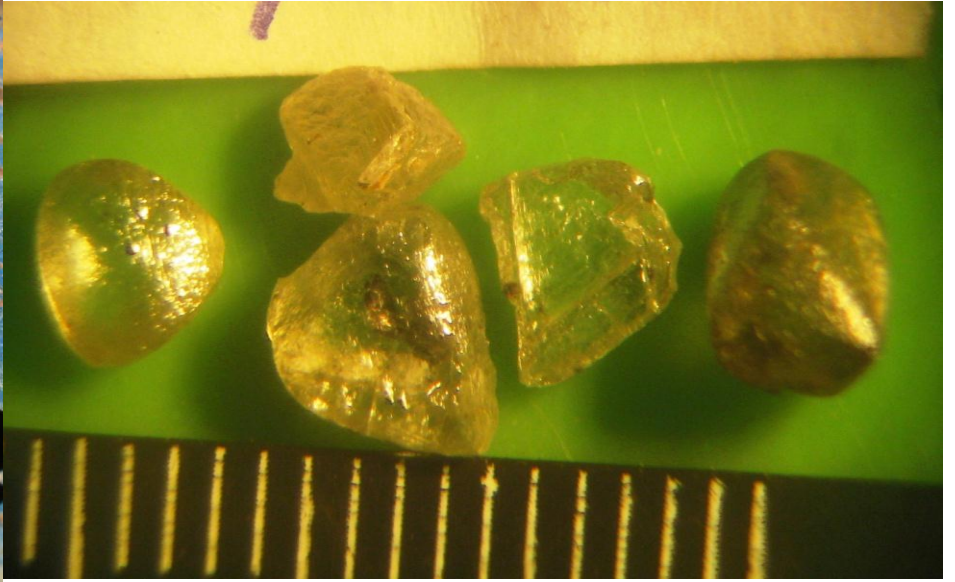


THE COMPLEX TECTONIC SETTING AND PROVENANCE OF THE CHIMANIMANI DIAMONDIFEROUS SEDIMENTS - A DISCUSSION

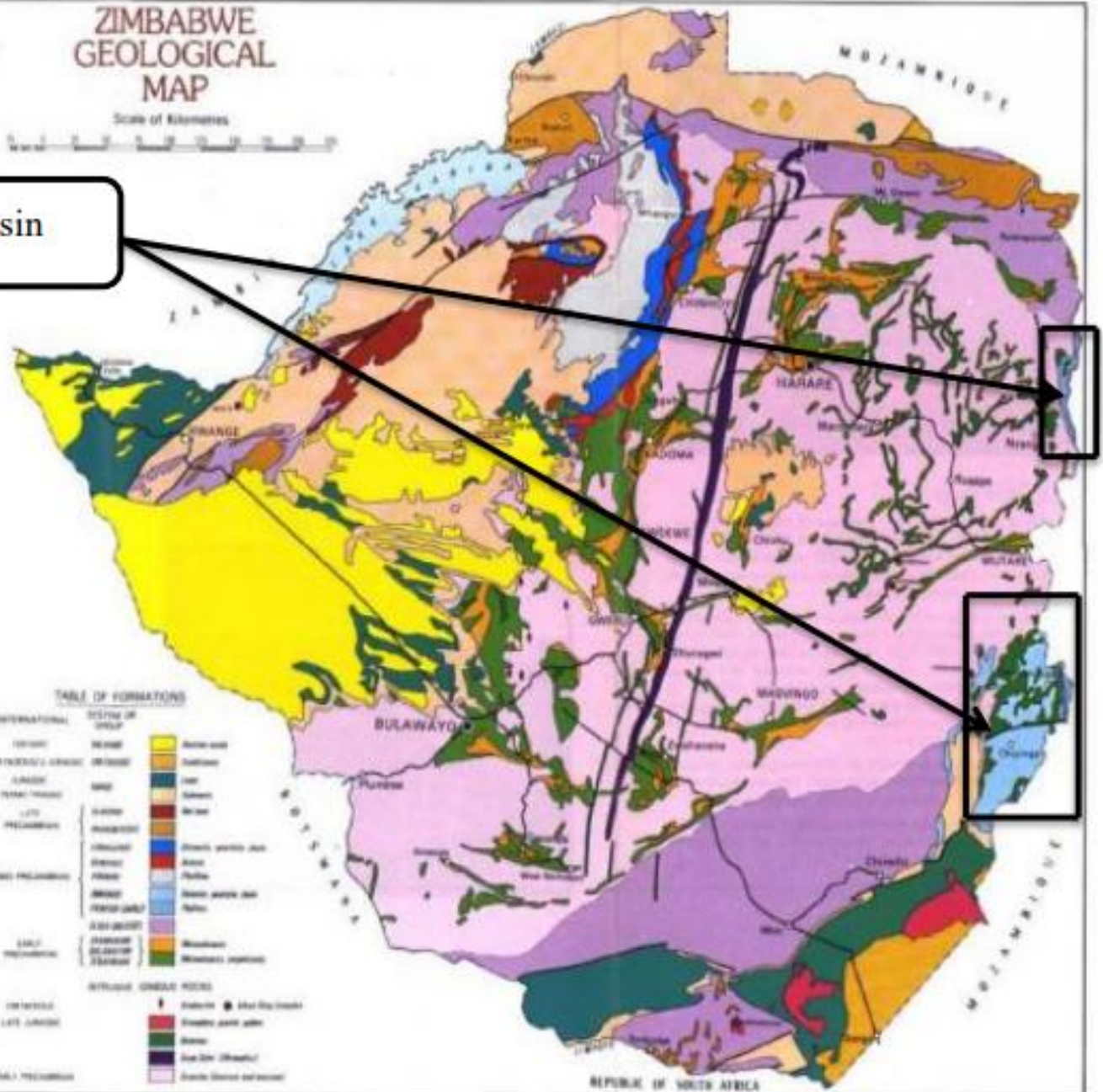
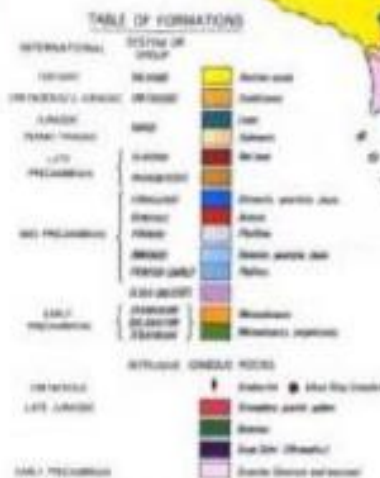
GEOLOGICAL SOCIETY OF ZIMBABWE
SUMMER SYMPOSIUM

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and Dirks P.H.G.M, 2021.



Scale of Kilometres

The Umkondo Basin



Introduction

- Ever since the discovery of the Chmanimani diamond deposit in 2008, geologists have generally debated the provenance of the diamondiferous sediments based on two models.
- One school (Master, person comm, 2012; Zhou, 2015) suggested that the diamondiferous sediments could have been shed from the Frontier Series, striking N-S along the border with Mozambique.
- The other school of thought (Kogan, person comm, 2012), on the basis of diamond morphologies and associated picroilmenites proposed that the source of the diamonds could be intrabasinal and proximal .
- Other observations in this thesis such as Pan African deformation of the Frontier Series (Mukwakwami et al., 2004) and the presence of two diamond formation ages in mobile belts (Koornneef et al, 2017), further make it not easy to decipher the provenance of the diamondiferous sediments in Chimanimani from general assumptions, as the provenance could be related to either of these two ages of formation. These models are hereby reviewed.

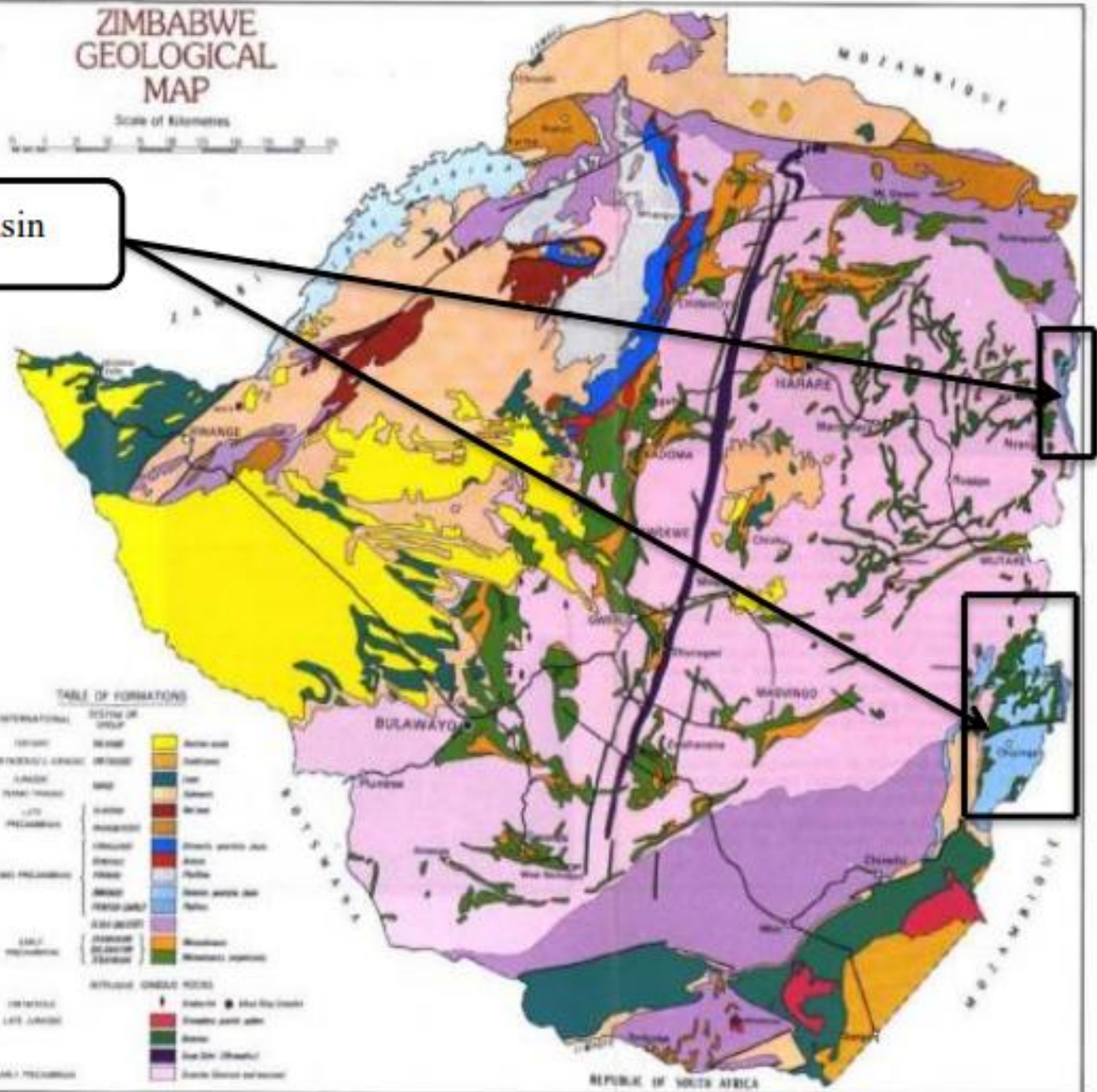
Introduction

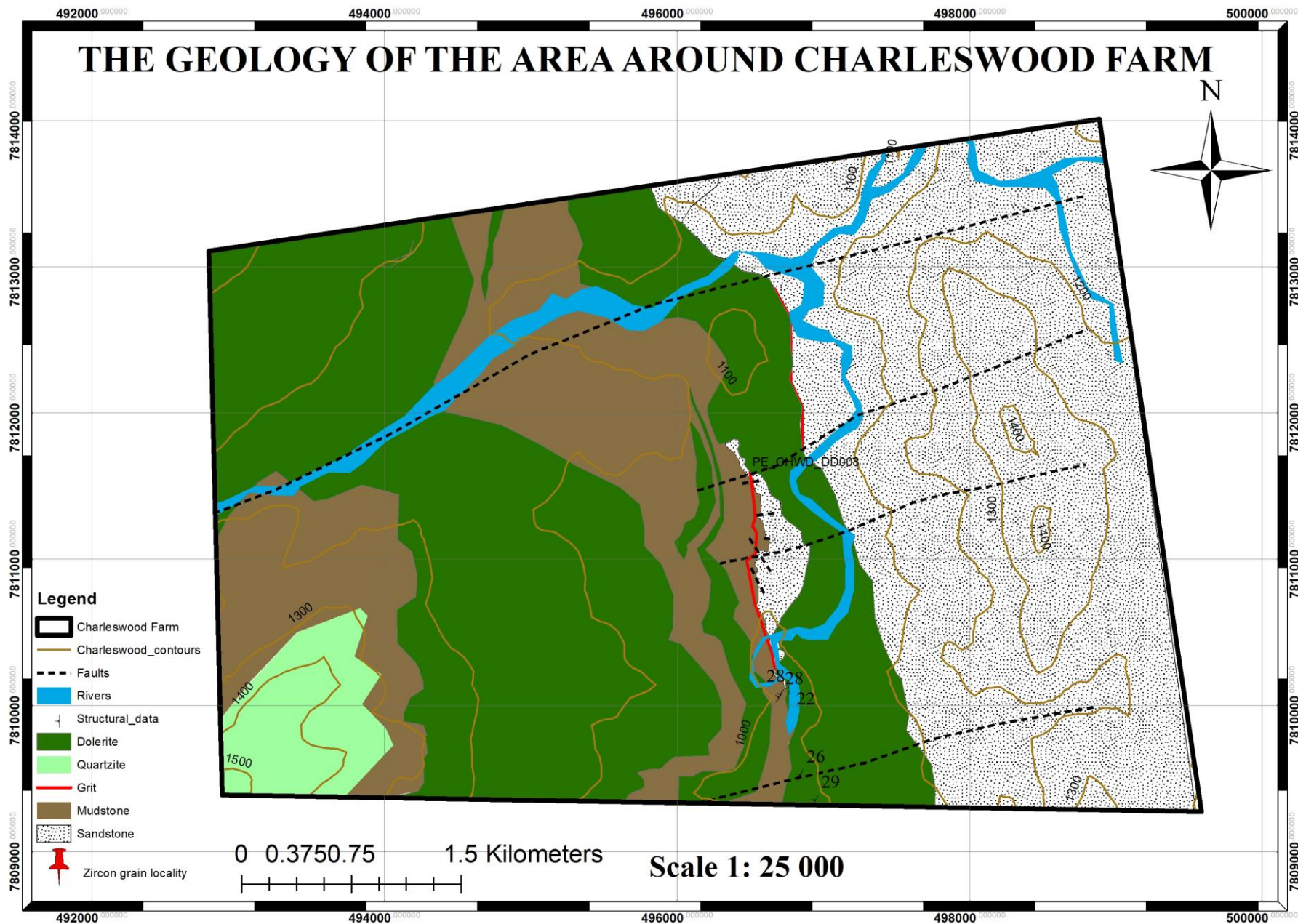
- The project investigates the genesis of diamonds in the Umkondo Proterozoic basin with emphasis on the recently discovered Chimanmani deposit. This is mainly because the key in understanding diamonds in Umkondo.
- Also, the timing of the diamond mineralization and sediments provenance has key implications on tectonics of the Umkondo.
- Specifically the project reviews previously discussed tectonic models of the basin with regards to the diamondiferous sediments and assess where we stand currently.

Geology and stratigraphy

- Various explanations have been advanced on the genesis of diamonds in the Umkondo Proterozoic Basin particularly the Chimanimani deposit and the famous Marange Alluvial Deposits on the western parts of the same basin.
- The Marange deposit is hosted in basal conglomerates overlying Archaean granites (Roberts, 2006), whilst the Chimanimani diamondiferous conglomerates are hosted in the upper facies of the Umkondo stratigraphy in the Lower Argillaceous Series .

Scale of Micrometers





Miners standing on the diamondiferous grit



System	Age	Series	Contact	Lithology	Thickness (m)
Umkondo	Precambrian	■	Major Unconformity		
				Umkondo Dolerites	Total over 1,700
			Intensive contact		
		Upper Argillaceous Series		Red/purple shales and siltstones	500–900
		Quartzite		Black quartz-magnetite ironstone	+450
		Lower Argillaceous Series	Chimanimani diamonds →	Black/grey Shales and siltstones	300–450 in west, 2,500 in east.
		Calcareous Series		cherty calc-hornfels and limestone	240–300 thinning to 0 eastwards
		Frontier Series	Unconformity	Diamondiferous conglomerates	0.1–2
				Upper Chlorite Schists (UCS)	0–330+ in south
				Upper Quartzite (UQ)	150 to over 450 in north
				Lower Chlorite Schist (LCS)	150–450
				Lower Quartzite (LQ)	210–300
			Major unconformity	Diamondiferous conglomerates	
Basement Complex	Archaean			Granite, gneiss, and greenstones	?

Major research question

Is the Chimanimani deposit a product from the same diamond field as Marange or not?

- Some Sedimentologists including Bockstael M., (Person. Comm; 2013) proposed a theory that the diamonds in Marange and Chimanimani are from the same source, based on transgression models where pebble sizes fine deeper into the sea from the shoreline.

Tectonic setting of Umkondo Basin

- Tectonics that led to deposition of the sediments contributes immensely to understanding tectonics of the Mozambique Metamorphic Province and probably discovery of larger similar diamond resources.

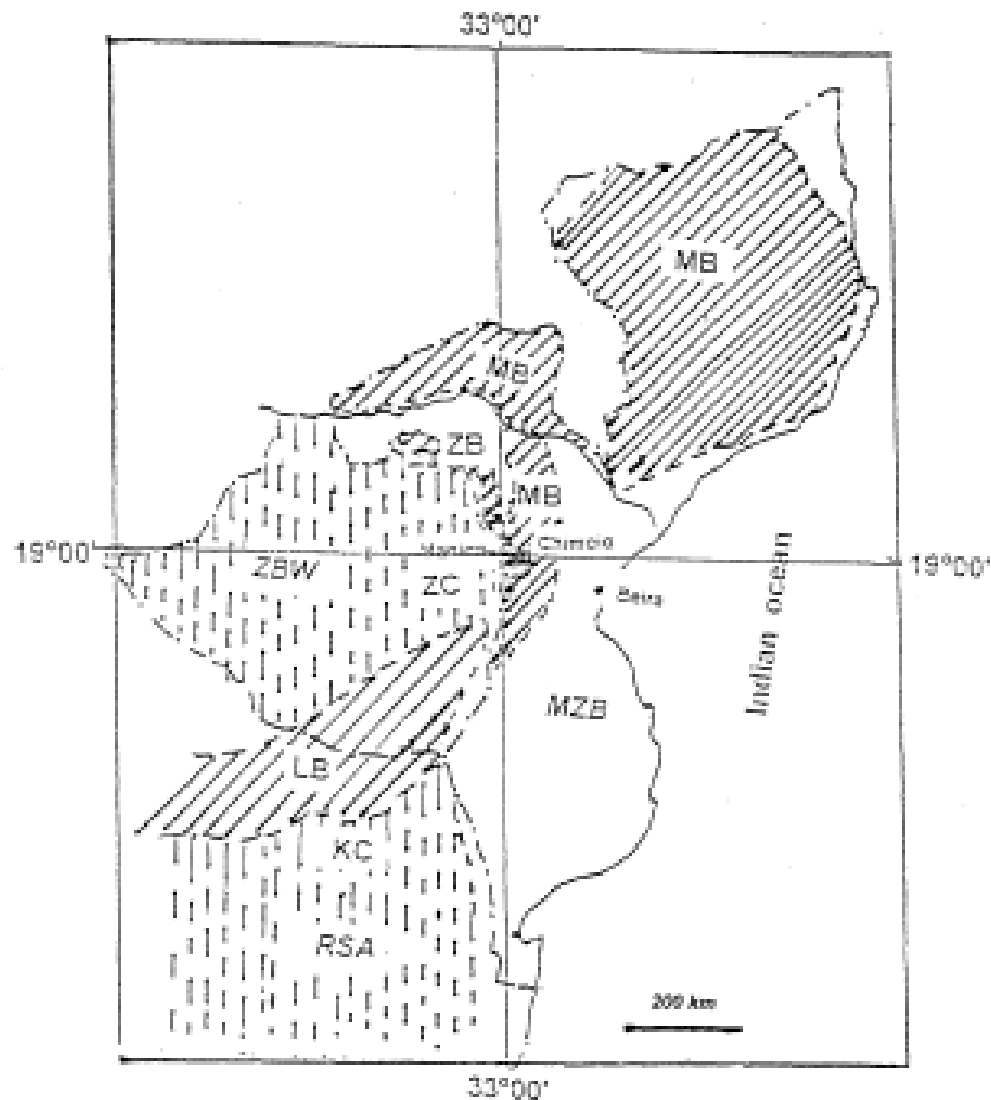


Figure 1.1: Location of the study area shown in the context of the regional geological structure of southern Africa. Adapted from Alfonso (1978), Petters (1991) and Dirks *et al.* (1998) data. LB- Limpopo Metamorphic Province MB- Mozambique Metamorphic Province, ZB- Mid-Zambezi Metamorphic Province, ZC- Zimbabwe Province and KC- Kaspraal Province. ZBW- Zimbabwe, RSA- South Africa and MZB- Mozambique.

1. The rifting school

- Continental rifts are linear zones where the earth's crust was pulled apart with typical features such as grabens/half grabens, flanking normal faulting (Orpen et al., 1989).
- The rifting event regionally coincided with the major epoch of crustal extension (Melanovsky, 1983).
- Early models on the tectonic evolution of the Umkondo Basin invoked rifting in a continental rift setting.
- Sediments were then eroded from formations above the granitic basements into the basin.
- The various sediments types alternating between argillaceous sediments and quartzites being a result of continued subsidence of the inner basin due to subsequent load.
- There appears a strong spatial relationship between rifting controlled development of sedimentary basins with mobile belt terranes (Orpen et al. (1989).
- Maybe during Columbia breakup-Rodinia assembly (Table 1).

Columbia		Rodinia		Gondwana	
Assembly	Breakup	Assembly	Breakup	Assembly	Breakup
2.0- 1.8 Ga	1.6-1.2 Ga	1300- 900Ma 650Ma	830 -	800- 530Ma Ma	c200- 96
swam	Mafic dyke kimberlite, lamproite, carbonate magmatism 1.4 - 1.2 Ga 	Proterozoic diamond formation 1.15 Ga 			

Table 1: Ages of assembly and break up of Supercontinents with diamond formation ages, compiled from Kroner (2001) , Zhao et al. (2012), Konoeerf (2017).

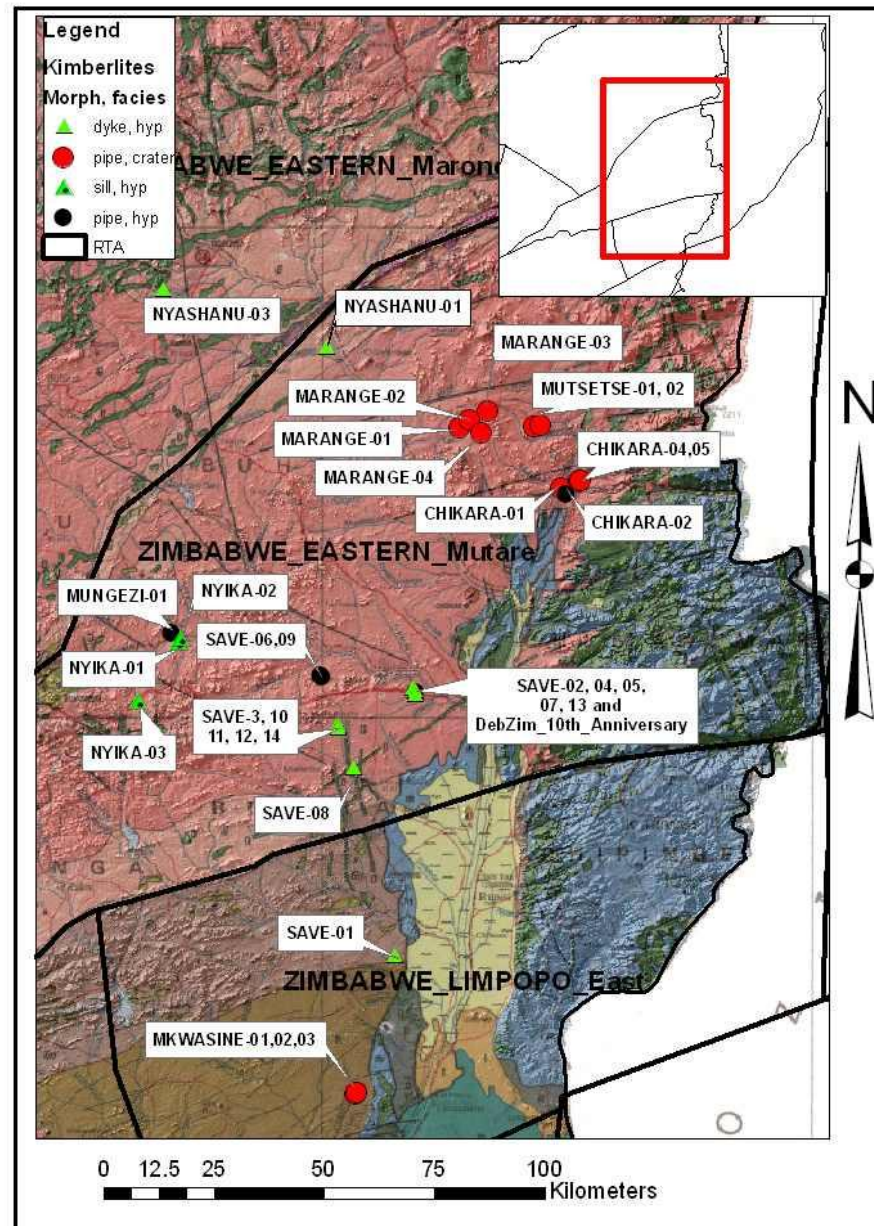
Rifting of the Umkondo (contd)

- The Umkondo reveals phases of tectonic processes; magmatism, sedimentation, metamorphism and subsequent deformation (Bicca, 2017), a complex event.
- Phaup (1969) from structural studies suggested that the Umkondo Group developed in a trough, then after the Frontier Series had been deposited and metamorphosed, later was folded and eroded at the same time the Lower Argillaceous Series were being deposited.
- Many active rift systems are associated with vulcanism e.g. the Great African Rift Valley and Cabbora Bassa Graben (Orpen et al., 1989), the Marange Kimberlites west of the Sabi Fault, that intruded the Umkondo Basin, could have resulted from vulcanism (e.g. Barber, 2018)

Rifting of the Umkondo (contd)

- Similar tectono-magmatic events that triggered diamond formation at Venetia Mine, that involved rifting accompanied by the widespread Umkondo dolerites (Koornneef et al., 2017) could be the source of the Chimanimani diamonds.

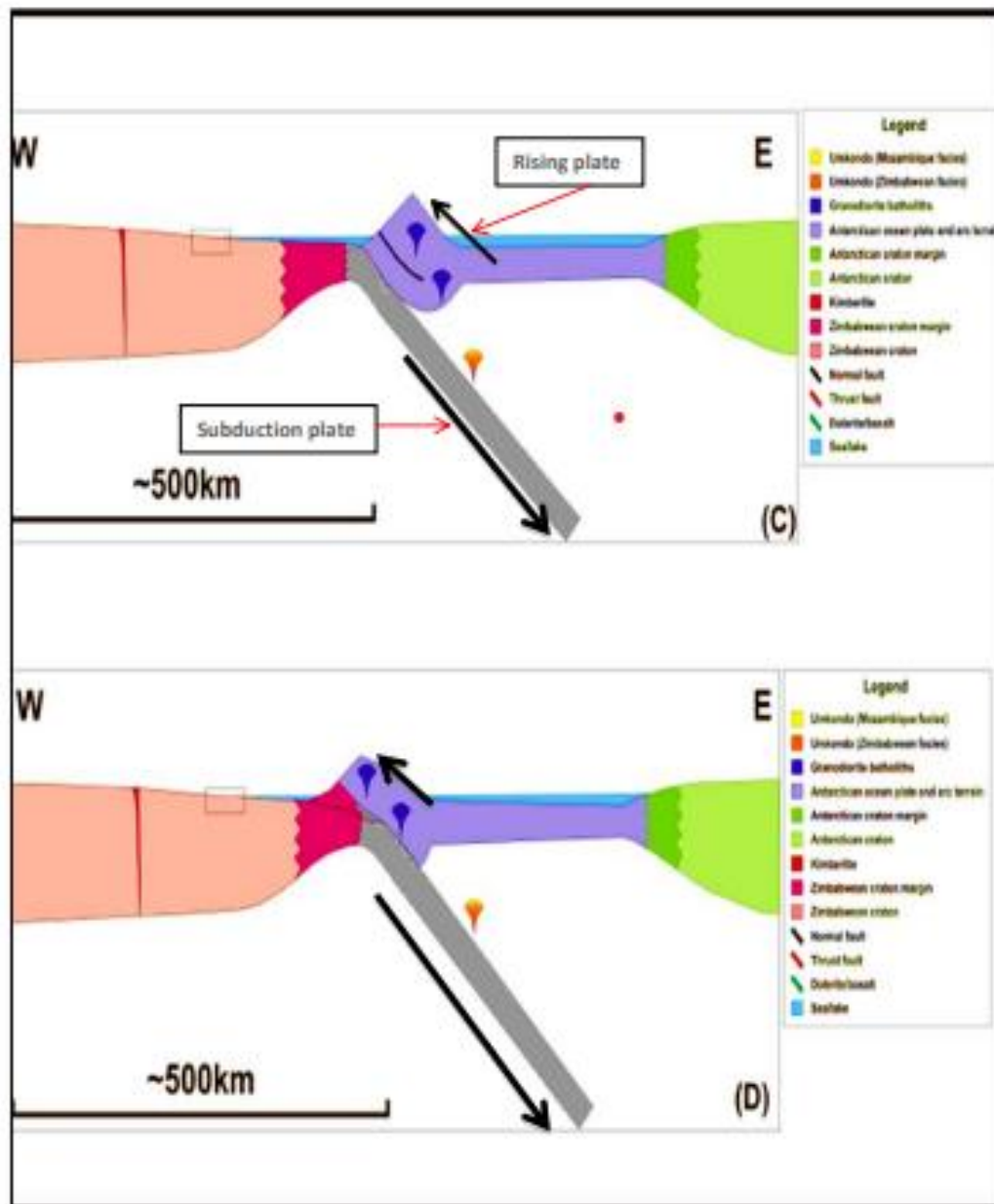
Eastern Zimbabwe Kimberlites

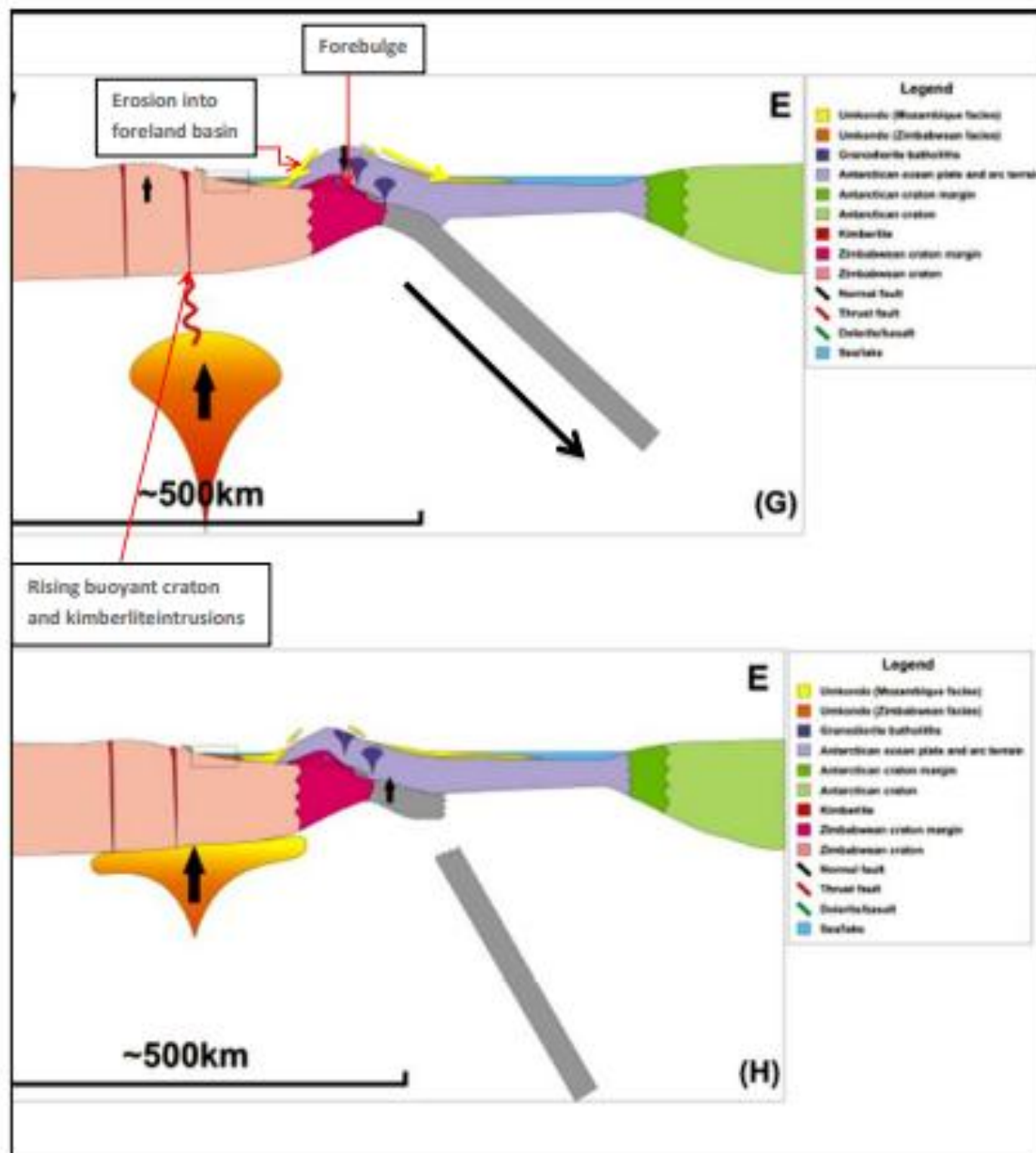


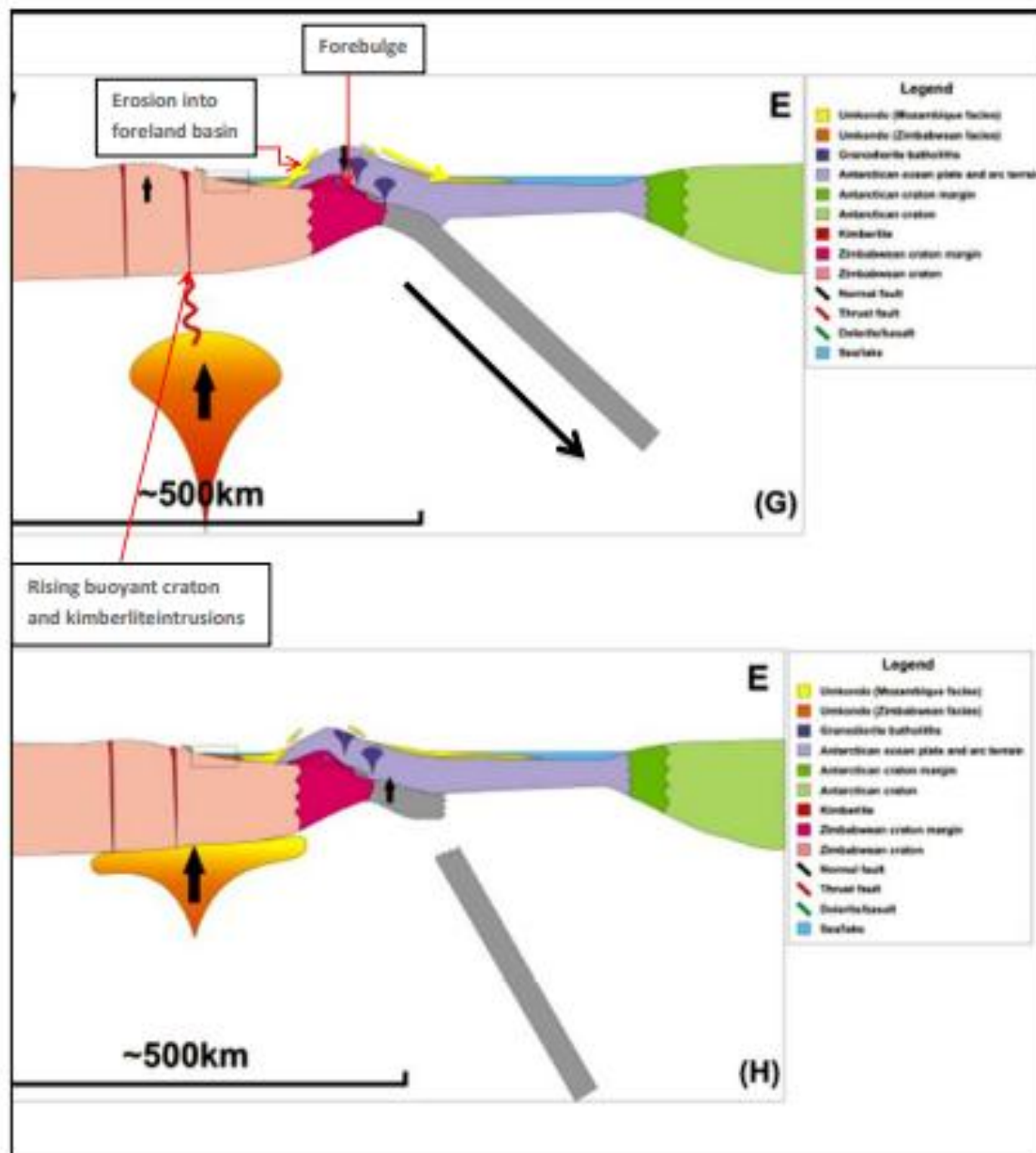
2. The Foreland basin school

- The regional tectonic setting of the Umkondo Basin is well summarised in the results of project 440 “Assembly and Breakup of Rodinia” of the International IGCP (Kroner, 2001).

- Detailing the tectonic dynamics, Master (2006, 2010) explained that the Umkondo Group is linked with the Ritscherflya Supergroup of Antarctica, and interpreted them as products of a foreland basin developed in response to arc collisions in the late Mesoproterozoic, during the formation of the Rodinia supercontinent.
- In agreement with this foreland basin model, Roberts (2006) postulated that the diamondiferous sediments were shed of the forebulge.







- *“Martin (2006) and Master (2010) proposed a tectonic model where the accretion of a volcanic arc terrane associated with possible docking of Antarctica during Rodinian assembly, may have resulted in the loading of the Zimbabwe Craton margin.*
- *This in turn produced the foreland basin where the majority of the Umkondo sediments were deposited.*
- *The initial Umkondo basal transgression was associated with subsidence of the foreland basin.*
- *Subsequent increase in sediment input from the Zimbabwe Craton is suggested to have been a result of the development of a forebulge on the Zimbabwe Craton in response to the loading of the Zimbabwe Craton margin”.*

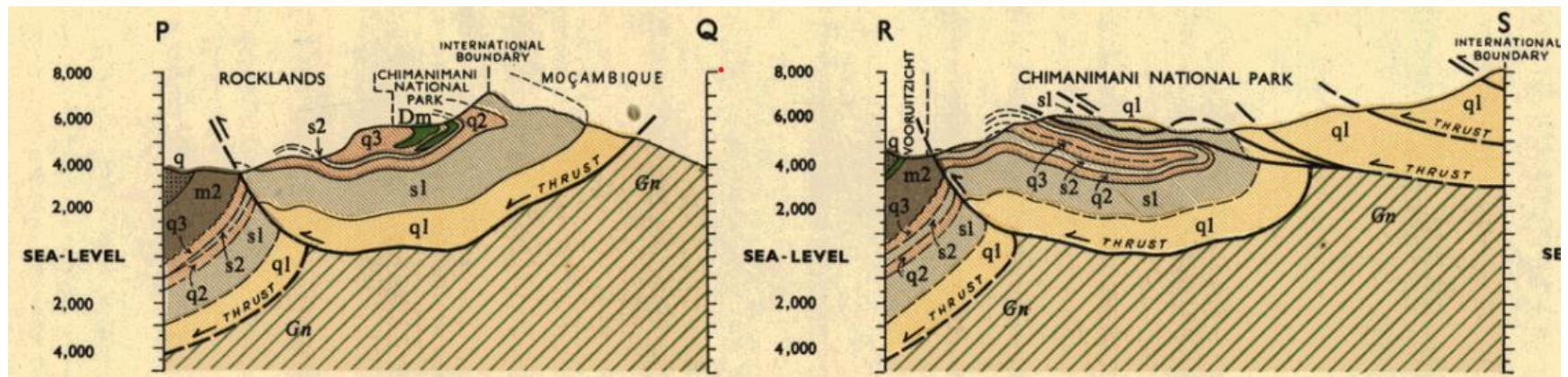
3. Diamondiferous sediments shed-off from the Frontier Series (Mozambique Facies)- model

- Watson (1969), discovered lithic fragments of quartzites in the ferruginous sandstones in the basal formations of the Lower Argillaceous Series which he interpreted to have been derived from the Frontier Series sediments in the east.
- This was assumed by Zhou (2015) to imply that the Chimanimani diamondiferous sediments could have been shed off from these (2399 +/- 19 Ma) sediments (Mänttari, 2008).
- Watson (1969) further suggested that the lithic fragments were already metamorphosed when they were deposited..
- Cutten et al. (2006), two principal domains were identified in the Mozambique Belt: The Western Mozambique Belt (WMB) that comprises upper amphibolite-grade gneisses with emplacement ages between 2970 to 2648 Ma (Johnson et al., 2003) but also as young as 1837 Ma, and represent reworked rocks of the Tanzanian Craton and Usagaran Belt, and The Eastern Granulites (EG), high-grade, arc-derived lithologies with Pan-African emplacement ages ranging between 841 Ma and 6

3. Diamondiferous sediments shed-off from the Frontier Series (Mozambique Facies)- model

- These Eastern Granulites probably link the Mozambique Belt to the Frontier Series (Mozambique Facies) thrust tectonics which Cutten et al. (2006) suggested to have been caused by the closure of the Mozambique Basin at ~550Ma.
- However, if the Frontier Series thrust was only during this last event, then the shed off sediments could not have been part of the already lithified Zimbabwe Series Lower Argillaceous sediments, which were pre-Pan African, that host the diamondiferous sediments, unless another earlier thrust occurred.

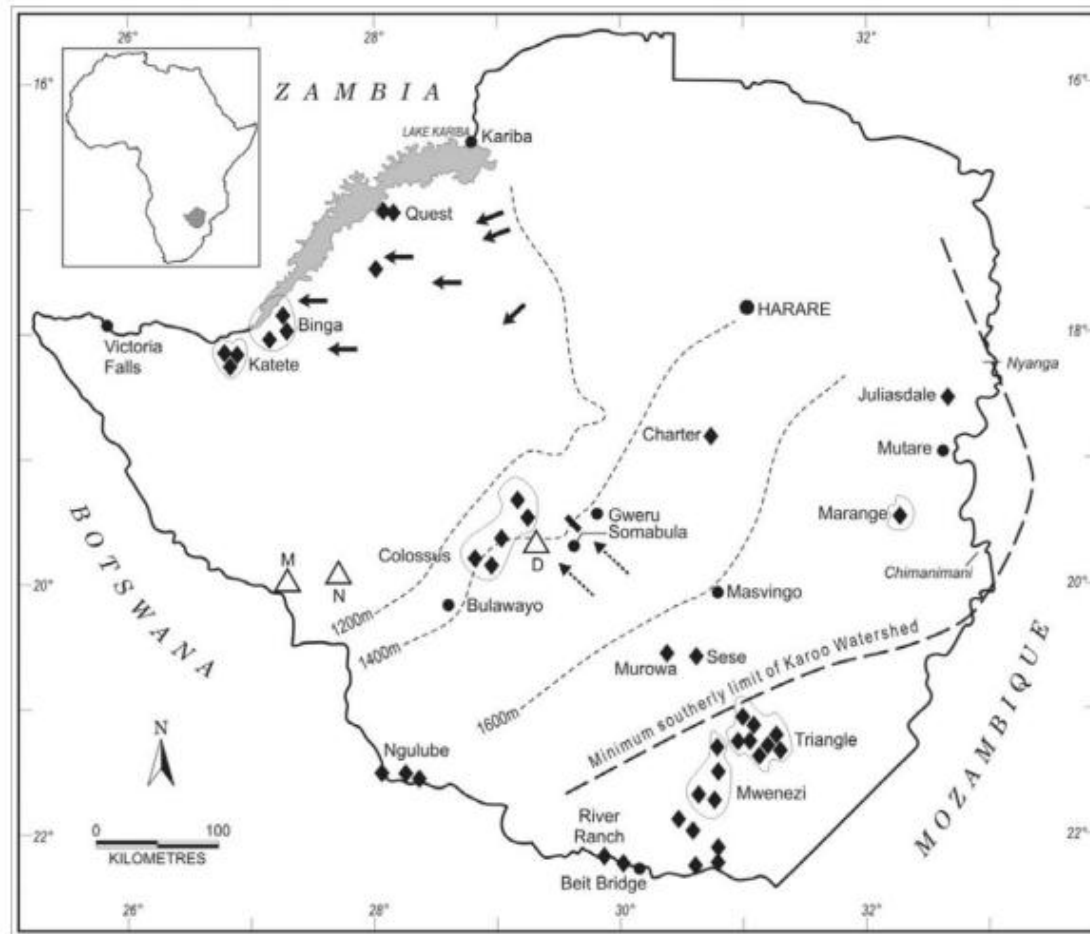
Crosssections showing Frontier Series sediments (q1, s1, q2, s2 and q3} thrust westwards on the Zimbabwe Facies (m2, q) from Watson (1969).



4. Intrabasinal provenance

- Kogan, person comm. (2012), suggested a possible intrabasinal source of the diamonds based on the abundance of octahedron diamond crystals and picroilmenites in the heavy mineral concentrates after milling the diamondiferous grits.
- They argued that the octahedron crystals could have been worn off if the source rocks were distal, whilst the basis for the second argument was that picroilmenites generally do not survive long distance of travel (Daniels, 1993).
- The bedding-parallel dolerite sills which suggests coeval deposition.
- Such a relationship could be linked to other mobile belts like Banganapalle in India, where the source of the diamondiferous conglomerates was intrabasinal lamproites, in the extensional setting (Joy et al., 2012).
- In addition, considering the several kimberlite clusters hosted in the Central Zone of the Limpopo Belt (Mafara, 2003), Chimanimani diamonds could have been derived from kimberlite clusters in the Limpopo Mobile Belt underlying the Chimanimani area of Umkondo.

4. Intrabasinal provenance



4. Intrabasinal provenance

- Kimberlite clusters in the Limpopo Mobile Belt being assumed to continue northeast into Mozambique, reproduced from Moore et al. (2009).
- Such an intrabasinal source of lamproite dykes has been discovered as the source of the Banganapalle conglomerates in India.
- It was proposed that the emplacement of lamproites occurred as dyke–sill complexes at 1.4–1.3 Ga (Joy et al., 2012).

Unresolved Questions

- There are problems however with the relationship between the Frontier Series (Mozambique Facies) and the younger Zimbabwe Facies, where some authors (Allosop, ; Payne, 1984), concluded that the Mozambique Facies was an allochthon juxtaposed on the Zimbabwe Facies, whilst others including Watson (1969), proposed that the Frontier Series were thrust at the same the Zimbabwe Facies were being formed, implying a different source of the Zimbabwe Facies sediments/ a mixture.
- The key question to be answered then is how many sedimentary basins comprised source of the sediments of the Mozambique Belt (See Cutten et al., 2004; Kroner, 2001).
- Since the Mozambique Belt which includes the Frontier Series (Mozambique Facies) comprise the WMB and EMB, which are of two different tectonic settings.

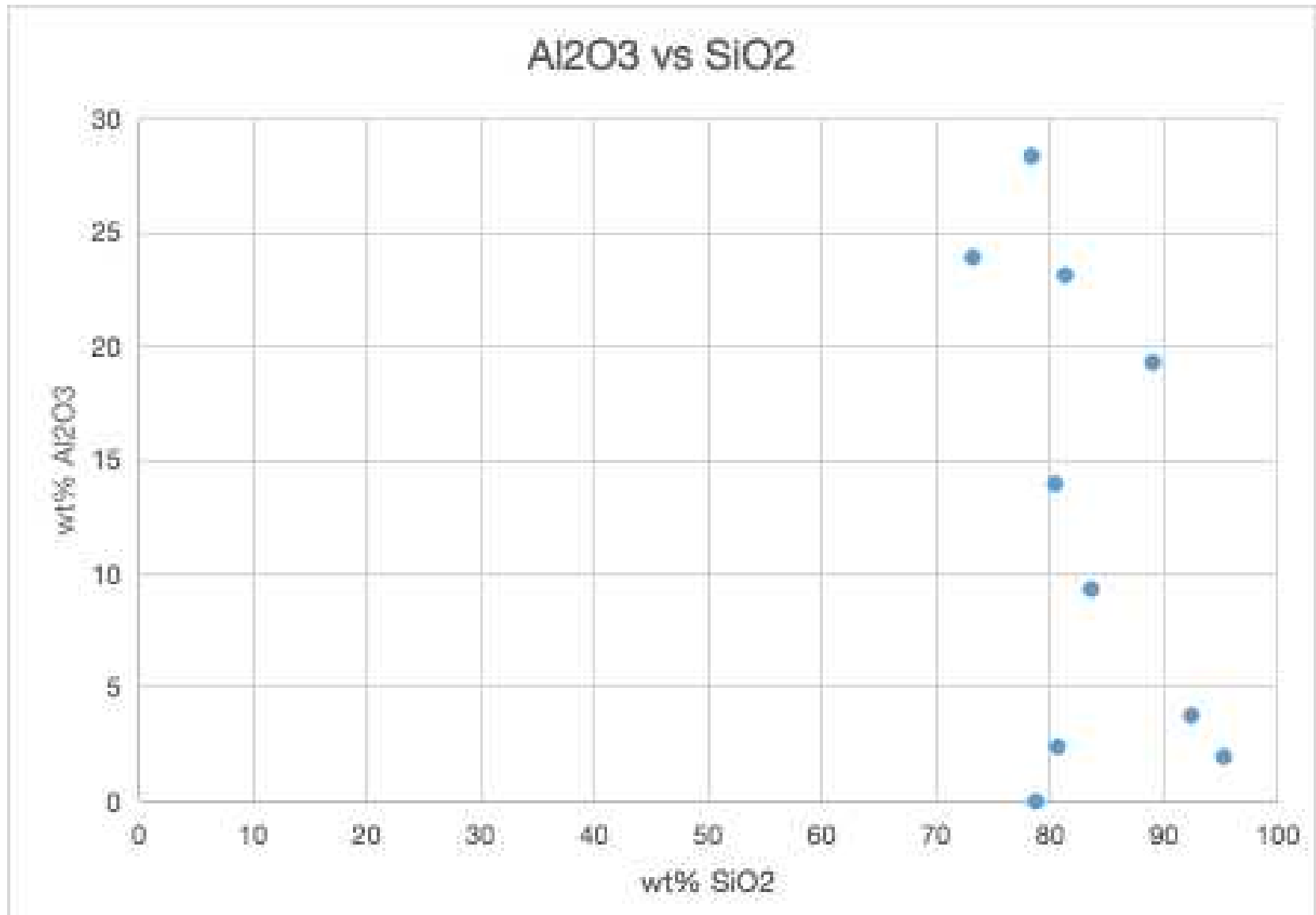
Ratios of major oxides and SiO₂

- The theory here is that the SiO₂ contents increases with decrease in grain-sizes, which reflects an increase in proportions of sizes of the matrix detritus (Roser and Korsch, 1986; Obasi et al., 2015).
- This means that deeper in the basin, the sediments were more exposed to longer periods of attrition, hence grain-sizes were reduced.

Major oxides analyzed by XRF

Sample-id	ZnO	K2O	CuO	NiO	TiO2	Al2O3	Cr2O3	MnO	SO3	Fe2O3	P2O5	SiO2	SiO2/Al2O3
TS 9-Fine	0.008	2.05	0.003	0.009	0.695	19.3	0.043	0.148	0.073	9.67	0.136	89.02	4.612435233
TS 34-Fine	0.006	4.82	0	0.037	0.704	28.36	0.027	0.073	0.124	5.07	0	78.39	2.764104372
TS 36-Fine	0	0	0	0	0	9.33	0.03	0.105	0.482	7.75	0	83.6	8.96034298
TS 38-Fine	0.008	4.22	0	0.038	0.599	0	0	0.099	0.082	3.73	0	78.74	0
TS 43	0.002	1.08	0	0	0	3.78	0.01	0.018	0.071	1.03	0	92.39	24.44179894
TS 45	0.004	0.07	0	0	0.01	1.97	0	0	0.292	1.18	0	95.24	48.34517766
TS 46-Fine	0.006	2.93	0	0	0.568	23.13	0.024	0.049	0.069	6.12	0.18	81.33	3.516212711
TS 49-Fine	0.003	3.81	0	0	0.712	23.91	0.034	0.046	0.085	4.28	0.249	73.23	3.062735257
TS 59	0	0.51	0	0	0.072	2.4	0.04	0	0.084	1.98	0	80.65	33.60416667
TS 60	0.006	2.63	0	0	0.388	13.97	0.034	0.104	0.342	7.12	0.147	80.44	5.758052971

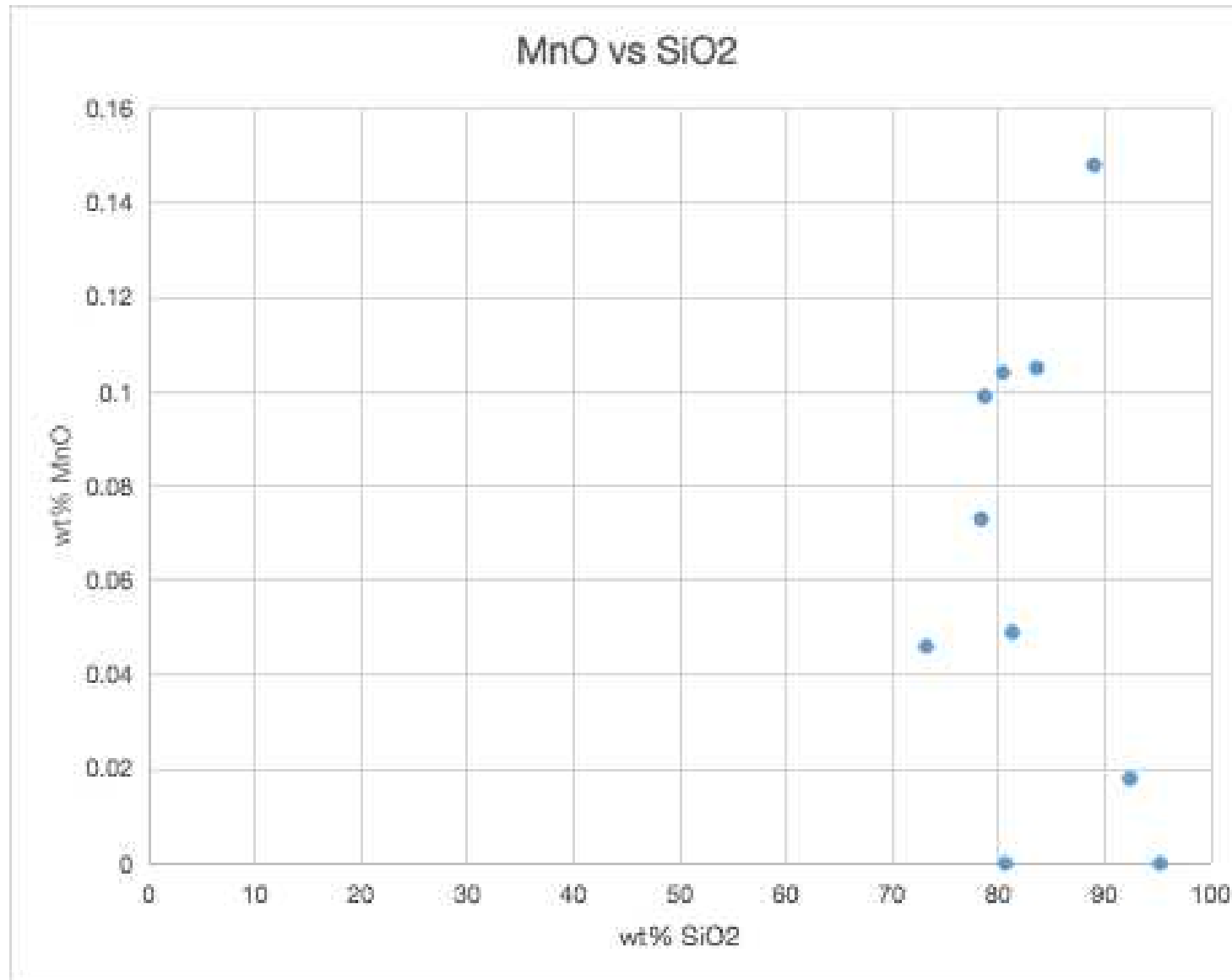
Geochemical analyzes of Chimanimani conglomerates



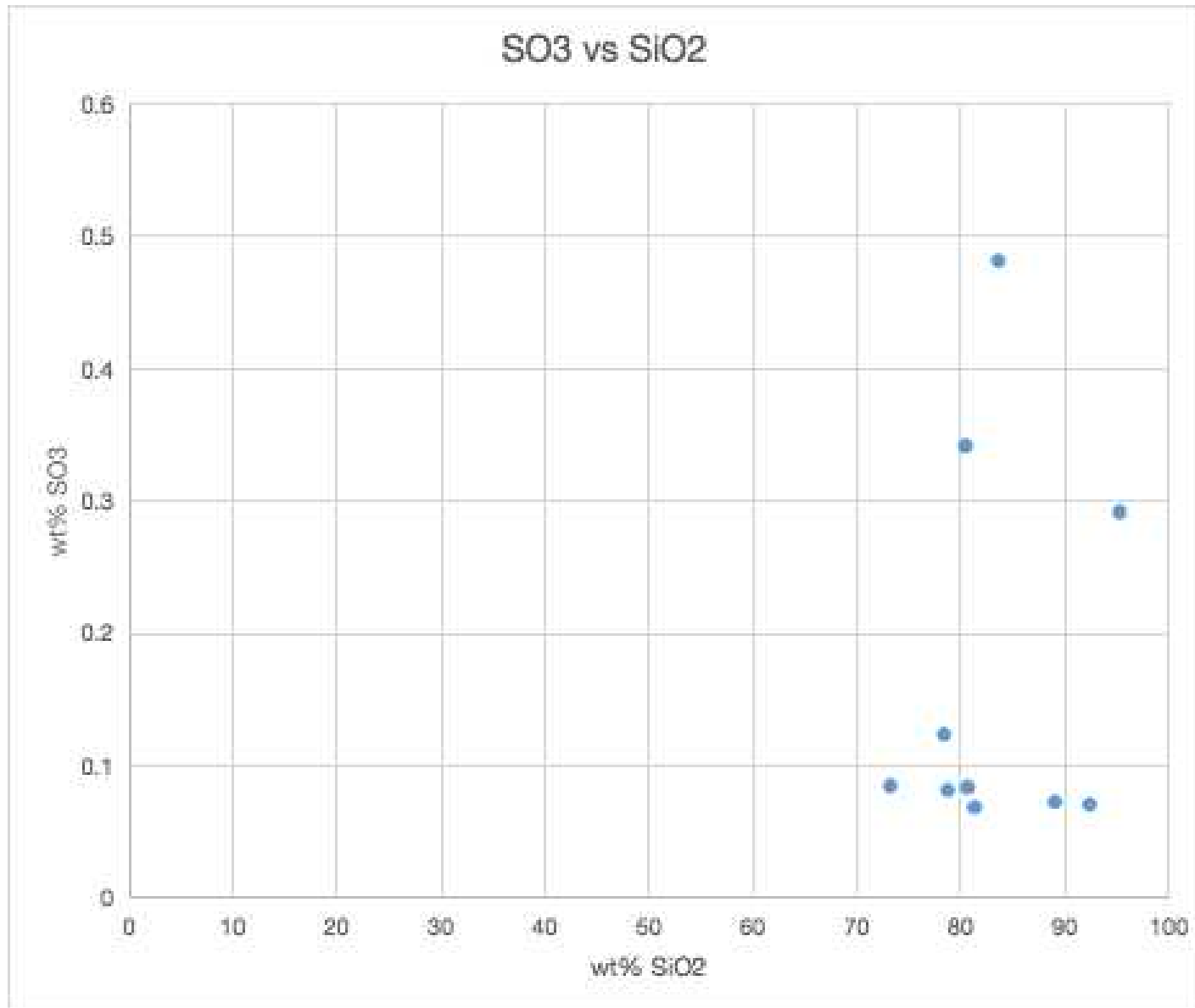
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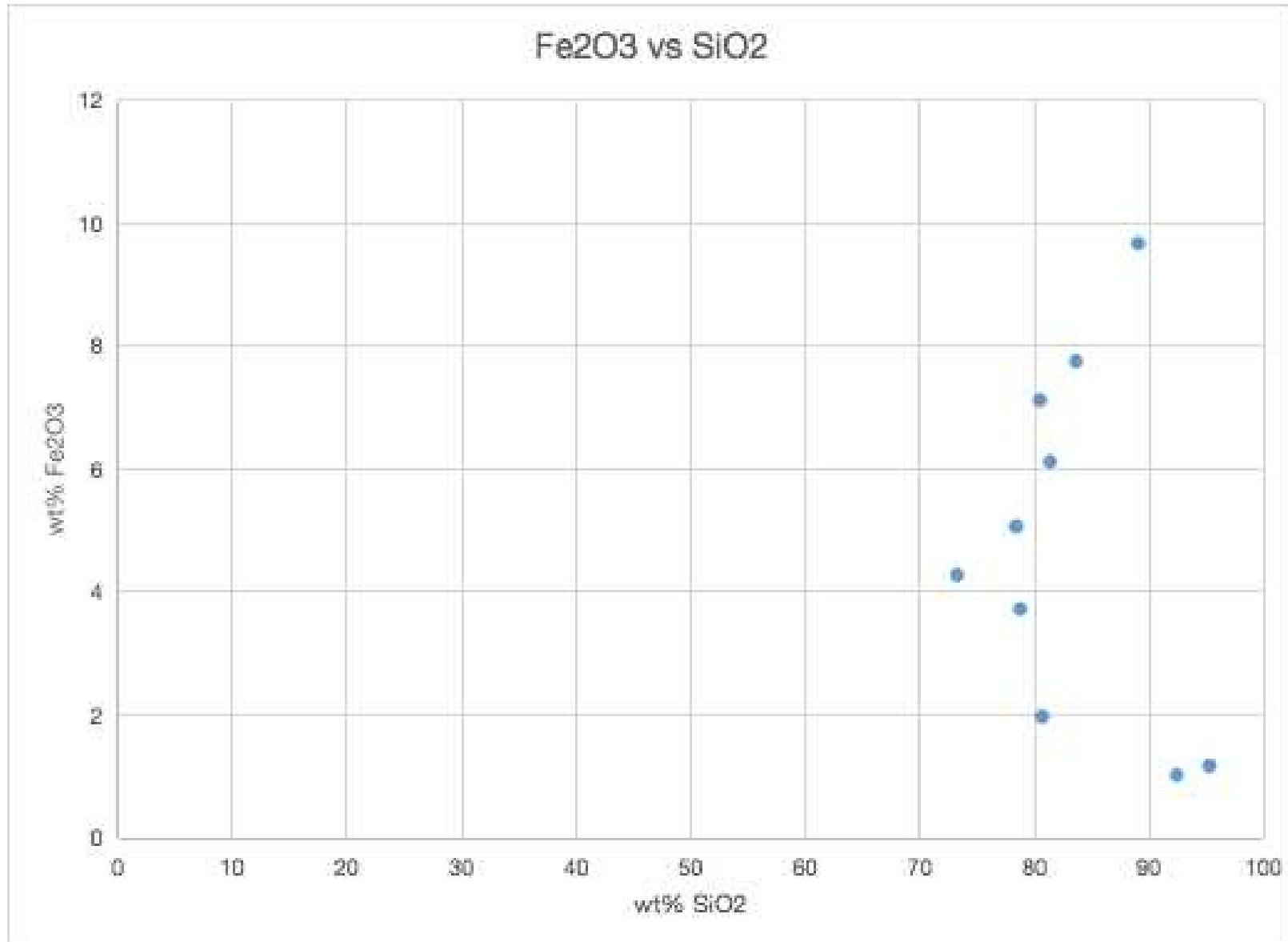
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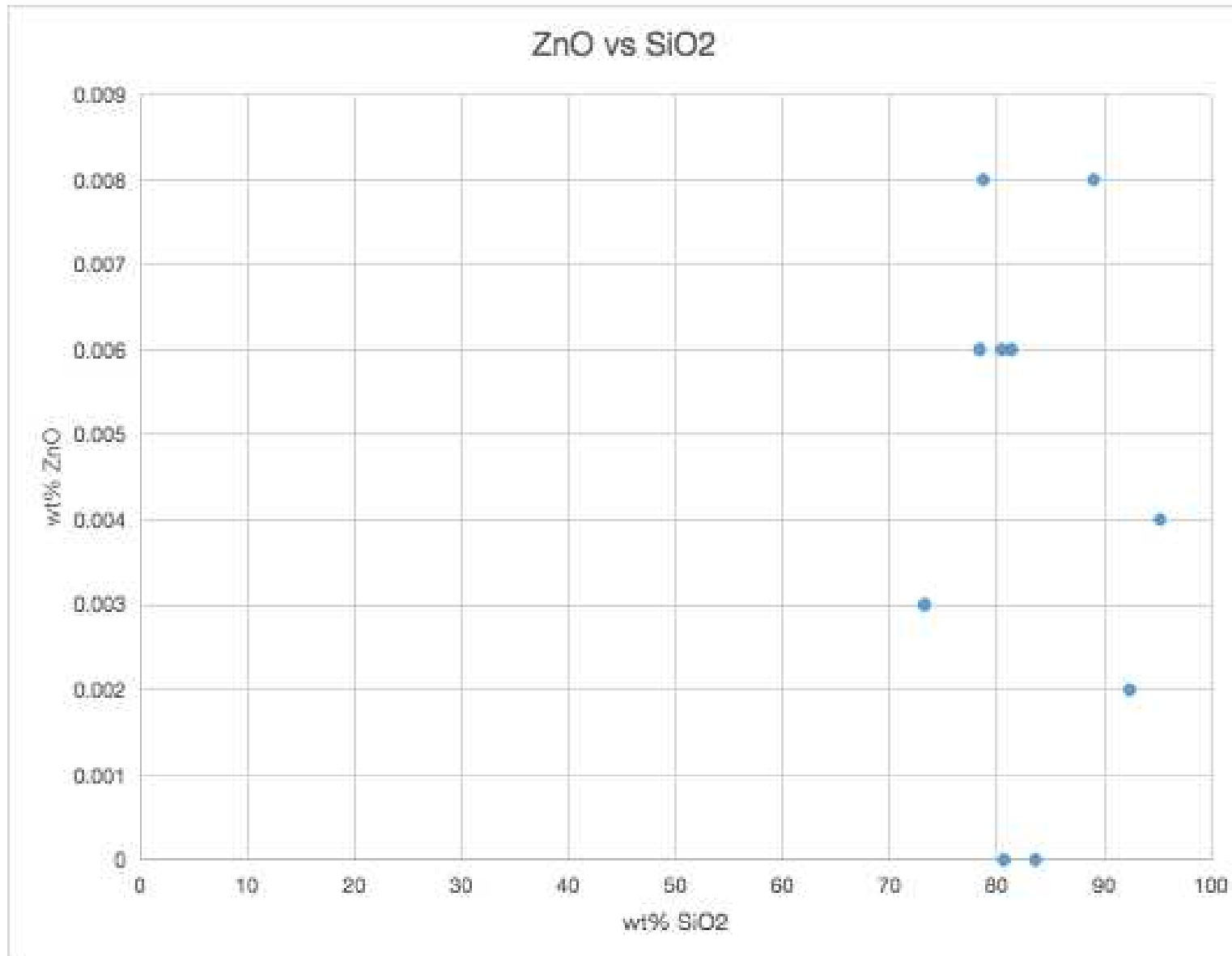
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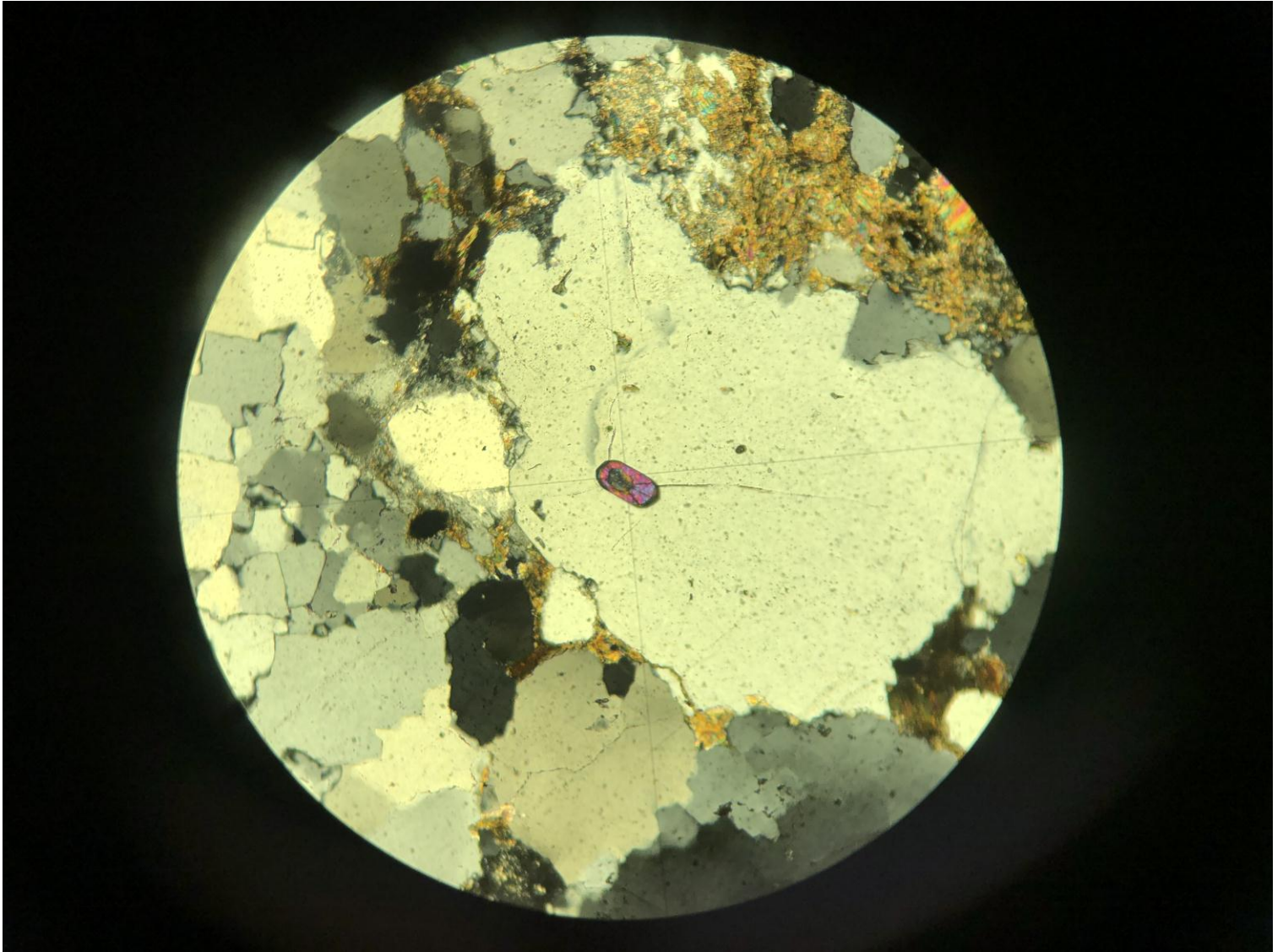
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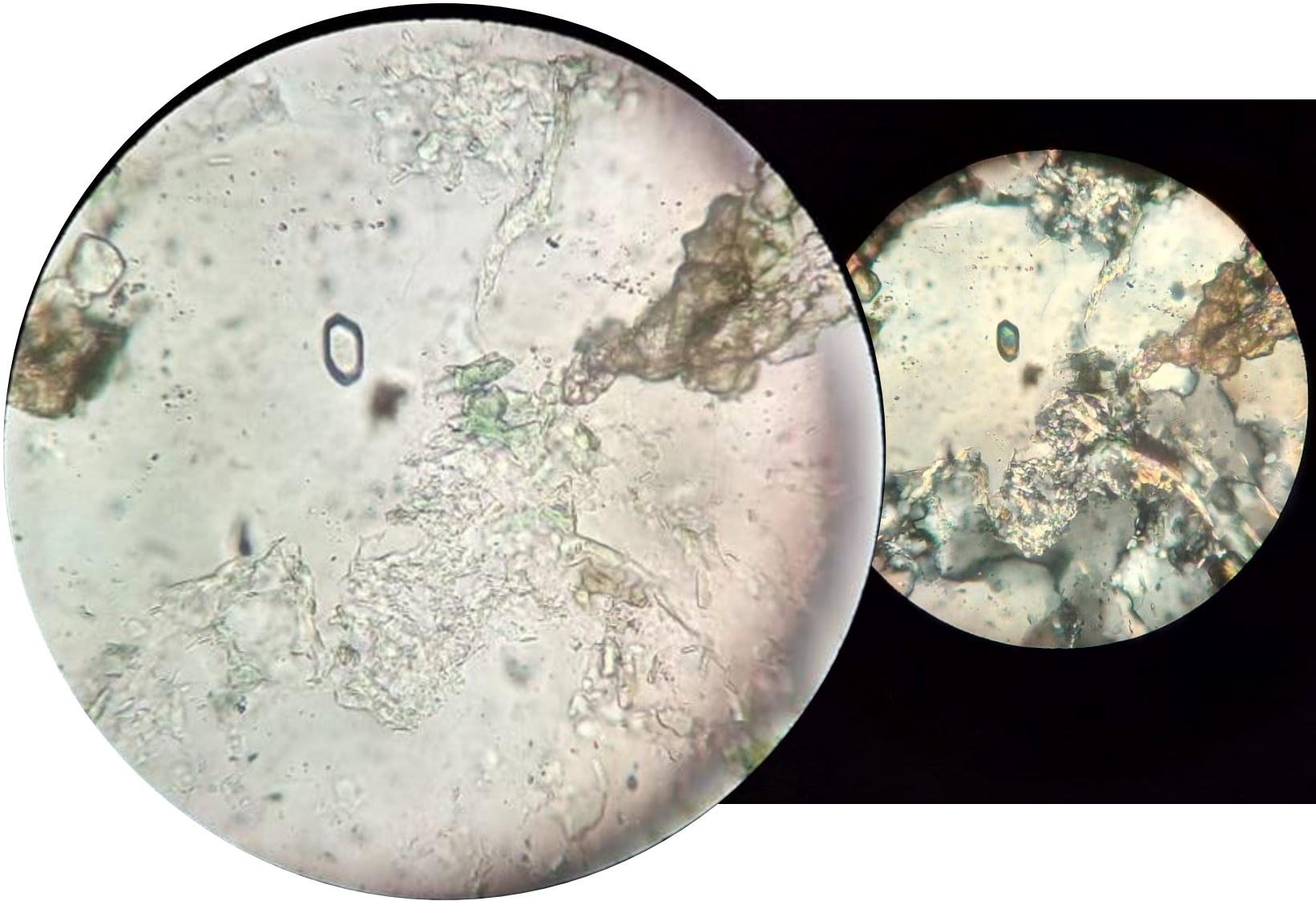
Geochemical analyzes of Chimanimani conglomerates



Zircon from Chimanimani drill core sample



Zircon in conglomerate in southern extension of the mining area in Dunstan Farm



Conclusion

1. There are many assumptions (possible provenance models) on the tectonic setting and possibilities for diamondiferous sediments.
2. However, these have not looked at detailed studies of the diamondiferous sediments themselves.
3. Therefore, the project presented all these models so that we can eventually zero in on the most likely appropriate model based on actual studies on the Chimanmani deposit.
4. Geochemical analyzes of major oxides vs SiO_2 suggest maturity of the diamondiferous sediments, next the project should establish from where the sediments are younging from.
4. A systematic study of the geology of the Chimanmani diamond deposit including dating of the diamondiferous sediments and geochemistry are prudent to decipher the provenance of the diamondiferous sediments.