3. Description of study area

3.1 Introduction

Both sites for this study form part of the KOSH gold mining region (Klerksdorp, Orkney Stilfontein and Hartebeestfontein). Harties 1-4 is a complex of 4 TDFs located just south of Stilfontein (North-West province), between latitude S 26.87°, S 26.89° and longitude: E 26.76°, E 26.78°. Currently, Harties 1-4 is under the ownership of AngloGold Ashanti and has been re-mined extensively since 2012.

New Machavie is an old derelict mine that falls under the ownership of the Tlokwe Local Municipality. New Machavie is located approximately 22 km east of Potchefstroom and 24 km north of Stilfontein between the latitudes of E 26.665, E 26.68 and longitude of S 26.865, S 26.88.

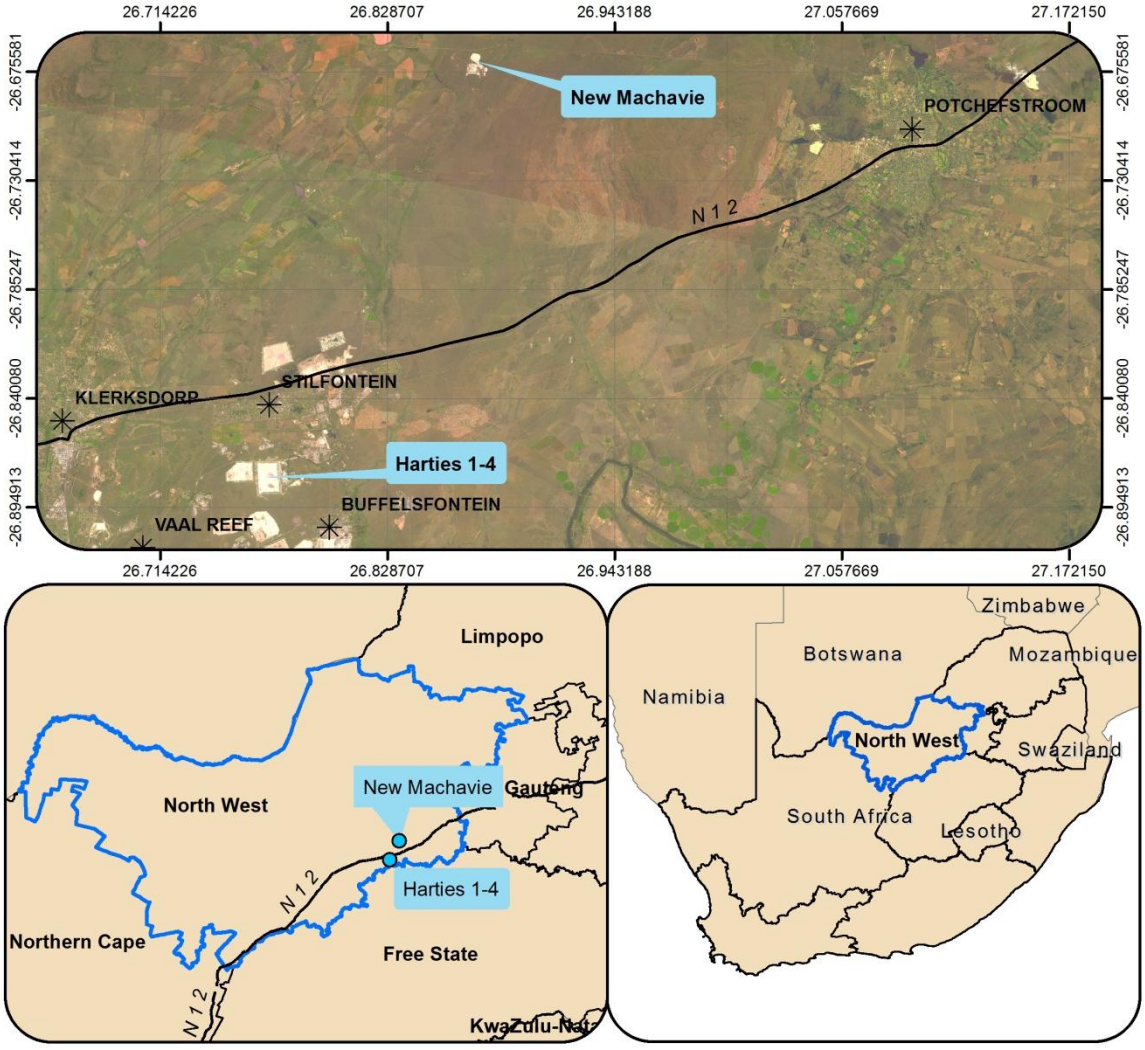

Figure 3.1: Locality map of Harties 1-4 and New Machavie (Google Earth A, 2013)

3.2 History of the study area

3.2.1 Harties 1-4

According to Menell (2000), the Harties mine has been the “flagship mine” for the Avmin mining group and its holding companies (Anglovaal and Avgold) for over 40 years until 1999 when the company opted to sell Harties to DRD. In 2005, DRD liquidated its North-West gold mines after continual losses and completely withdrew from the KOSH gold mining region, including the Harties mine (Tredway, 2005). Currently the underground workings of Harties belong to Simmer & Jack under the name of Buffelsfontein North Division (King *et al,* 2007). In 2007, First Uranium published its revised Buffelsfontein technical report in which it proposed an acquisition of Mine Waste Solutions (MWS), the owner of the Harties TDFs at the time, with the aim of constructing a U-processing plant, and adding the MWS TDFs and gold processing plant to their Buffelsfontein tailings recovery project (Anon, 2007). In July 2012 First Uranium announced that MWS would be sold to AngloGold Ashanti, the current owner of the Harties TDFs (First Uranium, 2012).

Field work done on the Harties 1-4 TDF complex included a north-south transect of boreholes and sampling at 1 m intervals. Harties 1-4 served as a testing site prior to the larger survey done at New Machavie in order to test the viability of the method, to assess the assumptions of this study, and to compile a list of data that will be needed in order to complete the modelling phase on New Machavie.

3.2.2 New Machavie

Aucamp (2000) stated that the New Machavie mine was actively mined between the 1930s and early 1940s, in which time five TDFs were constructed. King *et al.* (2007) mentioned that New Machavie was periodically mined from as early as 1904 and that approximately 5200 kg of gold was produced at New Machavie and that the mine exploited 1400 m of the conglomerate unit of the Black Reef Formation to a maximum depth of 130 m. The reopening of the New Machavie mine was scheduled for 2003 but this has been delayed due to problems regarding surface mining rights (King *et al*, 2007).

New Machavie consists of five TDFs as shown in Figure 3.2. TDF 1 is the focus of this study. TDFs 2 and 3 was sampled as part of the radionuclide leaching section (Section 7). These TDFs were of interest as TDF 2 showed high U spikes whilst TDF 3 has a higher inorganic carbon content.

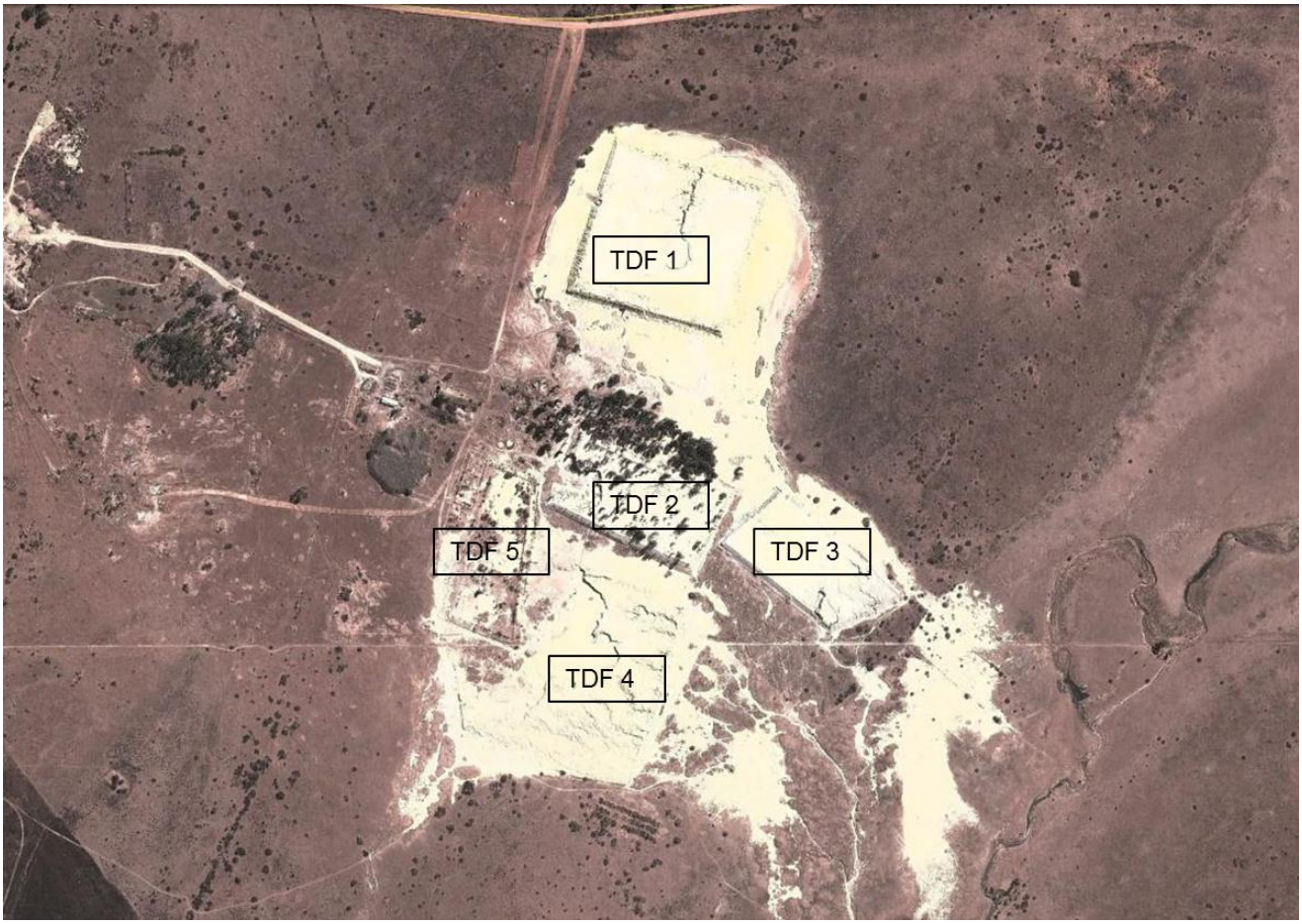

Figure 3.2: New Machavie complex (Google Earth B, 2013)

3.3 Climate

The study area is located close to the border between the Dry Highveld and Moist Highveld grassland climatic regions of South Africa but retains the characteristics of the Dry Highveld grassland region. The Dry Highveld grassland region is generally defined by highly fluctuating winds which tend to be more from a north / north-easterly direction. Rainfall ranges between 450 and 700 mm per year, most of which falls between December and January (Kruger, 2004).

According to the climate statistics from the Potchefstoom weather station, for a period of 29 years from 1961 to 1990 (as received from the South African Weather Service, 2013/07/09), the average rainfall was 631 mm per year with the highest rainfall months being the summer months of January (119 mm) December (94 mm), November (85 mm) and February (83 mm). The lowest rainfall occurs during the winter months of May (15 mm), August (10 mm), June (7 mm) and July (4 mm).

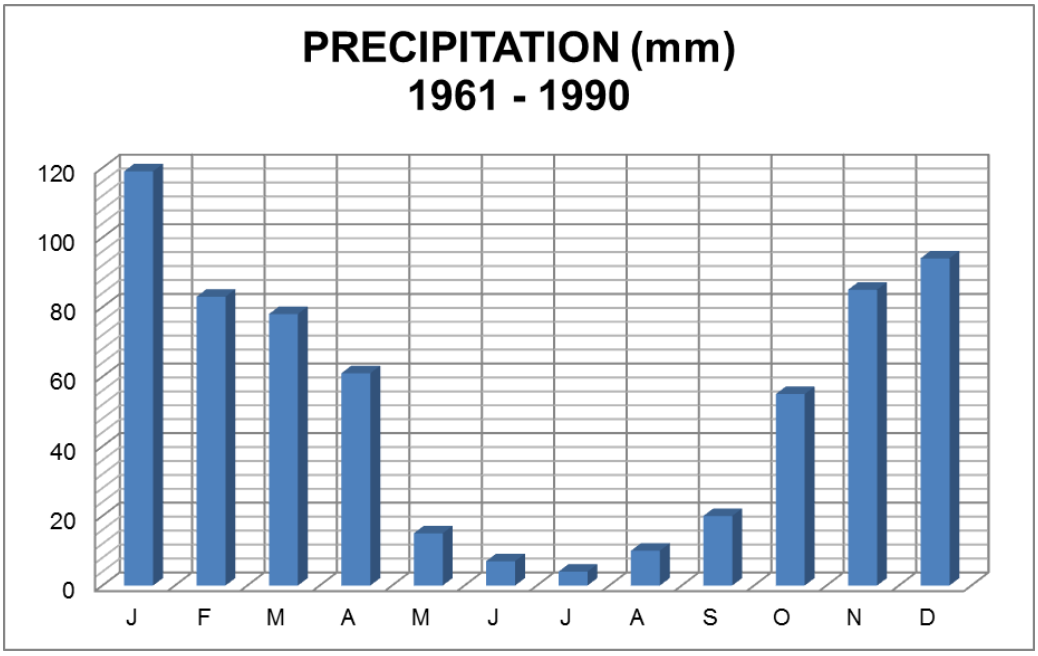

Figure 3.3: Annual Precipitation (Potchefstroom weather station)

The same information shows an average temperature range of between 29°C and 15°C for the summer months of January and December whilst winter months (June and July) ranged between 19°C and 0°C. Temperatures as high as 38 °C have been experienced in the summers with winters as low as -9.5 °C occurring as well. (South African Weather Service. 2013)

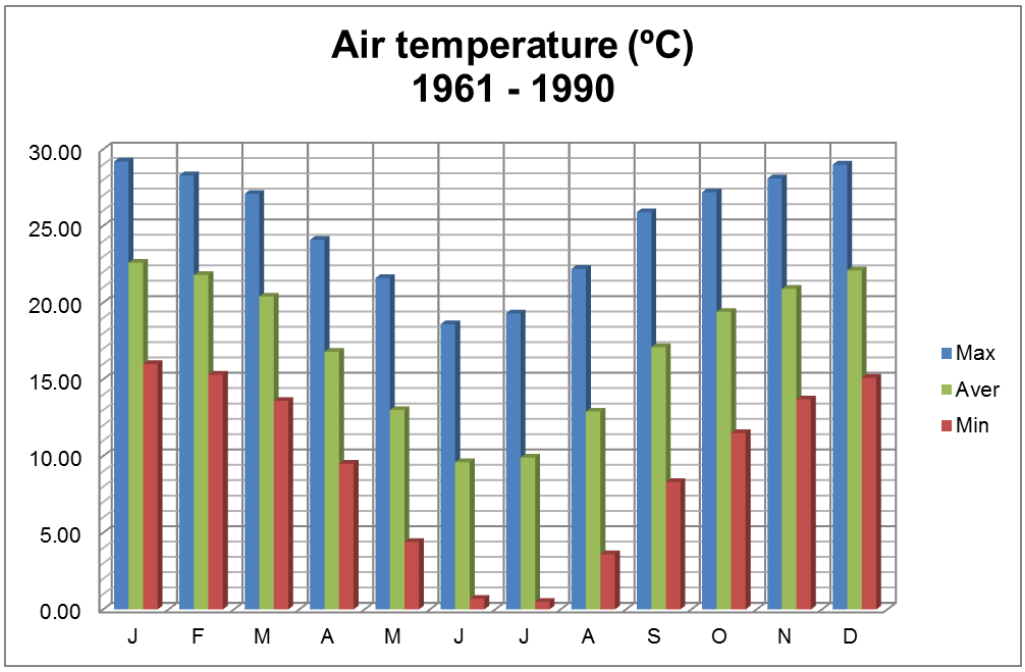

Figure 3.4: Annual Air Temperature (Potchefstroom weather station)

Wind speeds rarely exceed 8.7 $m.s^{-1}$ and only do exceed this speed between August and December. The main wind direction throughout the year is north and slightly lesser occurrences of north / north-east winds. The months of May and June may have north / north-east winds as the dominant wind direction.(South African Weather Service, 2013)

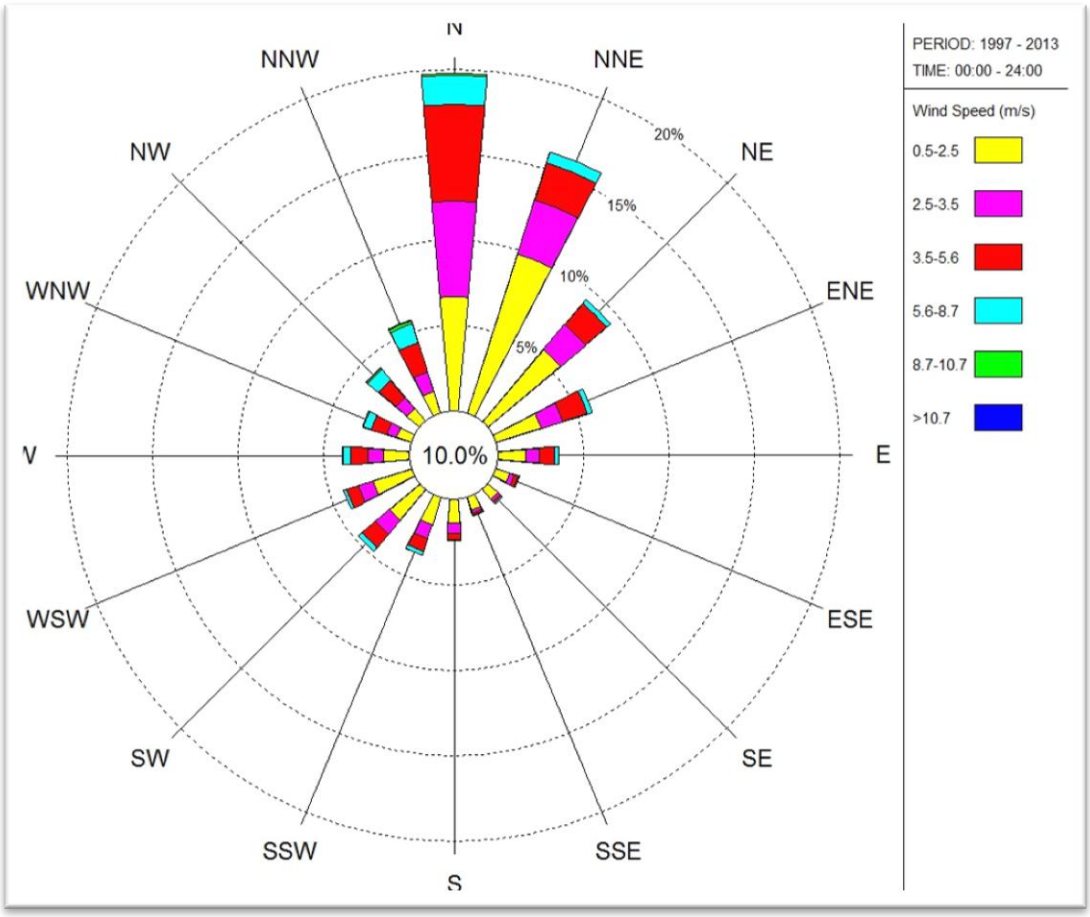

Figure 3.5: Annual average wind speed and direction for the Potchefstroom weather station. (South African Weather Service, 2013)

3.4 Geology

As indicated in the 1:250 000 Geological Map series 2626 West-Rand and Figure 3.6 (p30), both TDFs are underlain by sedimentary rocks of the Transvaal Supergroup. The sedimentary units of the Transvaal Supergroup represented in the study area are the Chuniespoort Group, subdivided into the Malmani Subgroup. Harties 1-4 is completely underlain by the Monte Cristo Formation whilst New Machavie is divided between the Monte Cristo and Oaktree Formations. North-east of both TDFs outcrops of the Black Reef Formation of the Malmani Subgroup is found. To the north of Harties 1-4, an outlier of the Karoo Supergroup (Volksrust and Vryheid Formations of the Ecca Group) is found. Further east in both locations, older stratigraphic units of the Ventersdorp Supergroup can be found (Anhaeusser *et al*., 2006). The Karoo and Ventersdorp Groups will not be discussed as they are irrelevant in the context of this study.

The lowermost formation of the Transvaal Supergroup is the Black Reef Formation which was deposited on a major angular unconformity on Archaean basement granites and Ventersdorp lavas. According to Coetzee (1996) the Black Reef Formation is comprised of a succession of interbedded siliceous quartzites and shales with erratic units of grit and basal conglomerate. The Black Reef Formation is known for its low grade placer gold and in fact has been mined at shallow depths in the study area, producing the New Machavie TDF, and has contributed to the Harties 1-4 TDF as well. The thickness of the Black Reef Formation varies dramatically depending on the depositional environment. The depositional environment has also created a fairly unpredictable distribution of gold in the Black Reef Formation, therefore most large mining houses have opted to avoid exploration of this formation, only mining the Black Reef at times when the gold price would allow it.

According to Anhaeusser *et al.* (2006), the Malmani Subgroup of the Transvaal Supergroup is subdivided into five formations by the following criteria: chert content, stromatolite morphology, intercalated shales and the erosion surfaces. These formations are (from oldest to youngest): Oaktree, Monte Cristo, Lyttelton, Eccles and the Frisco Formations. In the study area, only the Oaktree and Monte Christo formations are of importance.

The oldest formation, Oaktree, starts above the Black Reef Formation and is described as a “dark-grey, chert-free dolomite with large stromatolitic domes, carbonaceous shale marker beds towards the base and a tuffite unit” (Obbes, 2000). The Monte Cristo Formation is described by Obbes (2000) as light grey dolomite with an increase in chert content with regard to the Oaktree Formation. The Monte Cristo Formation is further divided into four members based on the chert-shale marker beds, chertified stromatolite marker beds and the presence of stromatolites. The individual members will not be discussed.

Manganese is present in both the Oaktree and Monte Christo Formations in the study area. As such, manganocrete (Mn oxides) forms abundantly as a pedocrete in the A and B horizons of soils found specifically in the Oaktree Formation and to a lesser degree in the Monte Cristo Formation (also applicable to section 3.5)

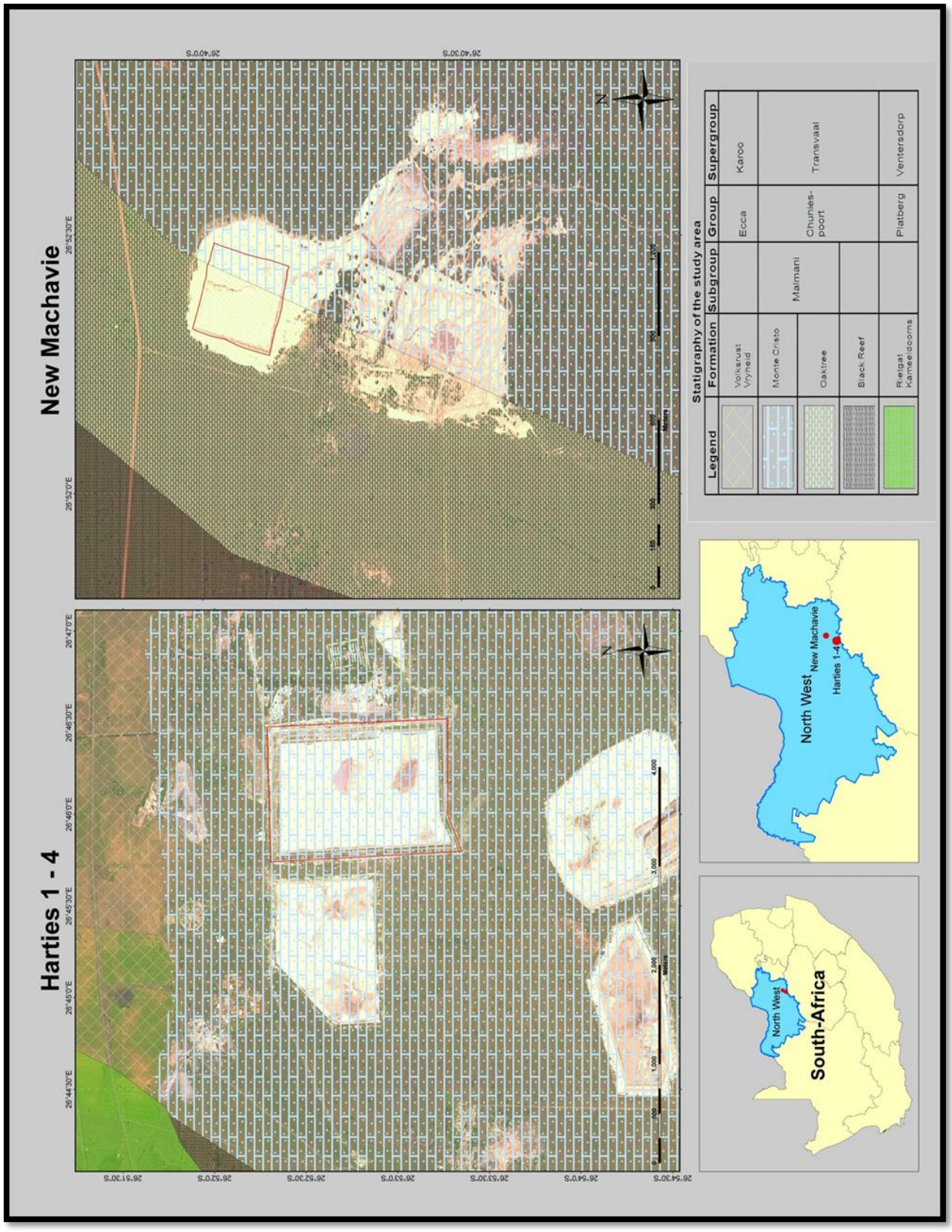

Figure 3.6: Surface geology of Harties 1-4 and New Machavie

3.5 Pedology

Both New Machavie and Harties 1-4 TDFs were constructed on very shallow dolomitic soils, described by land type Fa13 and Fa14 (Figure 3.7) as Glenrosa and/or Mispah soil forms with lime rare or absent from the landscape (SIR, 1987). Older gold TDFs were preferably constructed on dolomitic landscapes due to the rapid drainage of fluids away from the TDF. This rapid drainage meant that TDFs could be constructed faster as the geotechnical stability of the tailings material increases when the water content decreases (Robertson, 2008).

To the north of Harties 1-4, land type Bc24 can be seen (Figure 3.7) and to the north-west of New Machavie, land type Ba42 is found. Both of these land types are plinthic catena's indicating that the soil types found in these land types are dependent on the oxidation state of Fe. Thus red apedal soils will transition to yellow apedal soils as one move lower in the landscape. Land type Bc24 is described as eutrophic soils meaning that these soils have a high exchangeable calcium, magnesium, potassium and sodium content (higher than 15 cmol per kg clay) whilst land type Ba42 is described as dystrophic indicating that the elements mentioned have been leached to less than 5 cmol per kg clay (SIR, 1986., Soil-classification workgroup, 1991).

Soils with higher iron and manganese oxide content, as is the case in both locations, tend to adsorb radionuclides and act as a buffer that slows migration of radionuclides (Section 2.5)

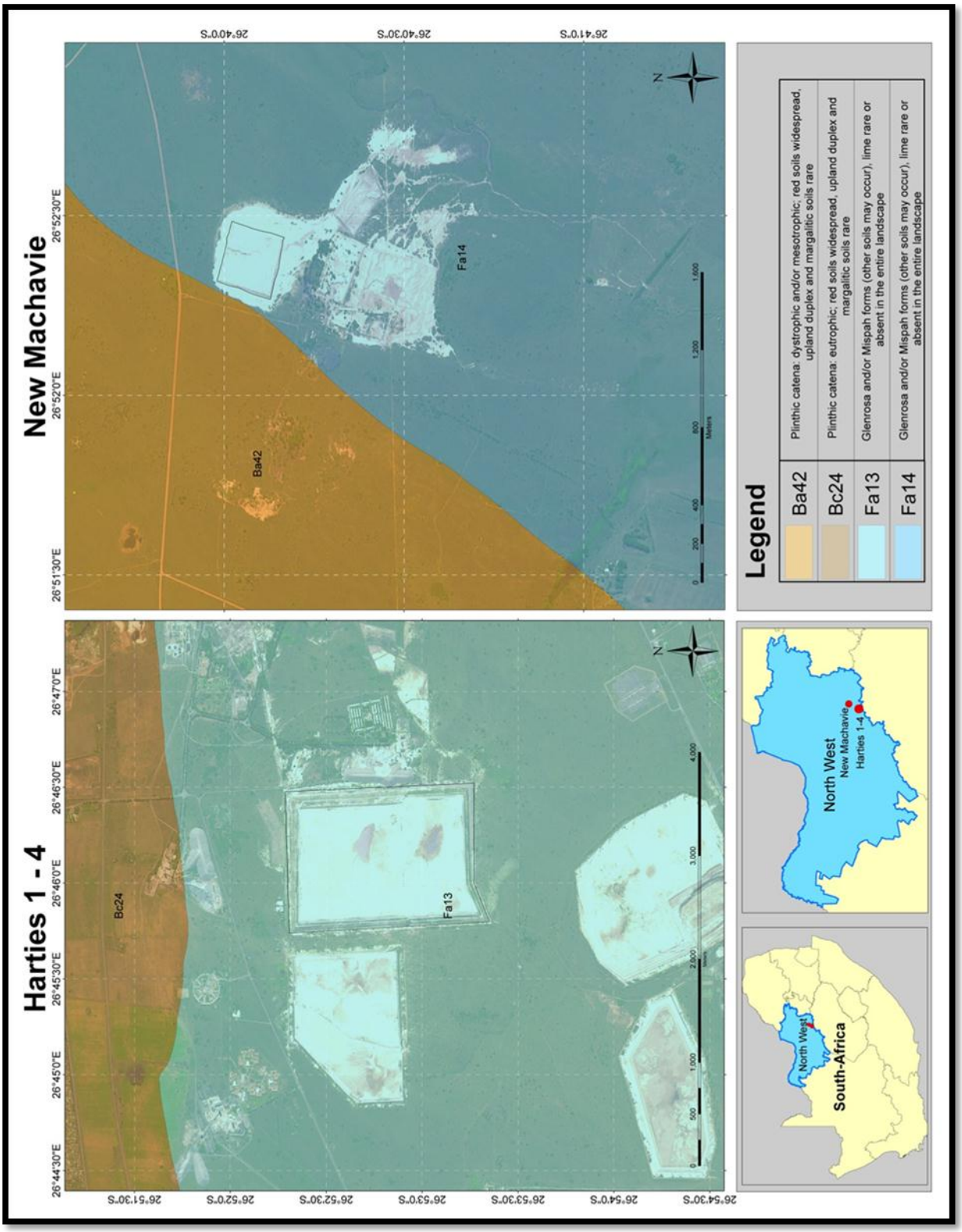

Figure 3.7: Pedology of Harties 1-4 and New Machavie