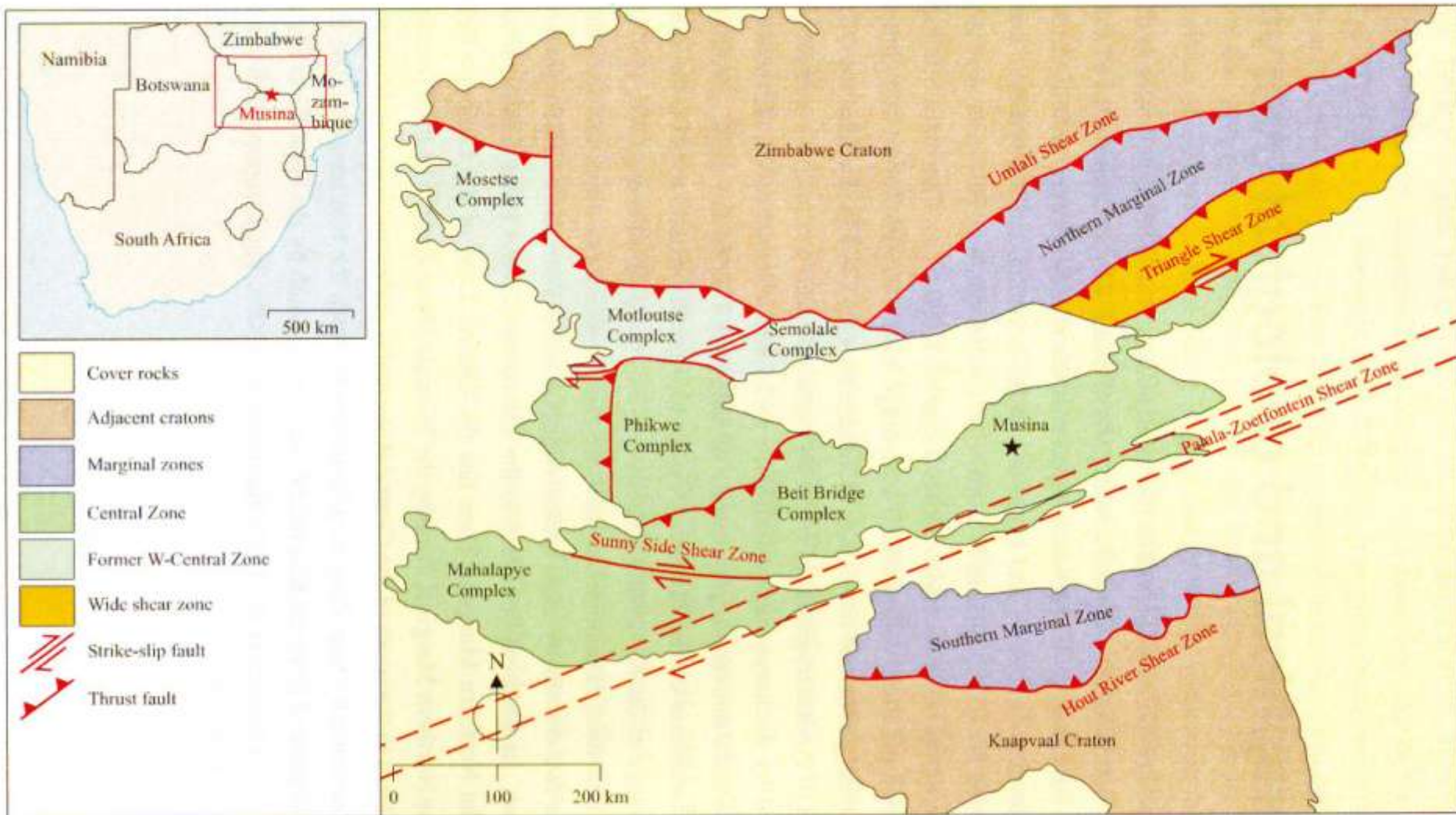


Seubert, R.E.B., 2009. Geochemical investigations on high-grade metamorphic rocks from the Central Zone of the Limpopo Belt, South Africa and implications on Archaean crustal evolution. Diplomarbeit (unpublished), Julius Maximilian University, Würzburg, 124 pp., 26 fig., 4 tab.

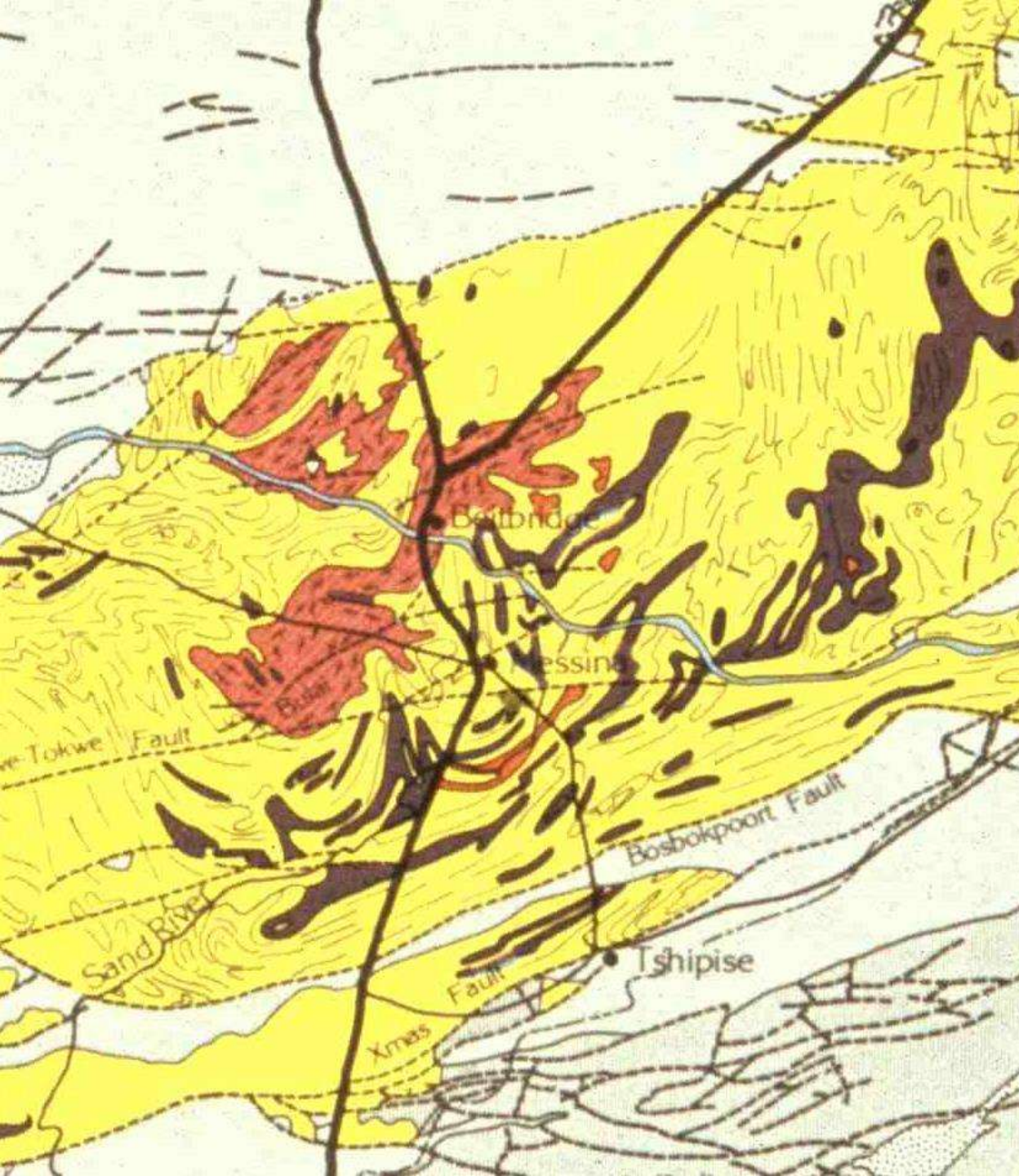
New information
presented here derives
from the Diploma thesis
of the first author

Thesis also dealt with
the Messina Layered
Intrusion and the
Singelele Gneiss

Age data: Zeh et al.,
2007; 2008; 2009,
2010a; b; Millonig et al.,
2010 and unpublished



The Sand River Gneisses are exposed approximately 10 km east of Musina in the Beit Bridge Terrane of the Central Zone of the Limpopo Belt



The Sand River Gneisses intrude the paragneisses of the Beit Bridge Group and the orthogneisses of the Messina Layered Intrusion



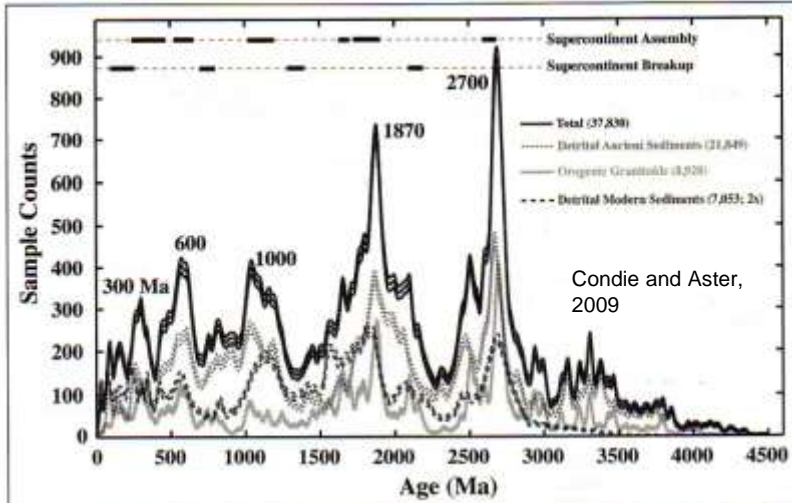
Sand River Gneisses

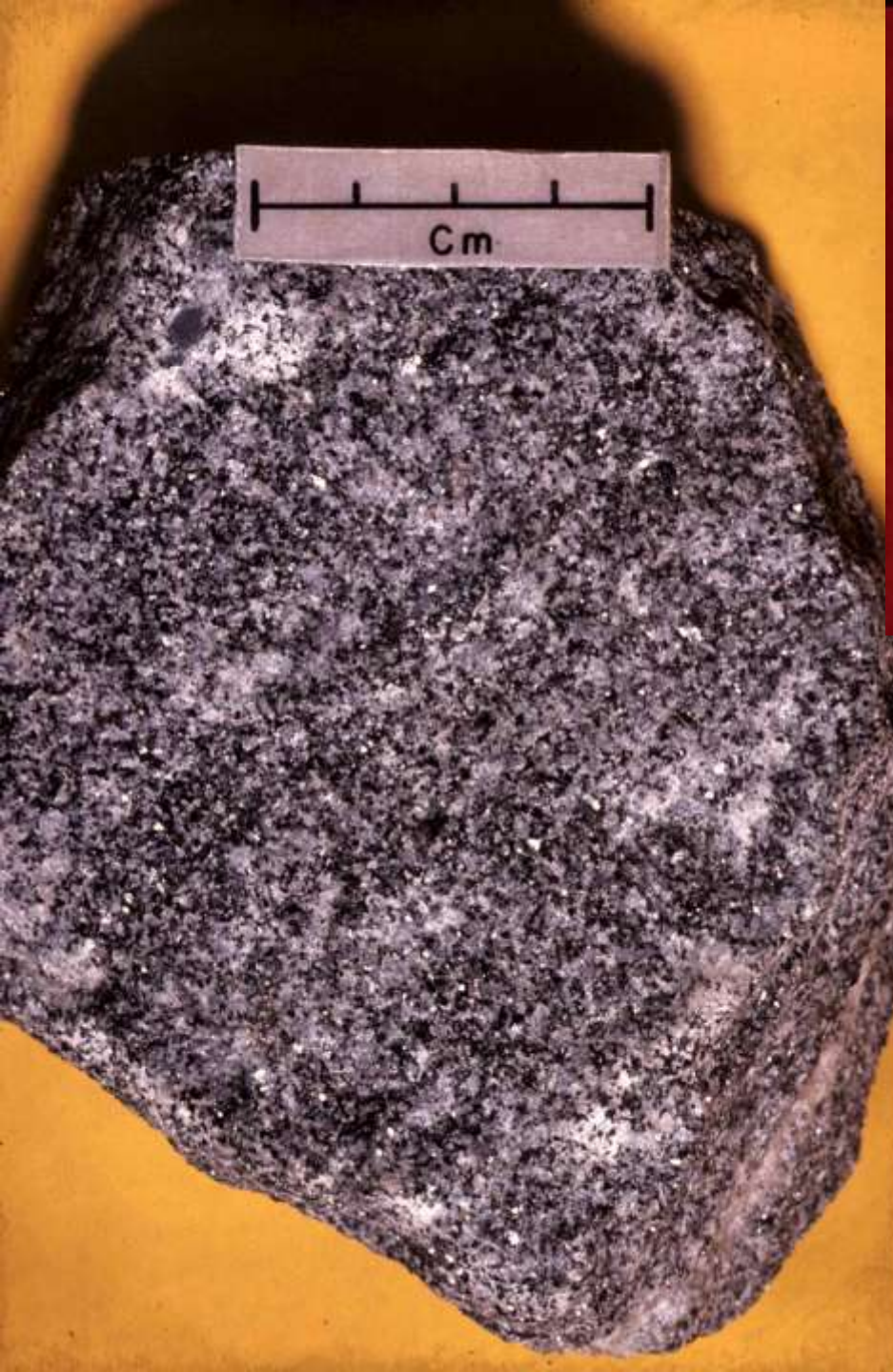
Grey, charnoenderbitic to charnockitic phase 3.27 Ga

Leucocratic, enderbitic phase 3.27 Ga

Lu-Hf age: 3.6 Ga, i.e. some zircon derived from an older crustal lithology

3.4 to 3.91 Ga zircon grains identified within the surrounding quartzite



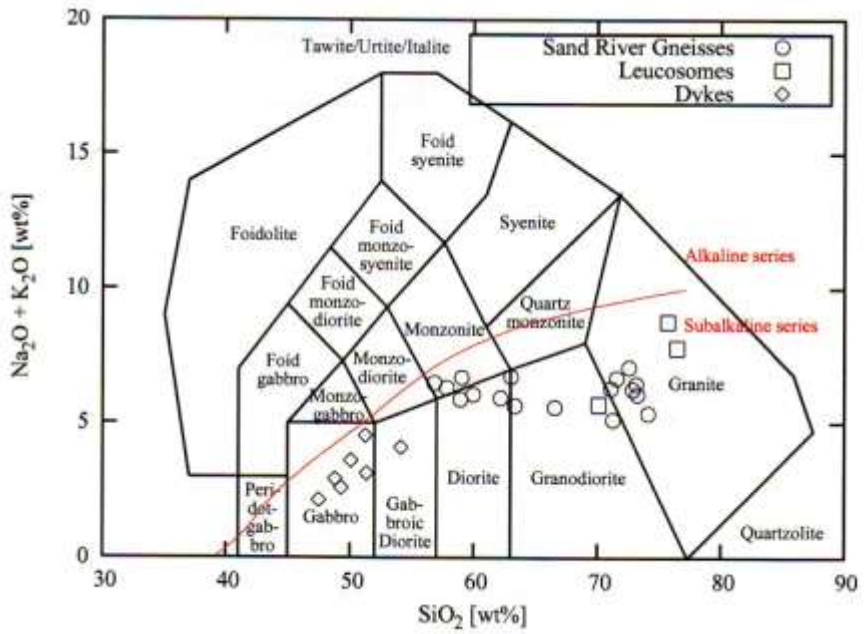
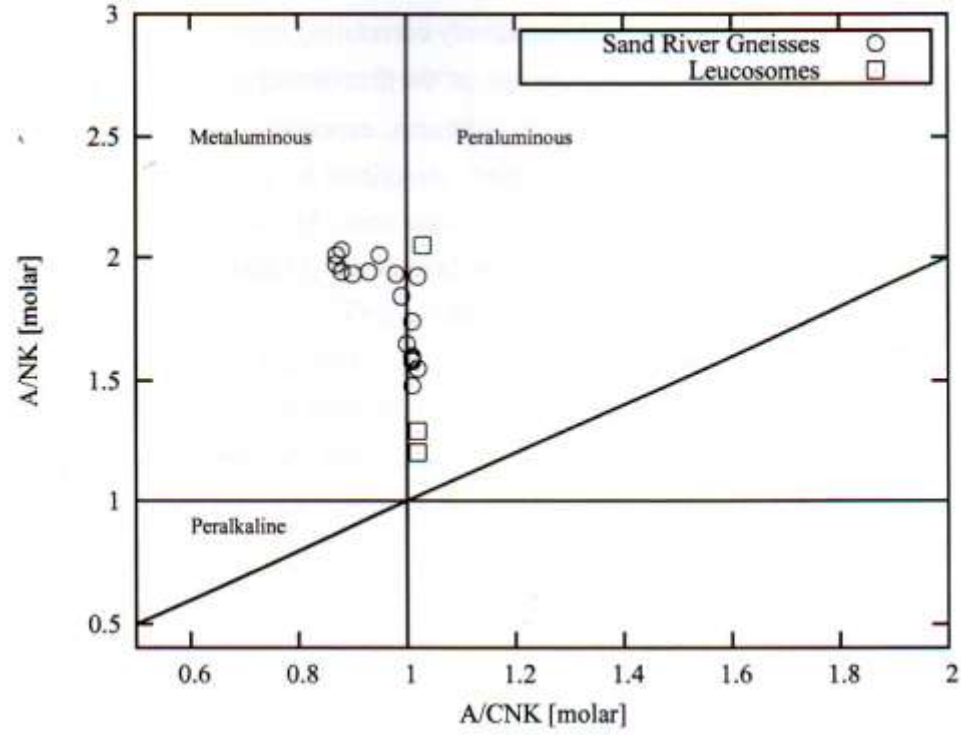
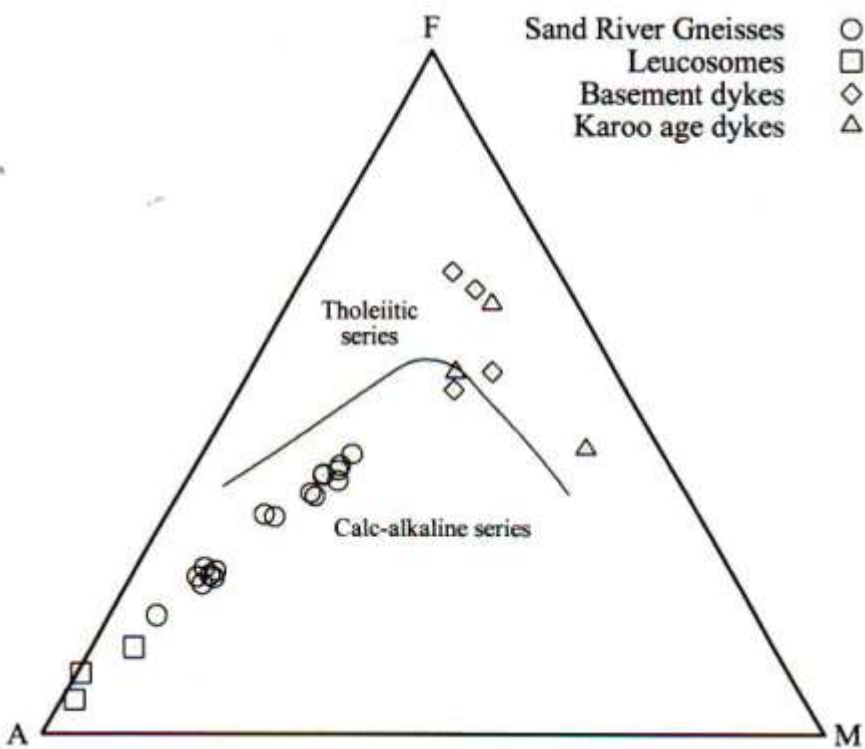


Sand River Gneisses

Grey gneiss phase left and leucocratic phase above

Leucocratic minerals: quartz + plagioclase potassium feldspar

Mafic minerals: biotite + orthopyroxene -- most K in biotite



Sand River Gneisses

- Calc-alkaline
- Metaluminous
- I-type



Intruding the Sand River
Gneisses are Older and
younger granitic leucosomes:
3.06 Ga and 2.02 Ga relative to
~3.0 Ga mafic dykes

Quartz + plagioclase + K-
feldspar biotite



Sand River Gneisses intruded the 3.36 Ga Messina Layered Intrusion



Sand River Gneisses were partially melted at 2.02 Ga and the melt was sometimes remobilized during deformation into veins of the younger leucosome

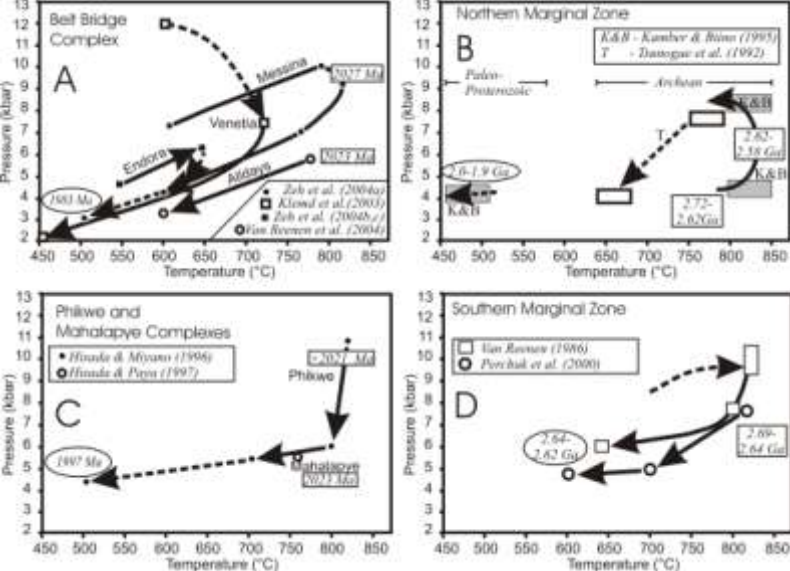
Sand River Gneisses

Partial melting at 2.02 Ga by
vapor absent biotite breakdown

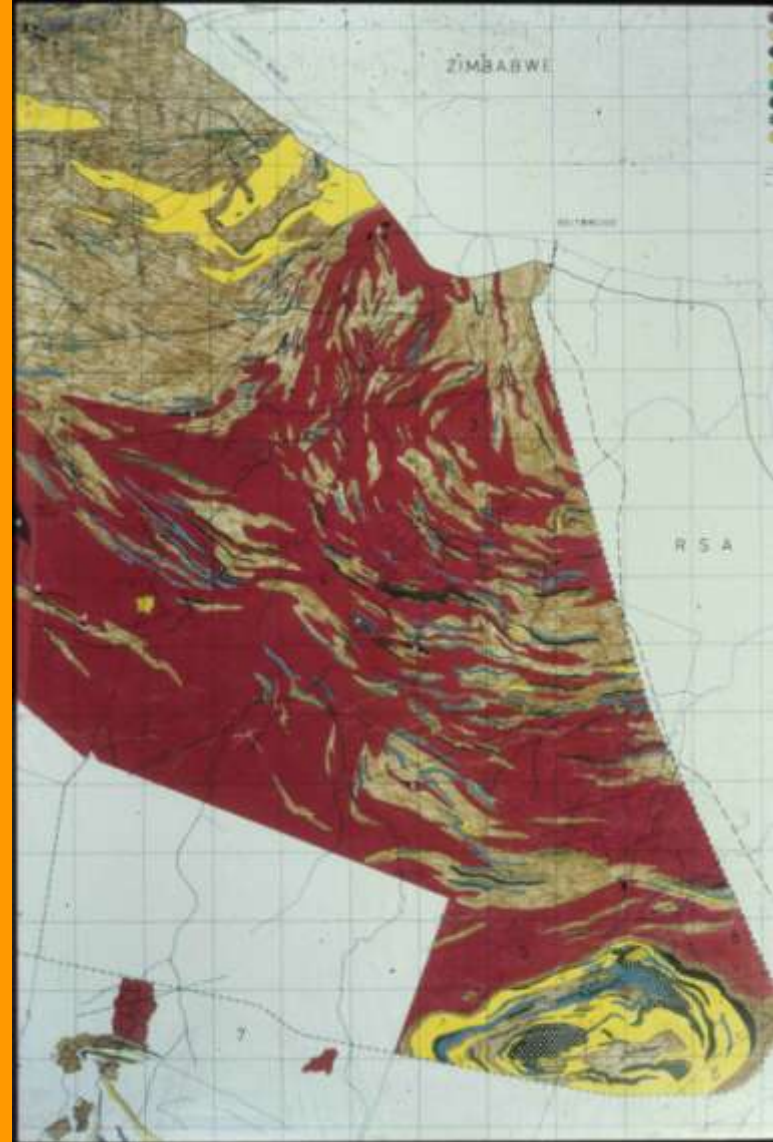
quartz + plagioclase + biotite =
orthopyroxene + K-feldspar +
granitic melt

Orthopyroxene is retrogressed
locally to biotite





Barton et al., 2006



The area around the Sand River Gneisses has experienced at least three periods of high grade metamorphism, ~3.06, ~2.6 and ~2.04 Ga. The ~2.6 event is associated with widespread magmatism.

What Is New?

- Trace Element Modelling

The Samples of Sand River Gneisses And Leucosomes That Were Analyzed For This Study For Trace Elements

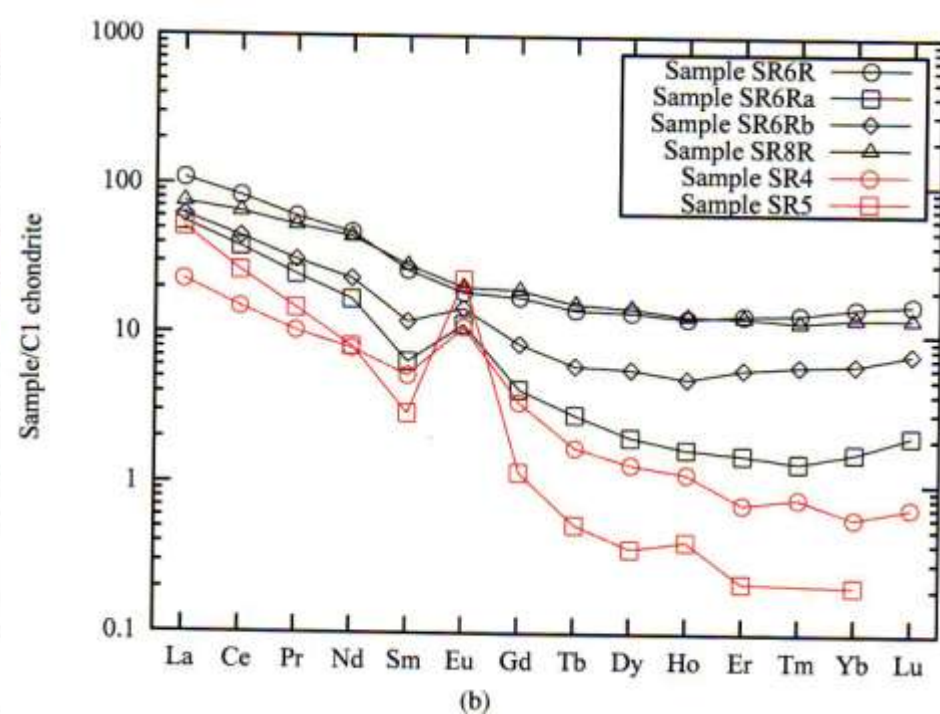
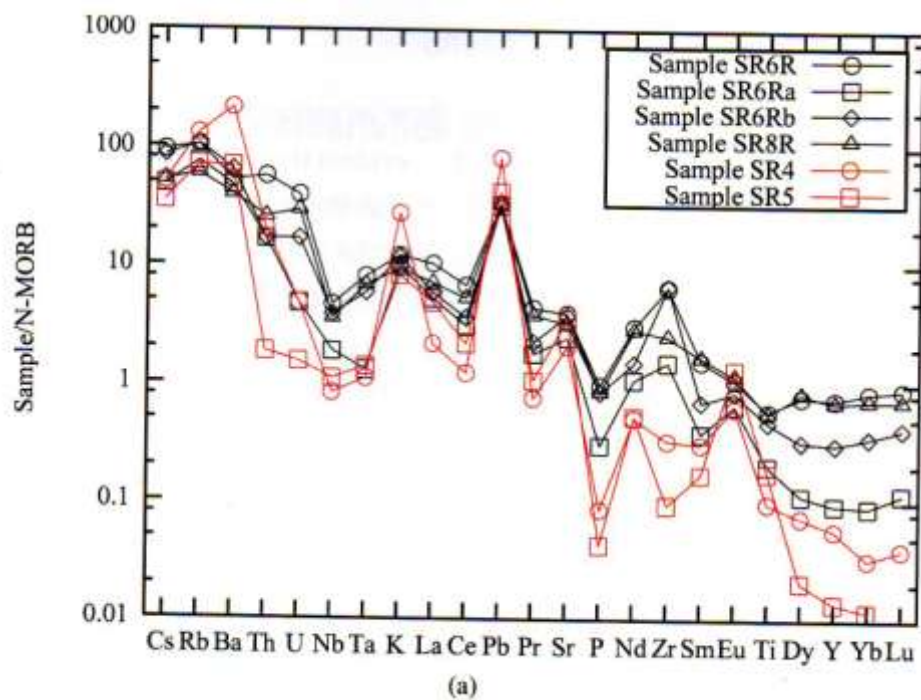
	Grey Gneiss				Leucocratic Gneiss		Old Leucosome		Young Leucosome	
	Frapp (1981) n = 20	SR6R	SR8R	SR6Rb	Frapp (1981) n=14	SR6Ra	Frapp (1981) n = 7	SR4	Frapp (1981) n = 7	SR5
SiO ₂	61.01 ± 2.36	58.84	59.96	62.79	72.82 ± 2.82	73.69	76.63 +/- 0.86	75.69	73.71 +/- 0.57	69.08
TiO ₂	0.75 ± 0.14	0.75	0.72	0.6	0.27 ± 0.12	0.26	0.13 +/- 0.05	0.05	0.06 +/- 0.01	0.15
Al ₂ O ₃	18.24 ± 0.65	19.35	17.91	18.52	14.41 ± 0.91	13.88	13.06 +/- 0.60	13.41	14.80 +/- 0.17	17.61
Fe ₂ O ₃ *	5.86 ± 0.83	5.4	6.31	4.33	2.39 ± 0.82	2.14	1.43 +/- 0.33	0.47	0.89 +/- 0.27	0.98
MnO	0.20 ± 0.08	0.08	0.09	0.05	0.08 ± 0.03	0.03	0.01 +/- 0.03	bd	0.04 +/- 0.02	bd
MgO	2.44 ± 0.25	2.45	2.66	1.71	0.64 ± 0.42	0.84	0.28 +/- 0.09	0.14	0.03 +/- 0.07	0.37
CaO	5.94 ± 0.64	5.91	6.07	4.72	2.81 ± 0.79	3.17	2.31 +/- 0.73	1.5	1.20 +/- 0.37	1.05
Na ₂ O	3.65 ± 0.41	4.91	4.71	4.98	3.82 ± 0.39	3.92	2.98 +/- 1.14	3.69	3.66 +/- 0.61	4.43
K ₂ O	1.56 ± 0.19	1.76	1.36	1.71	2.37 ± 0.85	1.42	2.81 +/- 1.87	4.03	5.27 +/- 1.17	5.77
P ₂ O ₅	0.34 ± 0.24	0.23	0.2	0.2	0.08 ± 0.06	0.07	0.04 +/- 0.02	0.02	0.08 +/- 0.03	0.01
LOI		0.44	0.28	0.5		0.31		0.38		0.72

Comparison of Sand River Gneisses With Adakite and TTG

	Low Silica Adakite	High Silica Adakite	TTG 3Ga<TTG<3.5Ga	SRGn Grey Gneiss 3.27 Ga	SRGn Leucocratic Gneiss 3.27 Ga
	Martin et al. (2005) n = 77	Martin et al. (2005) n = 267	Martin et al. (2005) n = 320	Frapp (1981) n = 20	Frapp (1981) n=14
wt. %*					
SiO ₂	56.25 ± 3.4	64.80 ± 2.5	69.65 ± 3.1	61.01 ± 2.36	72.82 ± 2.82
TiO ₂	1.49 ± 0.7	0.56 ± 0.1	0.36 ± 0.2±	0.75 ± 0.14	0.27 ± 0.12
Al ₂ O ₃	15.69 ± 1.1	16.64 ± 0.9	15.35 ± 1.3	18.24 ± 0.65	14.41 ± 0.91
Fe ₂ O ₃ **	6.47 ± 1.5	4.75 ± 1.0±	3.07 ± 1.6	5.86 ± 0.83	2.39 ± 0.82
MnO	0.09 ± 0.02	0.08 ± 0.02	0.06 ± 0.05	0.20 ± 0.08	0.08 ± 0.03
MgO	5.15 ± 1.5	2.18 ± 0.7	1.07 ± 0.6	2.44 ± 0.25	0.64 ± 0.42
CaO	7.69 ± 1.0	4.63 ± 0.8	2.96 ± 1.2	5.94 ± 0.64	2.81 ± 0.79
Na ₂ O	4.11 ± 0.5	4.19 ± 0.4	4.64 ± 0.8	3.65 ± 0.41	3.82 ± 0.39
K ₂ O	2.37 ± 0.8	1.97 ± 0.5	1.74 ± 9.7	1.56 ± 0.19	2.37 ± 0.85
P ₂ O ₅	0.66 ± 0.3	0.20 ± 0.2	0.14 ± 0.09	0.34 ± 0.24	0.08 ± 0.06
K ₂ O/Na ₂ O	0.58	0.47	0.38	0.43	0.62
ppm					
Sr	2051 ± 537	565 ± 150	429 ± 178	331 ± 46	230 ± 63
Ni	103 ± 58	20 ± 10	15 ± 12	27	9
Cr	157 ± 81	41 ± 26	21 ± 19	22	8
(La/Yb) _N	29.32	14.44	32.86	6.5	22
Yb	0.93 ± 0.2	0.88 ± 0.2	0.63 ± 0.4	2.4	1.9
Y	13 ± 3	10 ± 3	14 ± 19	20	5.7

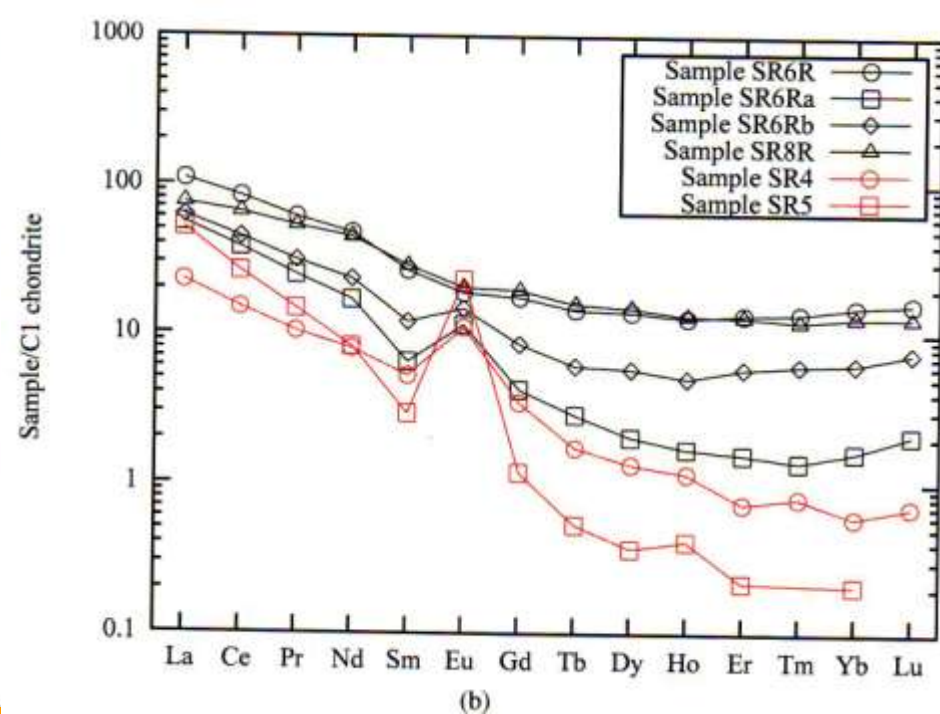
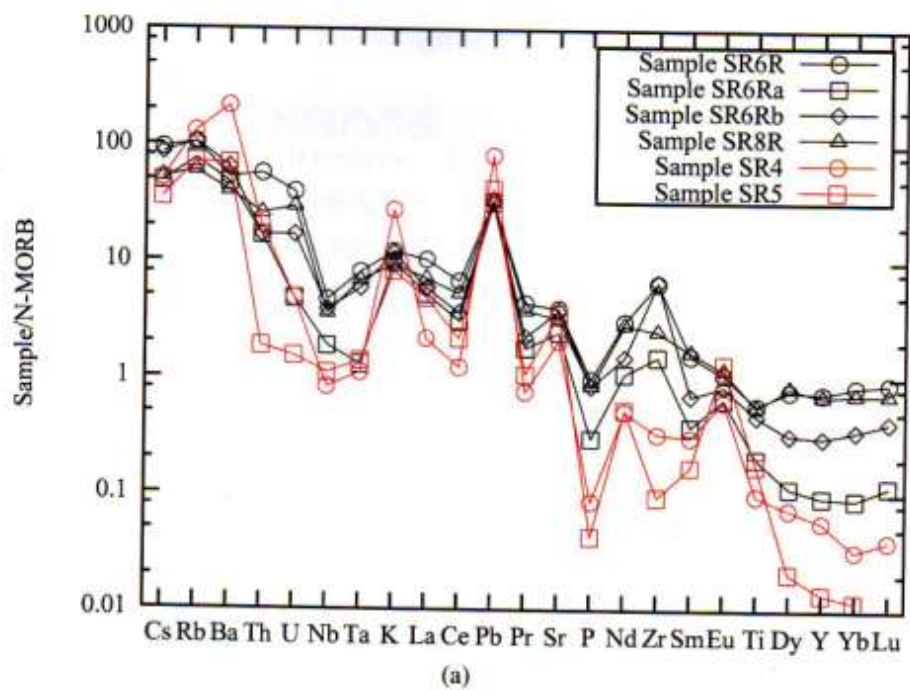
* reported volatile free

** total iron as Fe₂O₃



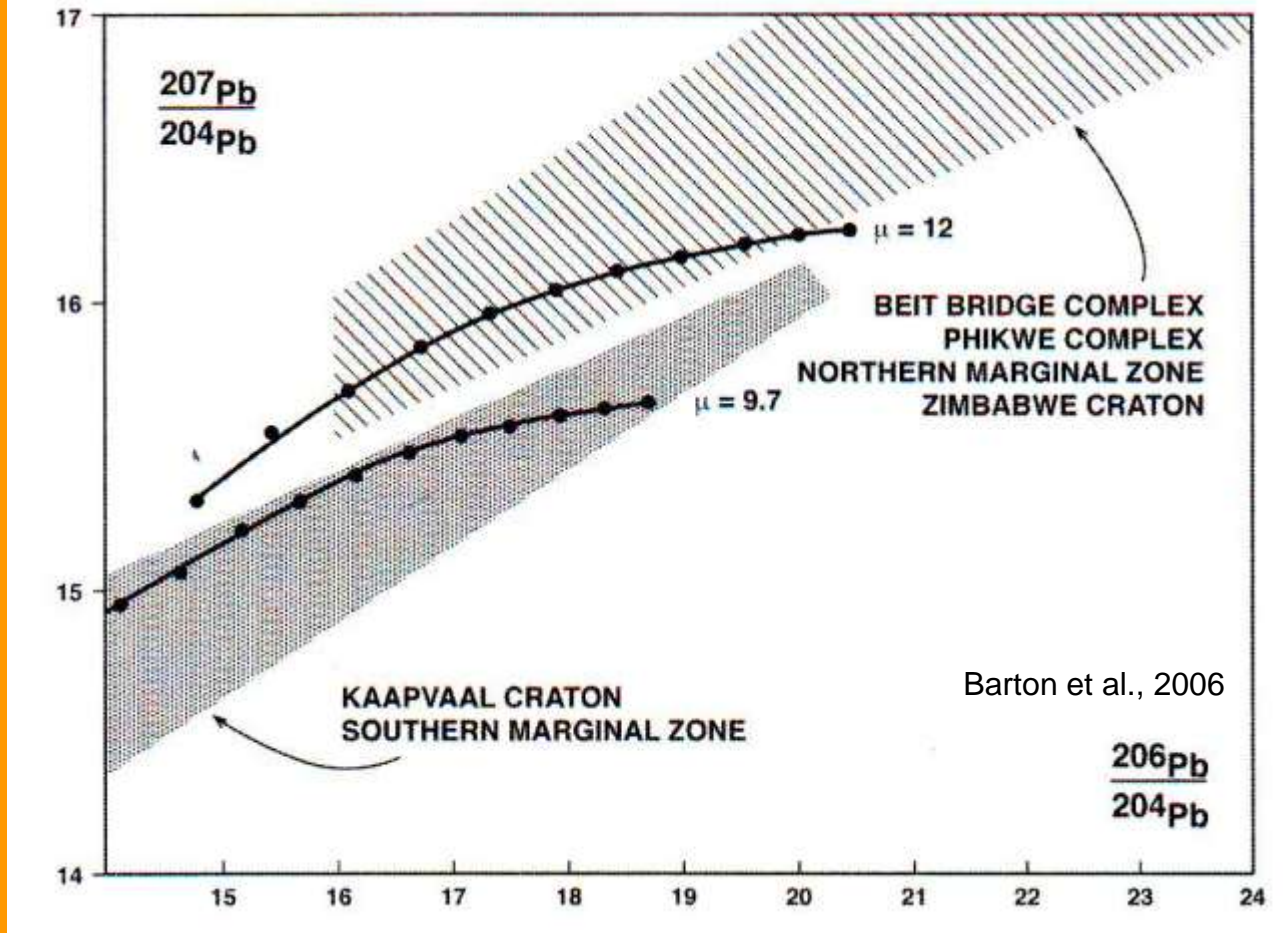
For The Sand River Gneisses (Black):

- Negative Nb, Ta and P and sometimes U, Th and Ti
- Positive Pb and in some cases Eu

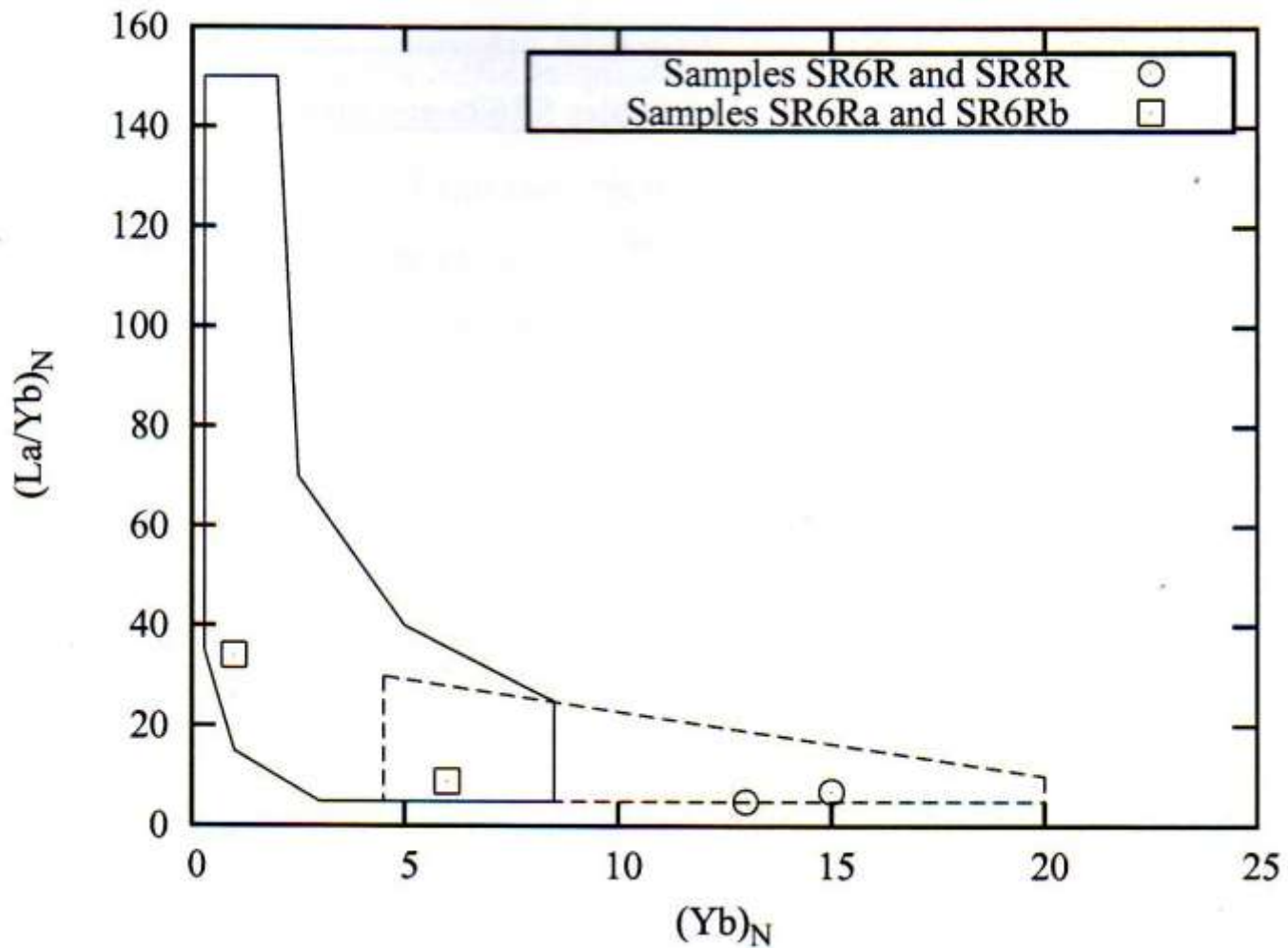


In Addition For The Leucosomes (Red)

- Positive K and Eu
- Negative Th and U

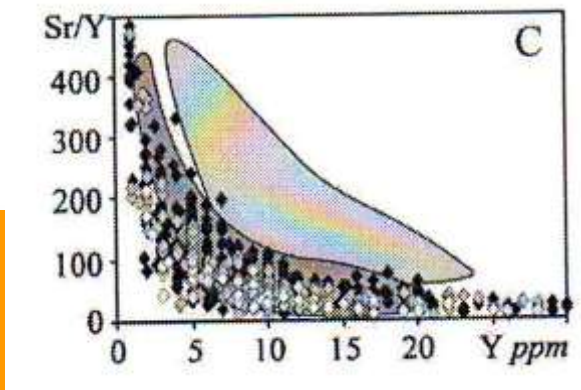
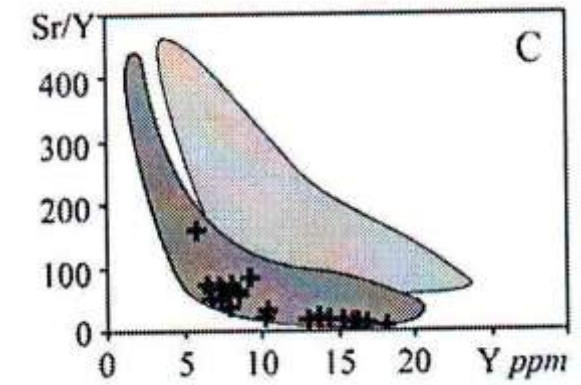
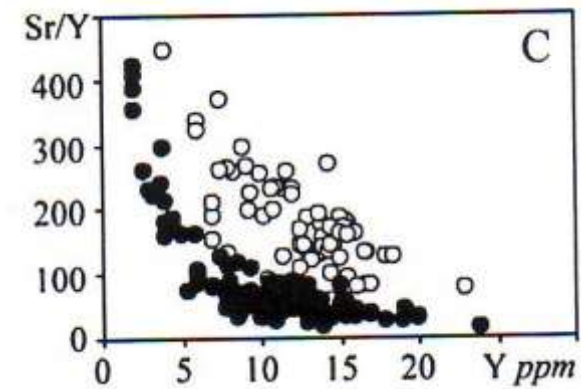
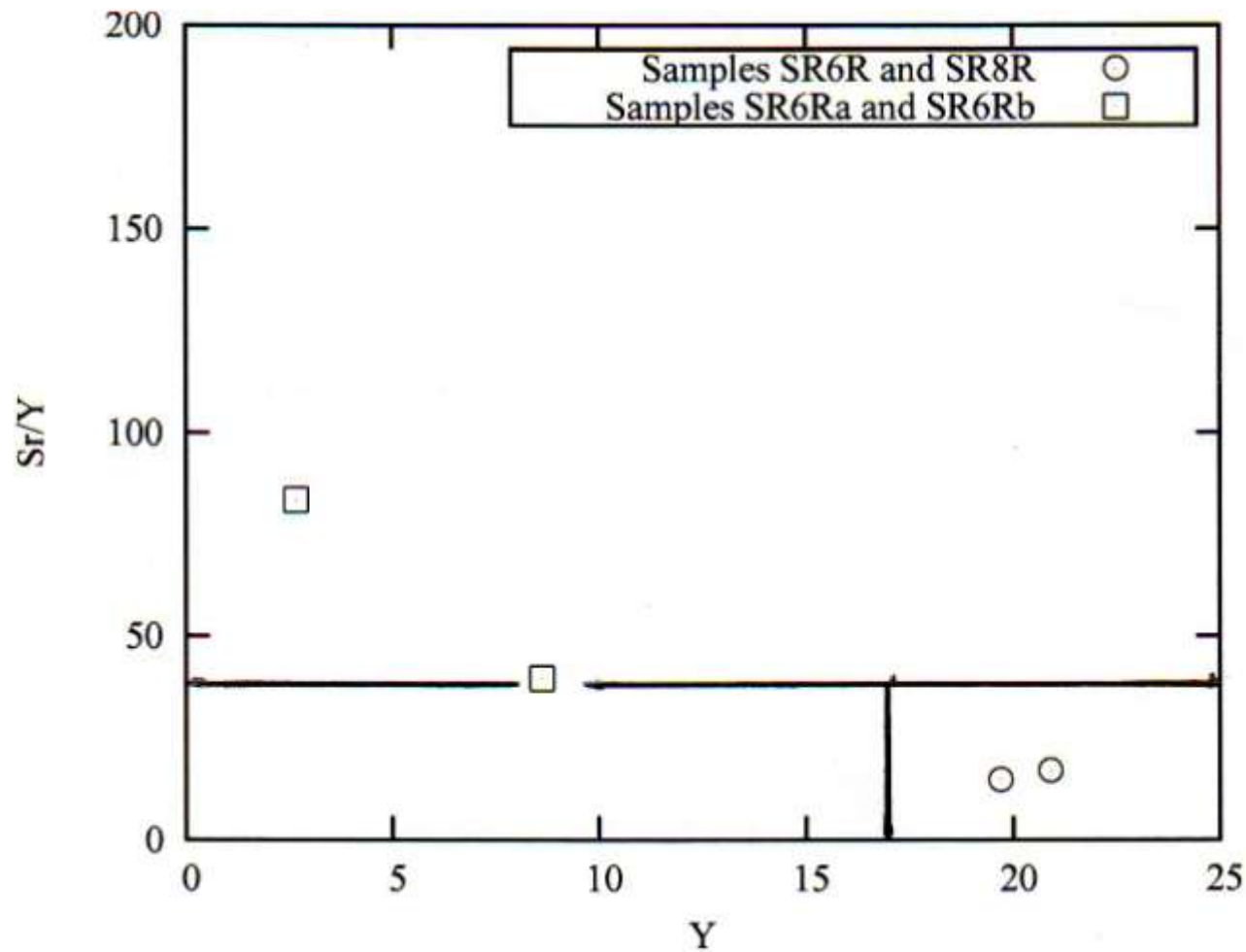


The high Pb concentration as well as the radiogenic nature of the Pb in the Sand River Gneisses strongly suggests that old (Hadean?) felsic rocks with large μ values formed part of the source of the Sand River Gneisses, i.e. crustal igneous rocks or pelitic sediments. See Kamber et al. (2002; 2003)



Seubert, 2009

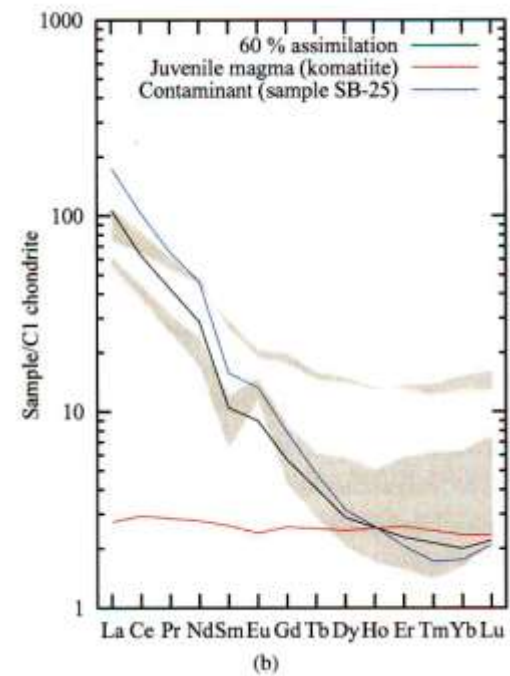
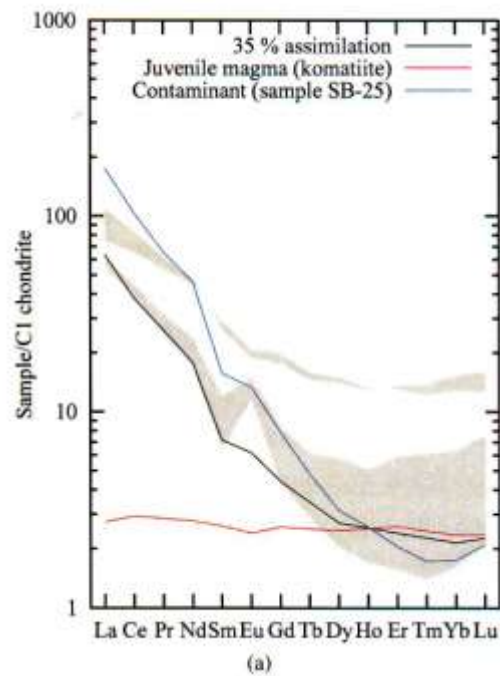
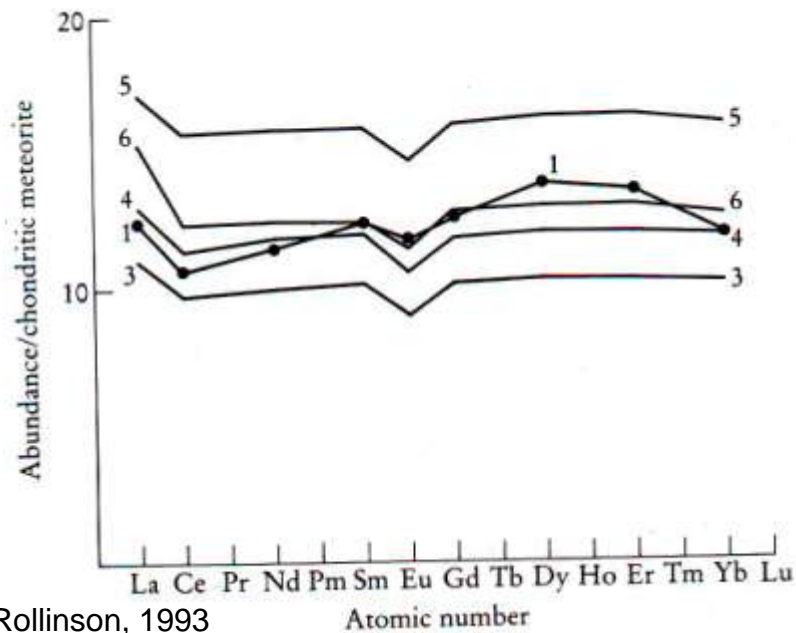
After Martin (1986): The solid field is for Archean TTG rocks and the dashed field is for post-Archean, arc-related, granitoids



Seubert, 2009

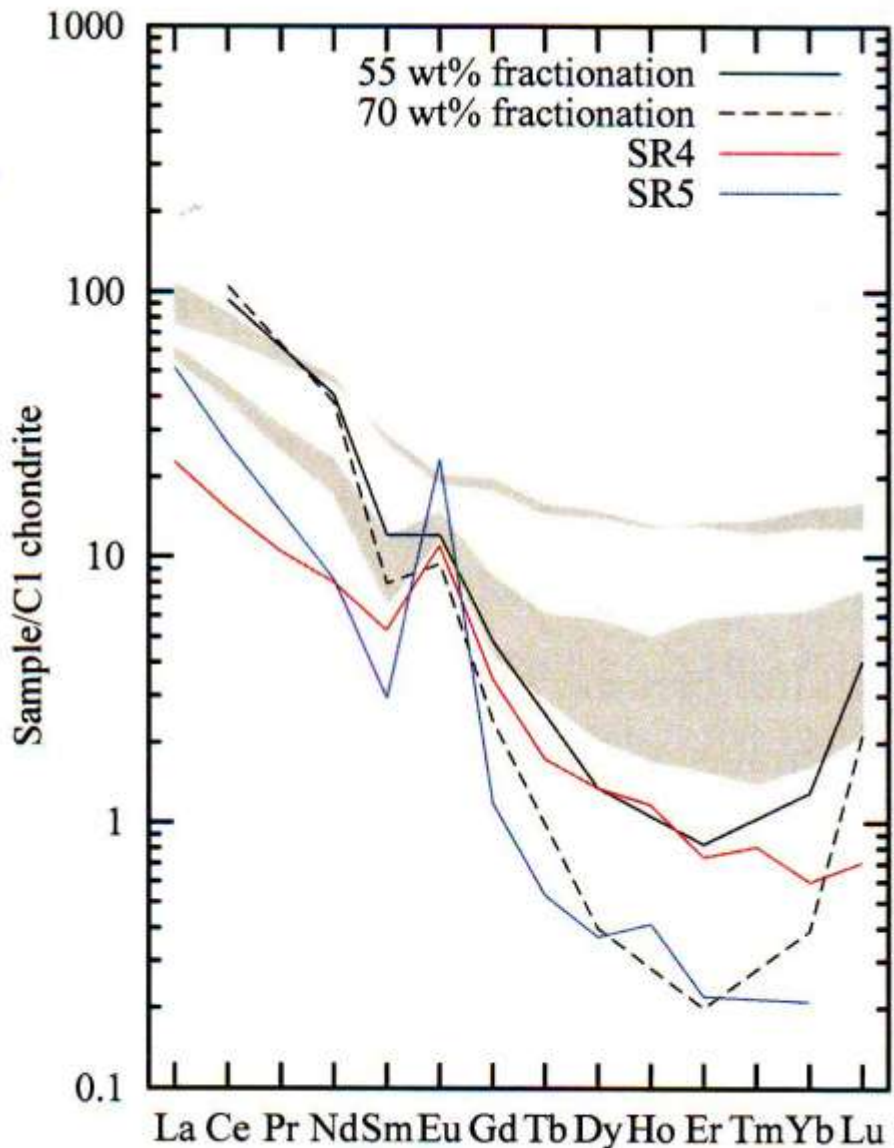
From Martin et al. (2005)

Sr/Y versus Y shows similarities to both high silica adakite and TTG

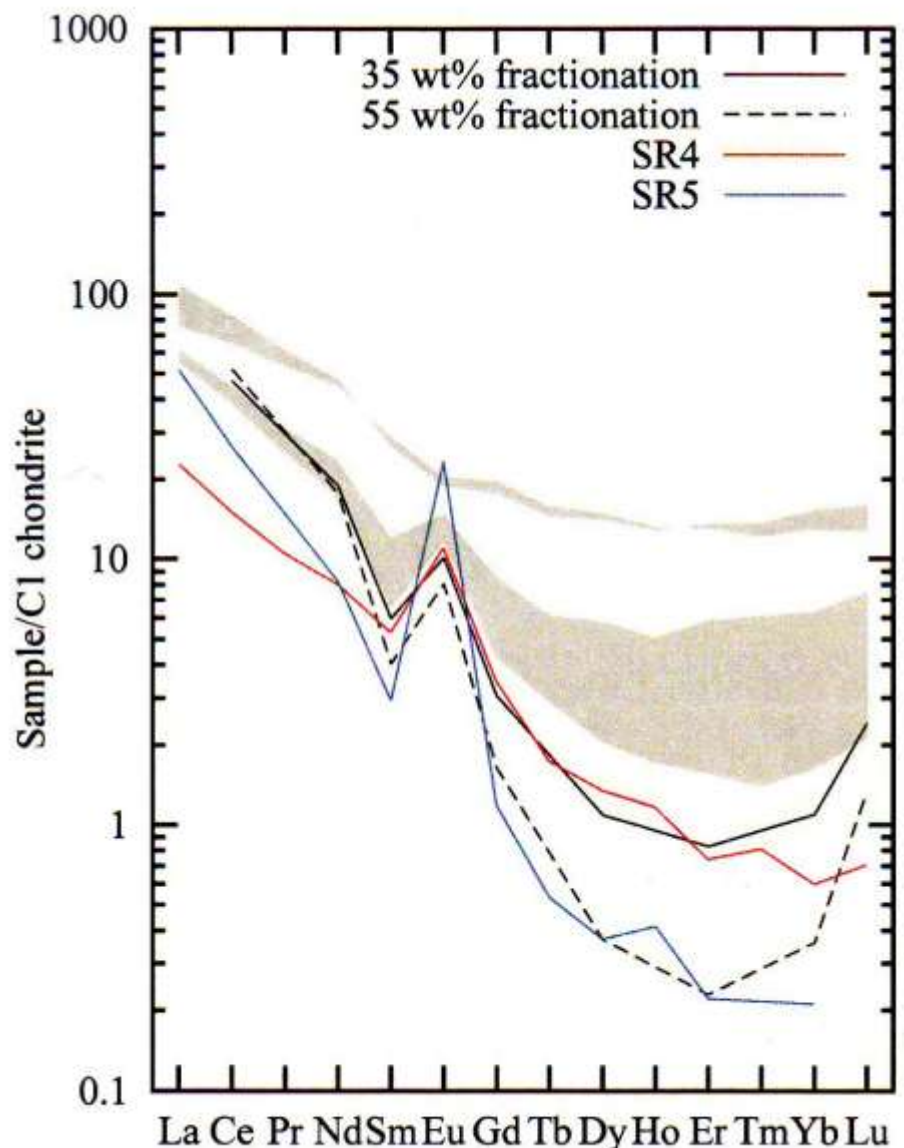


Partial melting of amphibolite with hornblende or clinopyroxene but no garnet can explain the grey gneiss phase

Partial melting of amphibolite with garnet is necessary to explain the leucocratic gneiss phase



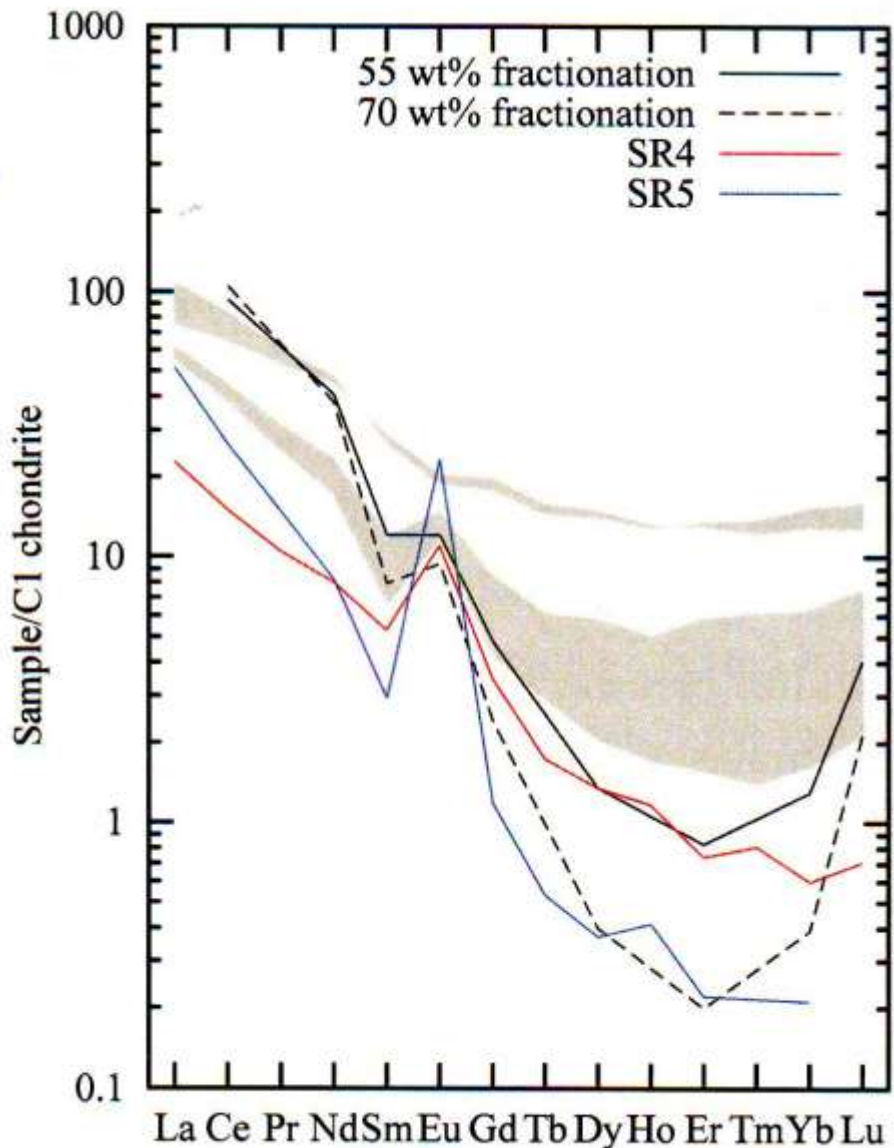
(a)



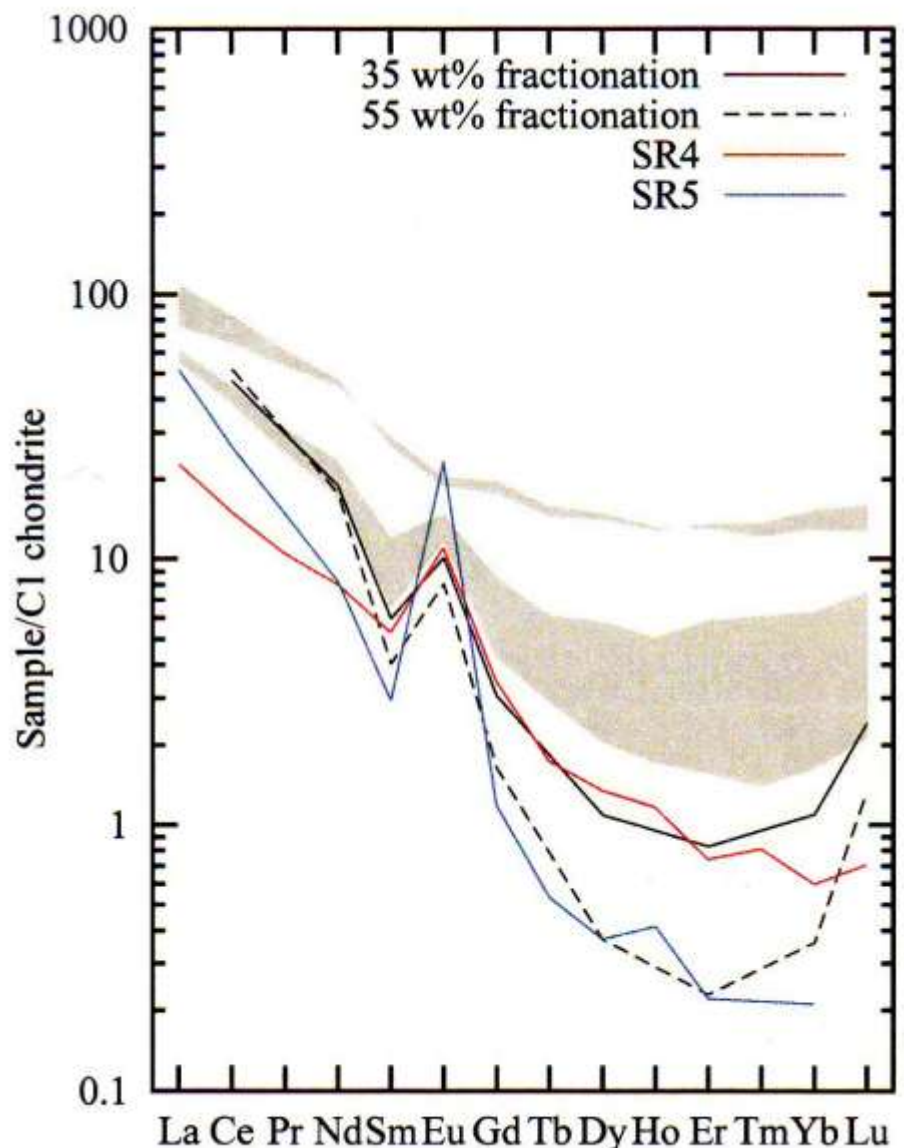
(b)

Seubert, 2009

Fractional crystallization of a magma of composition of the grey gneiss phase (a) and the leucocratic phase (b) can approximate the composition of the older and younger leucosomes



(a)



(b)

Seubert, 2009

But equally, partial melting of these lithologies can produce the leucosomes and partial melting was going on at least at 2.02 Ga

Conclusions

The grey and leucocratic phases of the Sand River Gneisses have chemical characteristics similar to high silica adakites and TTGs respectively

Their origin may be explained by slab melting of a amphibolitic composition with interaction with mantle peridotite in a mantle wedge, i.e. their formation can be explained by plate tectonic mechanisms at 3.26 Ga

The leucosomes may be explained by either fractional crystallization of a magma of the composition of the Sand River Gneisses or, more likely, by fractional melting of the Sand River Gneisses during two distinct periods of granulite facies metamorphism, ~3.06 Ga and ~2.02 Ga.

No leucosomes related to the ~2.6 Ga magmatism related metamorphism have yet been identified in the Sand River Gneisses