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Distribution of Heavy Minerals Sand in Namalope Deposit, Moma District, Mozambique

By

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A dissertation submitted in partial fulfillment of the requirements for the degree of

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I dedicate this dissertation to my family especially my sons Igor and Almiro, my wife Valdemira and my parents Ossufo Assane and Maria Andre for their constant support and unconditional love and care.

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DECLARATION

I, **Ali Ossufo Assane**, declare this dissertation to be my own work. It is submitted in fulfillment of the Degree of Master of Science at the University of Rhodes. It has not been submitted before for any degree or examination in any other University or tertiary institution.

Signature of the candidate:

Date:

ABSTRACT

The spatial distribution of heavy minerals along the mine paths 2014 and 2015 at the wet concentrate plant B shows an increase of heavy minerals sand concentration northwards and slime contents southwards, and it is commonly associated with depth and grain sorting; the increase of heavy minerals concentration with depth is considered to be from the surface formed by Unit 6 to the bottom of Unit 7. The Unit 82 is characterized by low heavy minerals concentrations and high slime contents declining northwards.

The mineral proportion estimation suggests that ilmenite is the most abundant heavy mineral in the entire area followed by zircon, rutile and mozanite, and some accessory minerals such as chromite, kyanite, staurolite, tourmaline, epidote, spinel and quartz. The ilmenite occurrence is divided into ilmenite low ($< 53\% \text{ TiO}_2$) and high ($> 53\% \text{ TiO}_2$); the ilmenite high with zircon and rutile shows tendency to increase northwards while ilmenite low increase southwards.

Zircon, monazite, rutile, chromite, kyanite and staurolite show low variability, which is probably associated with high resistance of minerals for abrasion during transportation and diagenesis

The depositional model of the Namalope deposit, in the flat area and wet concentrate plant B in particular, suggests deposition in a shallow marine environment associated with regression for deposition of Unit 6, 7 and 9 and transgression during deposition of Unit 82.

The spatial distribution of heavy minerals in the Namalope deposit and its environment of deposition are the key points for discovery of new deposits around the Namalope with the same characteristic of mineral assemblage and they are used for mine strategic plans such as update block model and mine design.

Keywords: Heavy minerals, slime, ilmenite and mineral assemblage.

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LIST OF ABBREVIATION

Abbreviation	Meaning
WCP	Wet concentrate plant
SRTM	Shuttle radar topography mission
HM	Heavy minerals
HMC	Heavy minerals concentrate
Mt	Million tones
THM	Total heavy minerals
LST	Lithium heteropolytungstates
HAD	Half absolute difference
HARD	Half absolute relative difference
OVSZ	Oversize
VHM	Valuable heavy minerals
QEM*SEM	Scanning electron microscope
EDS	Energy dispersive spectroscopy
XRD	X - ray diffraction
XRF	X - ray fluorescence

CHAPTER 1 INTRODUCTION

Mozambique is situated in the Southern Africa covered by two different geological-structural regions, the Precambrian basement and Phanerozoic units. The Phanerozoic units cover the large part of the country from Archaean mobile belt to Quaternary sediments basin along the Mozambique coastal line which is subdivided into basins namely the Mozambique Basins in the south to centre of the country, the Rovuma basin north, the transition zone between the two main basins (Pemba-Pebane zone), the Zambeze basin area covered by younger sediments from the Quaternary period, and the depression along the lower margin of Lugenda River (Lächelt, 2004). The Moma heavy minerals sand occurs in the transition zone between two main basins (Rovuma and Mozambique) along Mozambique coastal line.

Current thesis has an objective to identify heavy minerals sand distribution and formation in the Namalope deposit at the mine paths 2014 and 2015 in the wet concentrate plant B due to low data availability in that specific area and proximity of dredge for mining. The thesis focuses on infill drilling, data analysis, interpretation and finally simulation of depositional model for the Namalope deposit. Results obtained will be used for resource and reserve upgrade, update mine design from heavy minerals, slime and oversize distribution, and determination of depositional model of the deposit.

Valuable heavy minerals in Namalope deposit are ilmenite, zircon and rutile, constitute 90% of total heavy minerals concentrate fraction while non-economic minerals are garnet, silimanite, kyanite, monazite and other accessories minerals.

Photogeological interpretation and airborne/radiometric surveys helped to determine the occurrence of heavy minerals sand anomalies along south of the Nampula province coastal line, essentially in the North-East of Moma district. The reconnaissance exploration activity undertaken by a joint venture of BHP and Kenmare in 1997 used hand auger and machine auger drilling methods intersect a highly mineralized zone, (GREIG, February, 2001).

Heavy Minerals Sand are minerals found in conjunction with sand deposits with specific gravity not less than 2.9 g/cm^3 , include minerals such as zircon, staurolite, rutile, titanium, monazite, sillimanite (Dryden Jr, 1931).

1.1 HISTORICAL OVERVIEW

In 1986 -1990, Kenmare conducted exploration and evaluation campaign of the Congolone deposit at Angoche district, 80 km North-East of the Namalope deposit which culminated in a feasibility study at late stage carried out by consultant Davy McKee in 1989.

From 1993 to 2002 an exploration and feasibility study campaign for the Namalope deposit at Moma district were completed. During the exploration phase, photo-geological interpretations, surface prospecting, hand-auger drilling, and air-core drilling conducted by the joint venture of BHP Billiton and Kenmare, intersected a highly mineralized area.

Detailed investigations conducted for the Namalope deposit includes geotechnical studies, and later large mine and processing facilities have been constructed (Kenmare, 2013).

Since 2005, exploration work focused on air-core infill drilling across the Namalope and Nataka deposits; with purpose of increase confidence level for a future feasibility study.

In the second half of 2006, the mining operation started at Namalope with one wet concentrate plant and two dredges. Some detailed studies at the Namalope and adjacent deposit at Nataka have been developed using air reverse drilling since 2009 (Rothnie, 2011).

From 2009 to 2010, Kenmare completed a pre-feasibility study and definitive feasibility study in 50% for Brownfield expansion for the mine and processing plant at Namalope deposit; expansion mine operation started in the first quarter of 2013 (Kenmare, 2013)

In the two years of 2011 to 2012, hydrogeology exploration campaigns were carried out by Kenmare and Golder Associate Consultants in the Namalope and Nataka deposits, consisted of ground geophysics and drilling survey for groundwater, culminated in drilling additional water bore holes around mining areas.

1.2 LOCATION OF NAMALOPE DEPOSIT

The Namalope deposit is located in the north of Mozambique coastal line, south of Nampula province, in Moma district and approximately 2000 km from Maputo, the Mozambique capital city (Figure 1 below). The Namalope deposit is usually called Topuito due to proximity of Topuito Village, is linked to Nampula, the capital city of the province by unsealed road of variability quality depending on rainy season periods.

Connection to Topuito is also possible by flight as Kenmare has an airstrip on site with around 1.5 km length and 50 m wide. The road access from Nampula to Maputo and to Nacala main port of the northern part of Mozambique is sealed, and railway access is available from Nampula to Nacala as well.

According to the mine plan design, the mine paths 2014 and 2015 for the wet concentrate plants A and B are located in the north-east of Namalope deposit.

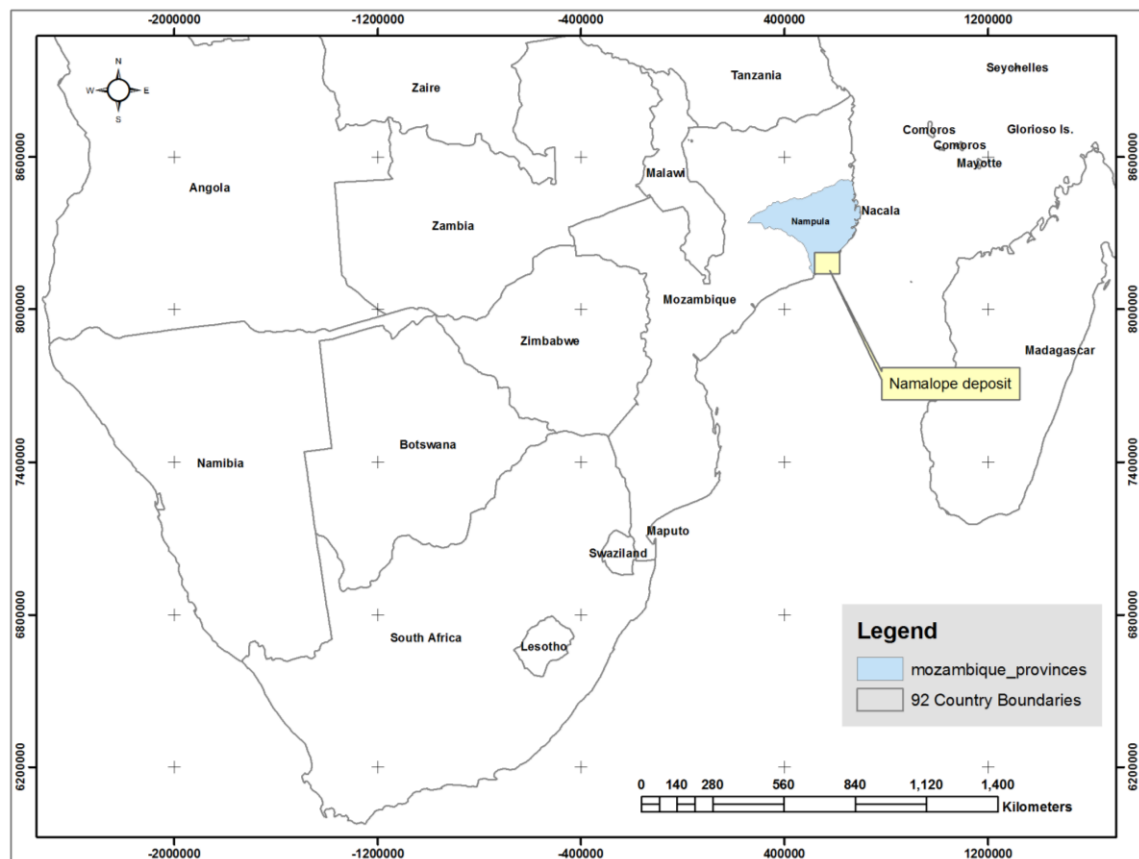


Figure 1: Location map of Namalope deposit, in Nampula province along Mozambique coastal line, northern part of the country.

1.3 TOPOGRAPHY

The Namalope deposit is located in two types of geomorphology - the high dune area formed by Red Sand, namely Old Red Dune in the south-west and the flat area in the north east and south of the deposit along the Namalope coastal line. The northern area is delimited by drainage line and wetlands connected to the Larde River, the main river in the area. The highest elevation in the high dune area is approximately + 90 m MSL and in the flat area is + 20 m MSL. In the south of the deposit is dominated by wetlands and frontal or beach dunes along the coastal line. The Namalope deposit is surrounded by wetlands except in the south-west where is in the high dune area, (Figure 2).

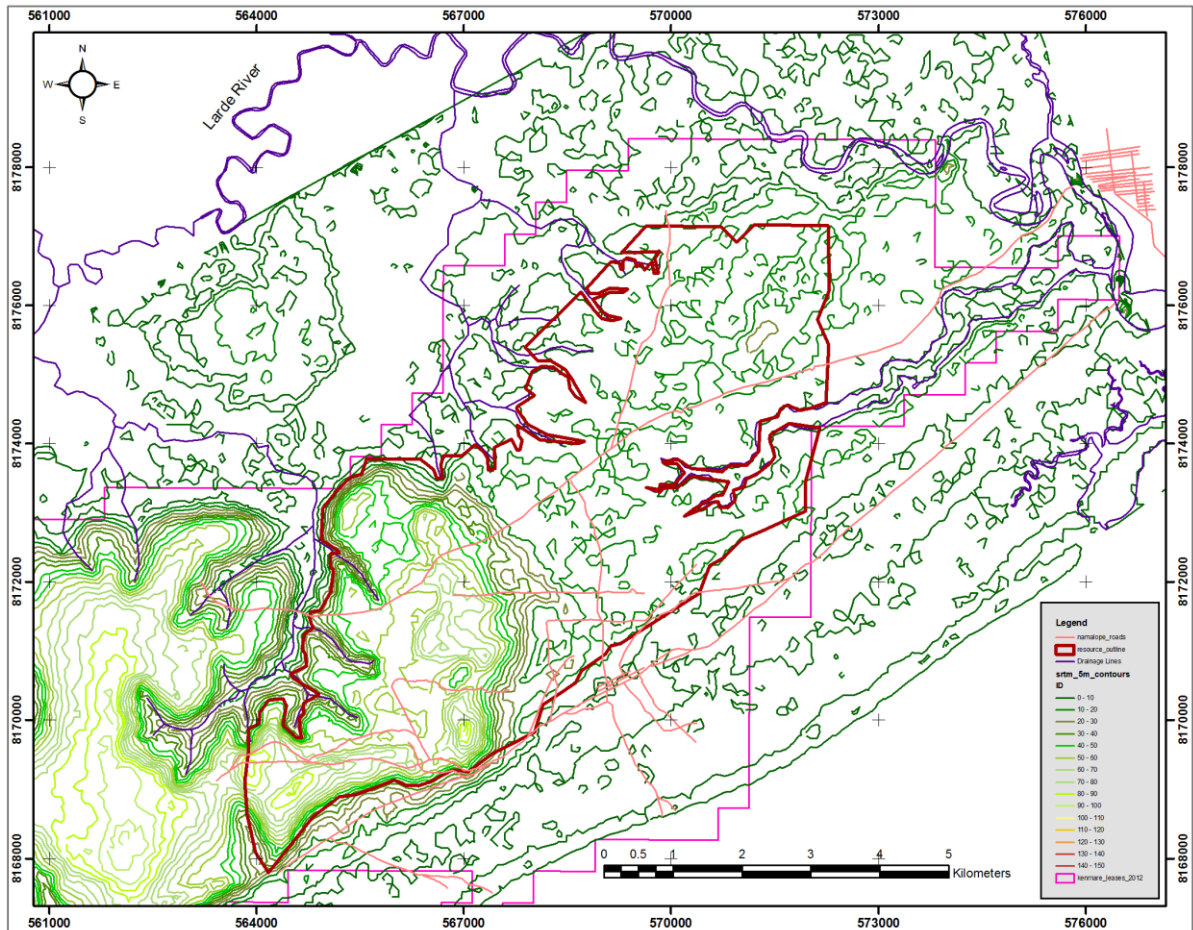


Figure 2: SRTM satellite image showing high dune area in the south-west, flat area from the north, east to the south; the Larde River north to the east, and the drainage lines crossing the deposit in the north-west.

1.4 CLIMATE

The climate of the northern part of Mozambique is differentiated in two seasons: the rainy season usually commences from the end of November and increases its duration from the inland toward the coast. At the coast, the rainy season generally starts from December to April while inland extends toward the end of March. The rainy season is characterized by hot and high humid conditions reflecting tropical climate of the region; the rainfall usually occurs from January to February (Marchand, 1966). The warm dry season in the coast, extends from May to November whereas the inland extends from April to the end of October. In general dry season is cool, with moist air, and light rainy in the coast.

The absolute high temperature recorded is more than 38°C in October, November and January. Temperatures ranges between 33°C to 38°C are common in all months and the lowest temperature of less than 15°C usually are registered in June and July. Mozambique is situated in the cyclonic region, where the wind periods are from September to November, and the dominant wind commonly comes from the south, south-east and east (Fourier and Paterson, 2000).

1.5 VEGETATION AND SOIL

The dominant vegetation in the Namalope deposit is *Deciduous Miombo Savana Woodland*, which occurs in the transitional woodland and sand soil area with rainfall ranging from 800 – 1200 mm per annum, and the dominant trees are *brachystegia spiciformis*, *mangrove* and littoral thicket and forest of recent dunes. The Surrounding areas of the mine, the community growth food crops dominated by cassava, peanut, different variety of beans, cashew nuts, and little maize. The North-east of the Namalope deposit, near Mulimune Village occur thick vegetation called Migurini in local language; it is part of conservation area (Figure 3), (Fourier and Paterson, 2000).

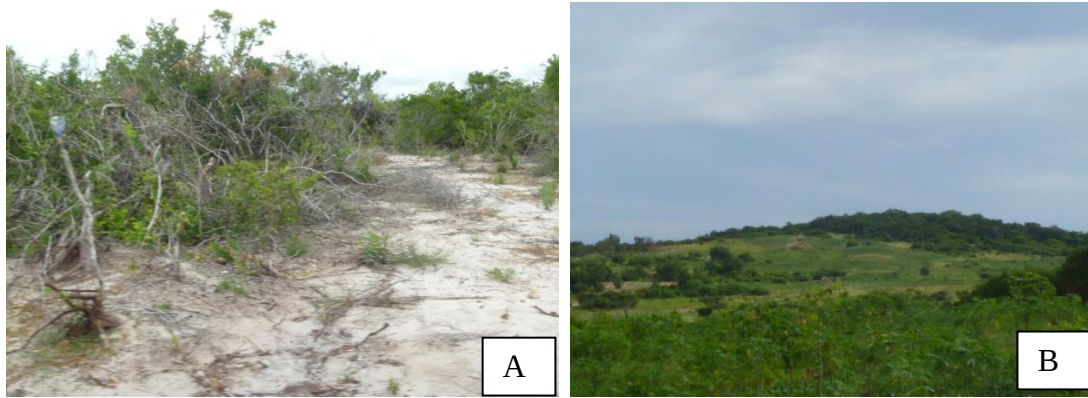


Figure 3: Pictures showing natural vegetation in the flat area (A) and some food crops in the high dune (B).

1.6 JUSTIFICATION

Currently the Namalope deposit is being mined and still needs detailed investigation with regard to drilling; some areas along the deposit still are classified as mineral resources while others are already proven or probable reserves. Detailed information is required in order to enhance the confidence level of data supplied to the mine plan for mine design such as, unit's depth and contact features among units (zones divided according to geologic feature, heavy minerals concentration, slime and oversize), ore grades distribution, slime content to plan adequate strategy for mining, and update ore reserves and resources. The Author in coordination with the Geology Department of Kenmare Moma Mining, planned infill drill program in the mine paths 2014 and 2015 at WCP A and B with general objective of **determining the spatial distribution and formation of heavy minerals sand in the mine paths area mentioned above.**

In order to achieve the planned objective, the Author proposes following specific goals:

1. Plan infill drill program in the reference areas, consisting usually of 100 x 100 m line spacing as the previous drill plan already drilled the remaining areas;
2. Conduct sampling process, data analysis and validation by applying QA/QC procedures;
3. Determine mineralization trend in the mine paths from HM assays;
4. Interpret geological units (zones) using data from cross sections;
5. Determine mineral assemblages in each fraction of concentrates from composite processes;
6. Propose formation model for emplacement of heavy minerals from correlation of drill holes along cross sections, in the Namalope deposit.

CHAPTER 2 GEOLOGICAL SETTING

The Mozambique coastal line extends around 2300 km formed by two principal basins; the Mozambique basin in the south to centre and the Rovuma basin centre to north of the country, their formation is related to Gondwana break-up (157-118 Ma) characterized by active sea floor spread formed of the Indian Ocean and Madagascar drift in Africa. The difference between two basins is centered in environment of deposition during Jurassic and Early Cretaceous, respectively (Salman and Abdula, 1995).

The Gondwana break-up during late Jurassic to early Cretaceous originated rifting along South-East African coastal line, basin formation and consequent filling of drained materials from hinterland. These sediments were drained from craton-type and mobile belt lithological components such as granites, gneisses, pegmatite, greenstone belts, metamorphic terrain and younger lithified sedimentary rocks. Deposition of the sediments was continuous from Cretaceous to the present (145.5 Ma to present) along the shoreline gradually building through the actual coastal plain developed by agents such as Aeolian action, cyclic sea level fluctuation during Quaternary (2.58 Ma to present). Combination of the deposition agents resulted in the formation of placer deposits containing some resistant minerals such as ilmenite, rutile and zircon (Wright, 2000).

According to (Salman and Abdula, 1995), the Namalope deposit is part of Rovuma basin which has a very long coastal line extending from the centre of the Mozambique to Kenya and Somalia. The stratigraphic sequence of the Rovuma basin extends from Karoo to recent with maximum sedimentary thickness of about 10 km according to regional seismic survey and aeromagnetic data. The Karoo sequence is not exposed in Mozambique but is visible from the palaeobasin in Tanzania (Mandawa basin) which was formed during Jurassic and is dominated by salt dome within the stratigraphic sequence, while the post-Karoo sequence is dominated by marine sediments from middle Jurassic to Tertiary considered to be the bottom of the Namalope deposit in the high dune area. The Upper Jurassic sequence occurs in the southern part of the Rovuma basin, dominated by arenaceous bioclastic limestone containing Kimmeridgian-Tithonian fauna. The northern part is dominated by terrigenous formations of the Lower Cretaceous sequence age dominated by progradational facies of conglomerate and sandstone overlain by arenaceous-marly belemnite sequence.

The Upper Cretaceous is formed by sequence of marl, argillite and some considerable gypsum accumulation while the Cenozoic sequence is characterized by shallow water facies from Palaeocene (65.5 – 55.8 Ma) to Miocene (23 – 5.33 Ma), with the Miocene most widespread deposit. The Palaeocene to Eocene (55.8 – 33.9 Ma) sequence is characterized by fossiliferous marl interbedded by quartzose sandstone and coarse bioclastic calcarenite with numulitic Eocene fauna at the end of sequence; the Oligocene (33.9 – 23 Ma) is dominated by shallow water marine sediment interbedded by marls and quartzose sandstone with some Oligocene Foraminiferous overlying by the Upper Cretaceous sequence.

The Miocene sediments occur in the shallow water and deltaic facies with shallow water marl. The Miocene is interbedded with calcarenite rich in fauna (Salman and Abdula, 1995) (Figure 4).

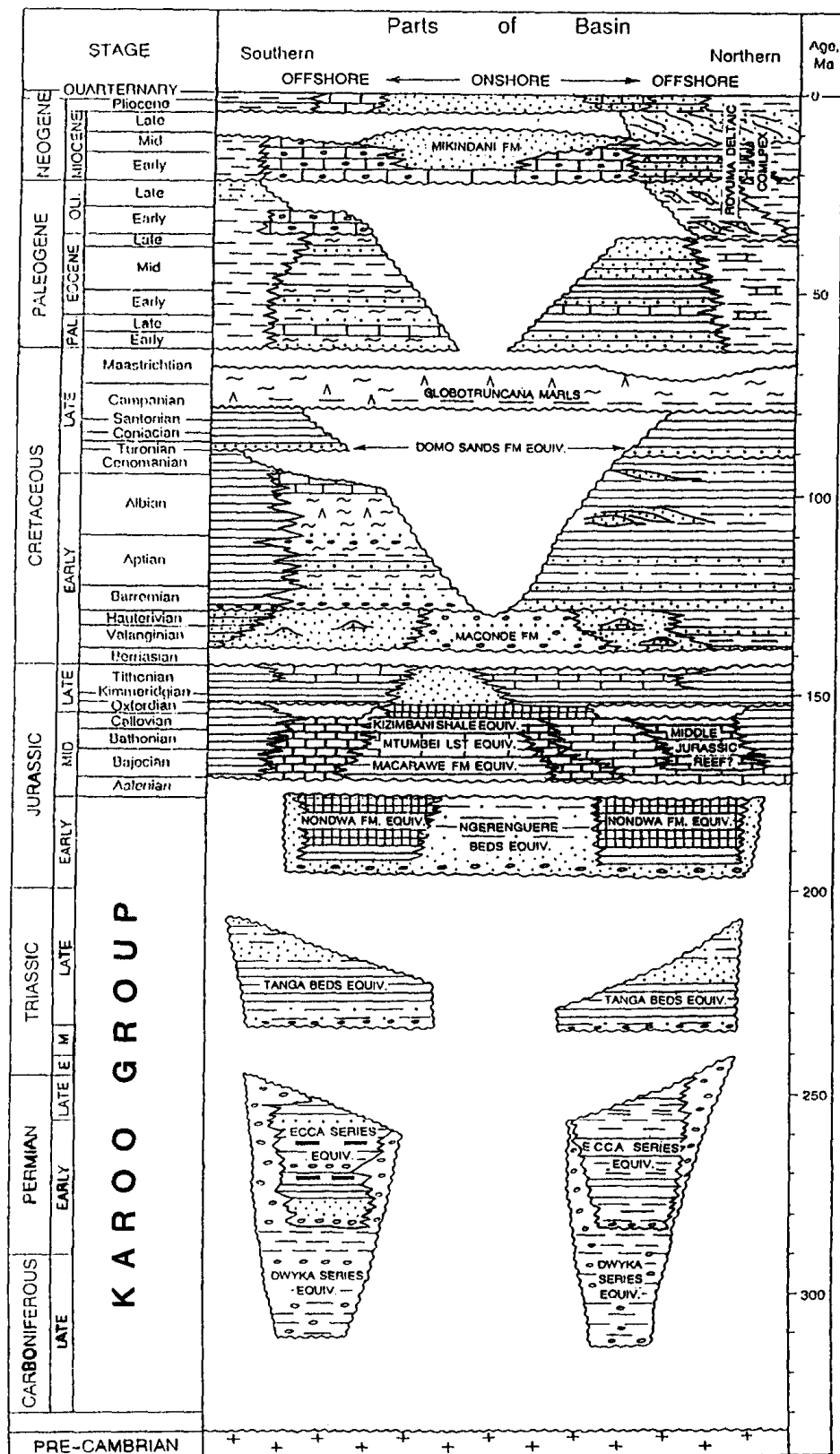


Figure 4: Stratigraphic sequences of the Rovuma basin showing different formation in the basin from Carboniferous to Quaternary periods, after (Salman and Abdula, 1995).

2.1 REGIONAL GEOLOGY

The geological evolution of Mozambique is related to reconstruction of geological-palaeogeographical and tectonic development of the entire Southern Africa region whereas tectonic geologic periods of the development range from Archean to present such as Eoarchean-Paleoarchean development of crustal formation including formation of Gondwana supercontinent and primeval oceans to Quaternary development with continuation of basin development, rifting and actual geologic events. Geologic units of the Eastern Africa were already formed since the Archaean, structural zones and lineaments have been in development or were already developed on the primeval continent (Lachelt, 2004).

The unconsolidated sediments of Southern and Eastern Africa are divided in two terrains, the Old Red Dune sediments and Younger white to orange sands.

The Old Red Dune sediments, also called Deck sands, comprise a mixture of poorly sorted terrestrial sands, including conglomerates and clay layers. They are regional formation associated with a major period of erosion. Deposits within this formation extend in the Eastern Africa coastal line from Kenya to Eastern Coast of South Africa (Richard Bay).

The red colour of Old Red Dune sediments result in high percentage of iron in sediment and consequent oxidation process probably resulted from weathering of ferro-magnesium silicates such as amphiboles, pyroxenes and biotite. Studies undertaken by (Walden and White, 1997) using mineral magnetic measurement, satellite imagery and dithionite iron suggest that the red colour in the Old Red Dune sediments is strongly influenced by hematite within the grain coating.

The younger sand formation is cleaner and extensively developed in a low lying coastal line (plain), approximately 10 km wide, between the Old Red Dunes to the current coastal line. These sediments have accreted over the time intercepted with periods of reworking to produce complex sequence of Beach, dune offshore bar and point, and some swamps deposits formed under a mixture of marine, lagoonal and Aeolian conditions. The source of these materials supposed to be washed Old Red Dunes sediments (GREIG, February, 2001).

The source of both formations of sediments and the heavy minerals sand suites associated with these presumed to be granitic and high grade metamorphic terrains of interior (Figure 5), although the distribution of specific source rocks is poorly

understood, at least in Mozambique. In some areas of the Mozambique coastal line, occur large exposures of Mesozoic basalt, many of them are deeply weathered. The littoral drift along the coast occurs where an average wave incident in the coast is not perpendicular to the coast, and the measured wave data confirm that the Moma coast, South of Nampula province has significant littoral drift in a Northward direction.

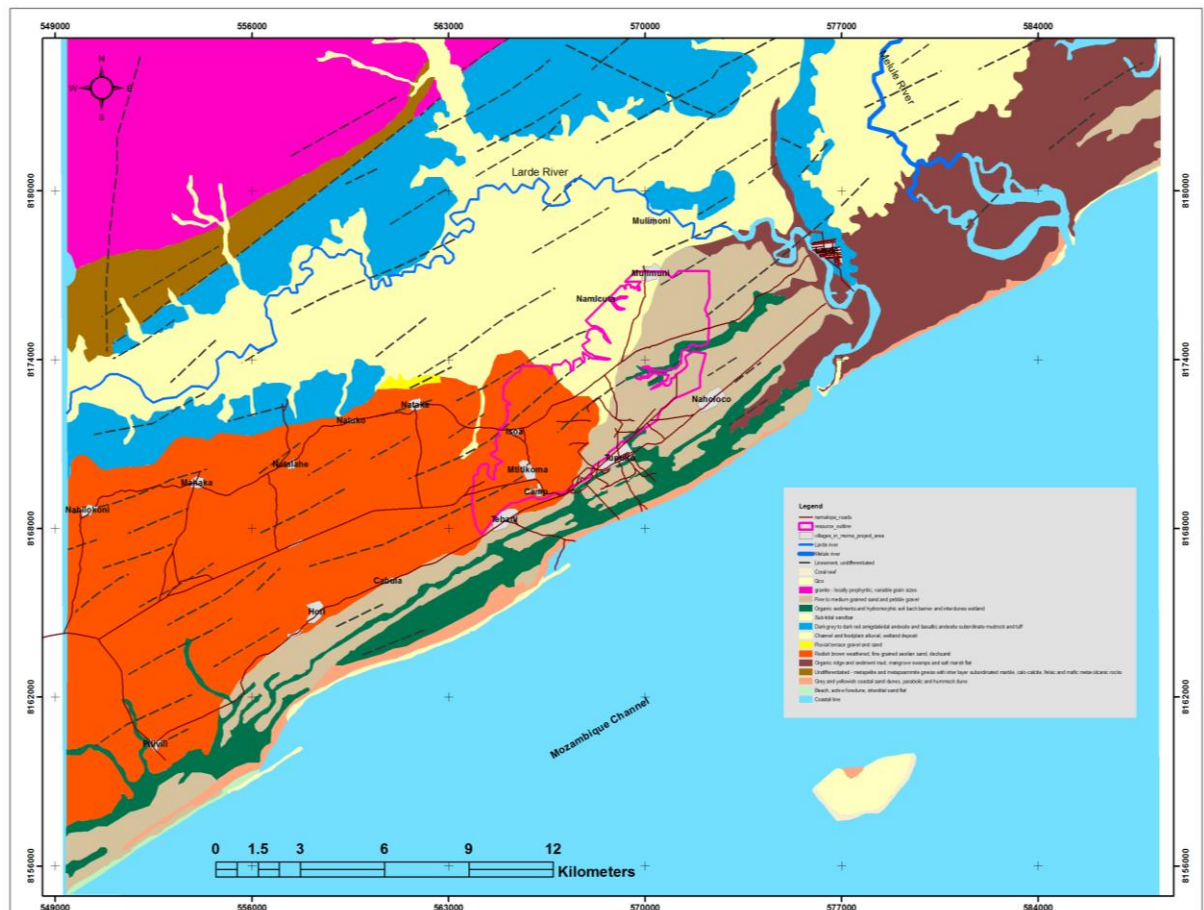


Figure 5: Regional geology map in Nampula province showing Quaternary sediments along the Mozambique coastal line, dominated by the Old Red Dune in red and fine to medium grained sand and pebble gravel in grey; granite locally porphyritic with variable grain size occurs in the north-east while dark grey to dark red amygdaloidal andesite and basaltic andesite with subordinate mud rocks occurs in the north-centre represented by dark blue; the centre of map is dominated by channel and floodplain alluvial, wetland deposits adjacent to major rivers; lineaments cut the entire area, adapted from (Ingram, 2005).

2.2 LOCAL GEOLOGY

In the coastal line of Nampula province in general and Moma district in particular, their geology and geomorphology areas is characterized by three different zones:

- ❖ High dunes – comprise Old Red Dunes area, approximately 2 to 9 km to the present coastal line. Old Red Dune system, ranges from 4-16 km wide and its highest elevation is approximately 145 m in the Nataka deposit at Mputine area, in the west of Namalope deposit is relatively homogenous unit dominantly composed of reddish, silt and fine to medium grained sand, with moderate to high HM contents of 2%-10%.

Towards the sea at slightly lower elevations, the Old Red Dune is covered by younger sands of variable compositions, including cleaner whitish sand areas with higher HM contents. This fact is observed in Topuito, Tebani and Namalope closer to the Nick zone (interface between high dune and lower area of the Namalope deposit). Several marine transgressions have eroded and reworked the edges of the Old Red Dune. A significant proportion of the original ridge has also been eroded in steep-sided creeks, with many of the resulted sediments contributing to the shoreline sediments. The reworked heavy minerals in these shorelines were possibly supplemented with minerals from rivers discharging into the ocean nearby. In the Nataka deposits, the Old Red Dunes shows drainage line associated with fluvial erosion of Rio Larde in the North of the deposit (GREIG, February, 2001).

- ❖ Flat Area – Covers the eastern to north-eastern of the Namalope deposit, with 15-20 m of elevation, and it lies at the end of the ridge of the Old Red Dune; where heavy minerals have probably accumulated by long-shore drift. The Heavy minerals can be found in one layer with a base a few meters below the current sea level, and a second layer of the greater extent with a base about 6m above of the sea level. Adjacent zones of the Old Red Dune are also sufficiently mineralized to be included in the reserve. Finally, there are zones of clean, high-grade dune sands overlying parts of the Old Red Dune that were probably deposited at the same time as the shoreline deposits
- ❖ Coastal Flats and Dunes – up to 3 km wide, and are located between the Old Red Dunes and the sea which is characterized by the presence of lakes, waterways, swamps or grassy flat land at elevation of 10 m. A narrow zone of

linear coastal dunes, with approximately 20 m of elevation comprises clean white well sorted sands. In the dunes, the heavy minerals (HM) contents can be high at surface (Pilivili deposit), approximately 12 m deep but generally these are low grade area, (Figure 6).

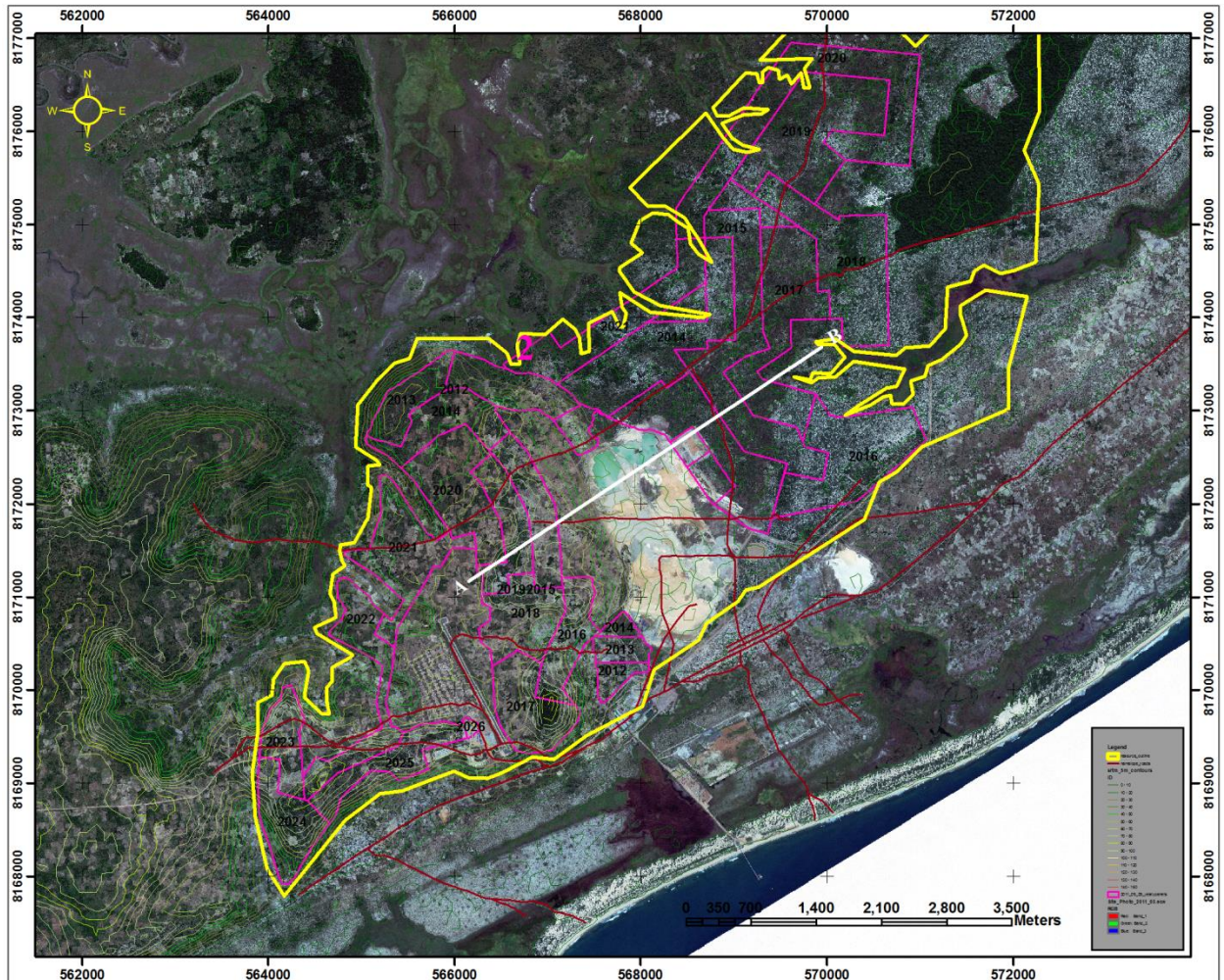


Figure 6: Site map showing Namalope deposit outline, the mine site and mined out area along the mine paths, where the flat area is in the north and east, the coastal line in the south and the high dune in the west of deposit.

Kenmare classified its stratigraphy sequence into units, according to HM concentration, clay content, oversize and colour. The Units are spatially distributed from units 1 to 4 in the Old Red Dune and from units 5 to 9 in the flat area.

Description of Old Red Dunes units:

- ❖ Unit 1: Clean, yellowish well sorted sands, typically has less than 5% of slime and HM grade higher than all of the Old Red Dunes units, over 5% on average.
- ❖ Unit 2: Silty, light orange, fine to medium, moderately well sorted sands, commonly contains from 5 to 15% of slime. In this unit, the slime content increases with depth. The HM content is more variables than in unit 1 but can be economically significant.
- ❖ Unit 3: Very silty with minor clay, orange, very fine to fine well sorted sands. The slime content is from 15 to 25% and HM from 2 to 4% but both can increase with depth as in unit 2.
- ❖ Unit 4: very silty to clay poorly sorted sands, colour varies but is commonly dark red or dark orange brown. Grit is composed of angular feldspars and quartz. The slime content is generally more than 25%, increasing with depth. This unit is defined as the base of Old Red Dunes (GREIG, 2001).

The flat area contains the following units:

- ❖ Unit 5: Characterized by clean white, light to pale tan, medium to coarse sand with grit, commonly has low HM.
- ❖ Unit 6: Clean light grayish yellow to tan or white, very fine, fine and medium, moderately well sorted sands. It generally contains less than 5% of slime and than 1% of oversize grains. This is the higher HM grade units in flat area.
- ❖ Unit 7: Slightly fine to medium silt to light gray and yellow, very fine, fine, medium and coarse, fair to poorly sorted sand with minor grit. Its colour can vary from pale, yellow, khaki gray to bright yellow; the slime content is from 5 to 15% and has same concentration of HM as in unit 6.
- ❖ Unit 81: This is the upper clay band, variable colour described as light brown, light khaki, dark gray and mottled grey. The slime contents range from 20% to 60% but mostly in the range of 30% to 40%. Few oversize of small iron concretion can be seen in the many intervals.
- ❖ Unit 82: lower clay band in the flat area, light tan to gray brown, the slime ranges from 40% to 70%, described as hard stiff clay. This clay band has approximately 3 – 6 m in thickness, and occurs near the Nick point to the North in the Namalope deposit.

- ❖ Unit 9: Clean to slightly poorly sort white to pale gray, sands with low HM commonly less than 1%. This unit is laterally variable and is underlain by a very fine micaceous sand and coarse silt unit (GREIG, 2001)

The stratigraphic sequence of the Namalope deposit in Figure 7 shows cross section projected from high area namely the Old Red Dune to the flat area as shown in Figure 6 cross section line A-B.

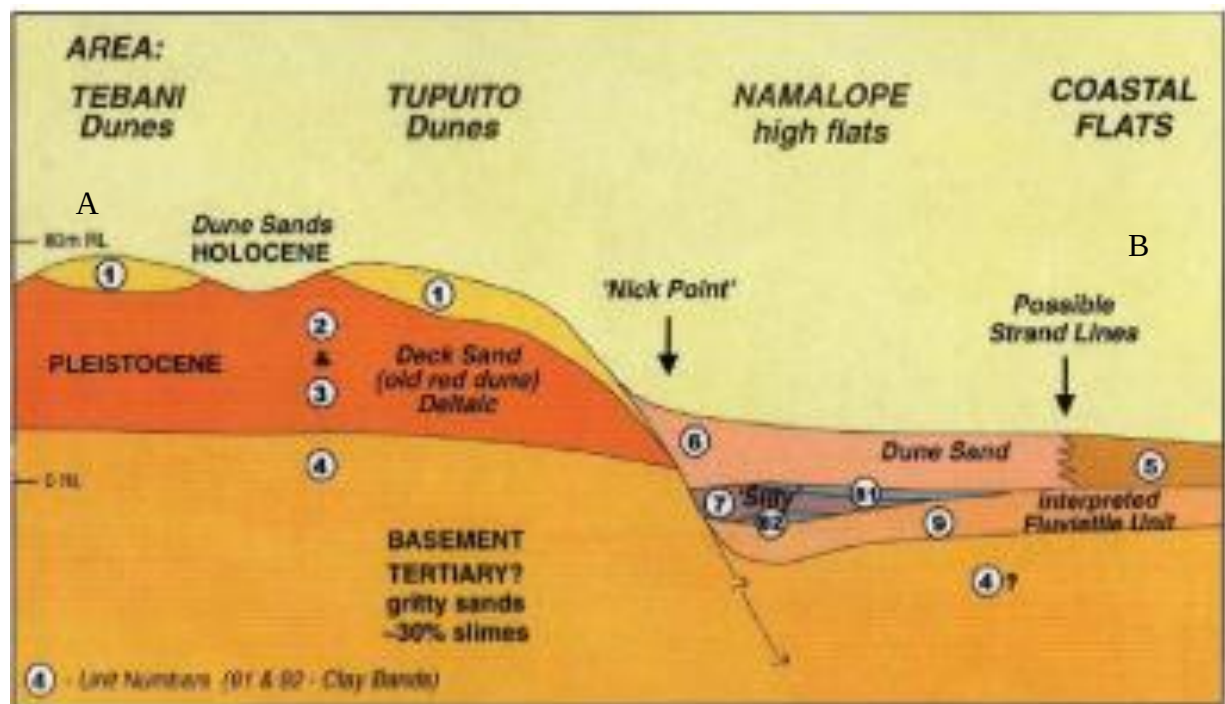


Figure 7: Cross section showing stratigraphic sequences of the geological units in the Namalope deposit, with unit 4 as the basement of all deposits, units 1, 2 and 3 in the high dune area, and units 6, 7, 81, 82 and 9 in the flat area, after (GREIG, 2001).

CHAPTER 3 DATA ON HEAVY MINERALS

SAND FORMATION

Heavy minerals sand are part of placer deposits formed by liberation of valuable mineral resources such as titanium, zirconium, rutile, monazite and many rare earth elements from weathering of parent rocks and deposition by geochemically complex bodies in sedimentary basins through sedimentary process.

3.1 PROCESSES OF ACCUMULATION

The formation of sedimentary rocks in general and placer deposits in particular involves transport of particles to the deposition in the basin by gravity, water, air, ice, mass flow, chemical or biological growth of materials in place.

Sediments move through a fluid as function of size, shape, density, velocity and viscosity.

The formation of sedimentary basin starts with uplift of pre-existent rocks (igneous, metamorphic or sedimentary), submission to the weathering on the rock surface, forming clastic detritus release ions into solution in the water or near water surface. After formation, they are removed by erosion from bedrock surface transported and deposited in land or in the sea as dissolved or particulate matter by various mechanisms such as physical, chemical and biogenic processes. The last stage is the formation of sedimentary rock exposed on the surface (Nichols, G., 2009).

Uplift of pre-existent rocks is related to tectonic activity. The rocks weathered close to surface are subject to physical and chemical modification by different weathering processes such as water percolation into the joints, frost shattering (water entering into the cracks, rocks expand and force cracks to widen), salt growth, temperatures changes. The chemical processes of weathering involves rock solution forming sedimentary bedrock, minerals hydrolyses (formation of clay minerals from feldspar), oxidation forming iron oxides and hydroxides from iron minerals. Erosion and transport are governed by gravity, water, wind, ice or combinations of all these processes; denudation and landscape evolution are determined by topographic, related to altitude of the terrain and its relief during basin deposition and climatic factor responsible for chemical weathering process (chemical reactions, surface rock-water) of rock surface by introducing water in the system and temperatures most of those chemical reactions undergoes at high temperature areas (Nichols, G., 2009).

In summary, heavy minerals sands are formed in beach or dune basins with different stages of accumulation from suitable rocks containing heavy minerals and underwent long period of surface rock weathering, uplift and destruction of landscape surface, erosion and transport of resistant materials in the stream, and finally deposition along coastal line in one or different cycles (Figure 8). Deposition of heavy minerals sands normally occurs in narrow strips often with high concentration, carried by wind current for formation of dune deposits; in the Namalope deposit, wind deposit formed are in the high dune area characterized by red colour (Deck sand area, Figure 7).

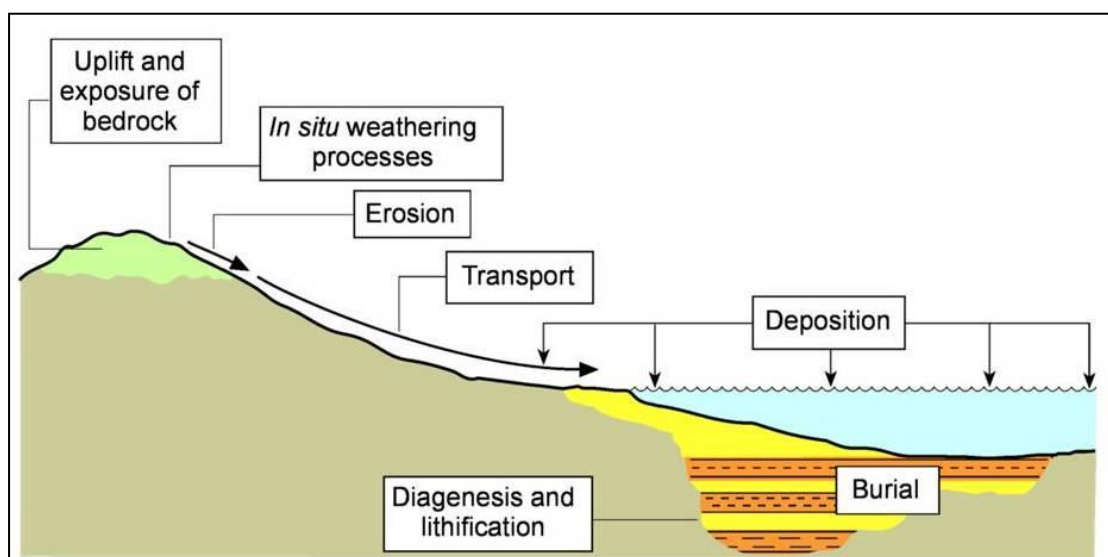


Figure 8: Scheme showing formation of sedimentary deposits (placer deposits), from the uplift and exposure of bedrock to diagenesis and lithification of sediments, after (Nichols, G., 2009).

3.2 TITANIUM AND ZIRCON MINERALS

Common titanium and zircon minerals are ilmenite (FeTiO_3), anatase (TiO_2), brookite (TiO_2), leucoxene (FeTiO_3), rutile (TiO_2), zircon (ZrSiO_4) and baddeleyite (ZrO_2). Common minerals in the Namalope deposit are ilmenite, zircon rutile as principal and economic minerals, and monazite ((Ce, La, Pr, Nd, Th, Y) PO_4), magnetite (Fe_3O_4), chromite (FeCr_2O_4), kyanite ($\text{Al}_2\text{O}_3 \cdot \text{SiO}_2$), staurolite ($\text{Fe}^{2+}_2\text{Al}_9\text{O}_6 (\text{SiO}_4)_4(\text{O},\text{OH})_2$), tourmaline ((Ca,K,Na,[])(Al,Fe,Li,Mg,Mn) $_3$ (Al,Cr,Fe,V) $_6$ (BO $_3$) $_3$ (Si,Al,B) $_6$ O $_{18}$ (OH,F) $_4$), epidote ($\text{Ca}_2\text{Al}_2(\text{Fe}^{3+};\text{Al})(\text{SiO}_4)(\text{Si}_2\text{O}_7)\text{O}(\text{OH})$), spinel (MgAl_2O_4), and quartz (SiO_2), as accessories and uneconomic minerals. The high content of iron in the ilmenite is caused by intergrowth of hematite or magnetite. The most important and abundant titanium minerals in the world are ilmenite followed by leucoxene,

which is alteration of ilmenite, and rutile as the most important titanium oxide. Natural alteration of ilmenite by partial removal of iron results in the formation of pseudorutile, which is intermediate iron titanite of poorly defined structure, complete removal of iron from pseudorutile lattice of grains comprising crystallites of rutile and anatase. Leucoxene is alteration of product with high content of TiO_2 , (Koroznikova et al., 2008, Table 1).

Table 1: Classification of TiO_2 contents containing in minerals sands and its specific gravity, after (Koroznikova et al., 2008)

Heavy mineral name	Specific gravity	Formula	TiO_2 Content (%)
Ilmenite	4.7 - 4.79	FeTiO_3	35 – 65
Pseudorutile	3.9	TiO_2	60 – 65
Leucoxene	4.2 - 3.9	$\text{FeTiO}_3 - \text{TiO}_2$	65 - 90+
Anatase	3.8 - 3.9	TiO_2	> 90
Rutile	4.2 - 4.3	TiO_2	94 – 96

Most of titanium minerals are used to produce TiO_2 for white pigment, in plastic, paper, and rubber, additive in frits, glazes and titanium ceramics mixtures. Other utilities of titanium minerals are titanium metal used in aircraft industries, rocket and satellite construction, atomic industry, submarines, special machinery for chemical, textile and metallurgical industries, and in medical appliance. Production of titanium dioxide is based on sulfate route or chloride route. The sulfate route is an old method, requiring ilmenite content from 45–55% of TiO_2 , or titanium slag of 70-80% TiO_2 ; the chloride route is a new method, more complicated and expensive requiring high content of TiO_2 , more than 85% chlorinated at 850-950° for production of TiO_2 .

Zircon is refractory and resistant to corrosion with low neutron absorption material, used to produce refractory bricks for ceramic and refractory industry; zirconium is used to produce casing for fuel rods, in ferroalloys, as abrasive, in the chemical industry.

Usually titanium minerals have magmatic rock as parent rock and their derivatives is mainly the basic magmatic rocks; rutile is concentrated in acid magma as accessory minerals such as pegmatite, contact deposits and vein deposits; zirconium minerals

with hafnium are common in granitic rocks, pegmatite, granodiorite and baddeleyite as accessory minerals (Koroznikova et al., 2008).

3.3 RESOURCES AND RESERVES

Heavy minerals sand deposits are placer deposits, occur in the mouth of the main rivers as result of deposition of material from hinterland along coastal line. In Mozambique the major rivers with mouth along the coastal line are Zambezi, Save, Ligonha, Lunho and Rovuma, and they have alluvial uneconomic heavy minerals deposits in their beds with small tonnage, which makes them poor in term of concentration of heavy minerals and not economically viable, common heavy minerals are ilmenite, leucoxene, rutile, zircon, monazite, kyanite, andalusite and magnetite. TiO_2 content is less than 50% from South Africa border to Save River south of Mozambique; good ilmenite content occurs in Pebane, Angoche, Quinga, Gorai, Idugo, Moma and Moebase; TiO_2 content in rutile varies from 89.5% to 99% while zircon has 46% to 60% of ZrO_2 (Wright, 1998).

The south of Mozambique is characterized by long coastal line with approximately 80 km wide and presence of heavy minerals at the beach, which make this area good target for heavy minerals exploration whereas possible conflicts can occur due to ecotourism activity. Heavy minerals in this area are from Pleistocene to Holocene in age, except in Marracuene area, which is Red Dune in Pliocene. The central part of Mozambique has approximately 100 km wide of coastal line and is important target for heavy minerals; the north of this area is located in the Moebase deposits at Pebane district, Zambezia province, which is considered one of the good deposits in Mozambique. The northern part of the Mozambique coastal line extends from Moma district to Rovuma River, bordered with Tanzania; heavy minerals sands occur in the Red Dune and Beach Dune from Moma to Mogincual districts, along Nampula province coastal line with good quality of ilmenite, zircon and rutile (Wright, 1998) (Table 2), map shown spatial distribution of heavy minerals sand in Mozambique is appended to this thesis (Appendix 1).

Table 2: Ore resources of South, Centre and North of Mozambique show deposit tonnages, heavy mineral concentrations and geological information, after (Wright, 1998).

Locality	Deposit (Mt)	HMC (Mt)	Geological Information
Southern Mozambique			
Ponta de Ouro	108	3.24	Area of ecotourism conflict
Lagoa Pati	4	?	
Marracuene	?	?	Pliocene (?) deposit
Limpopo River Mouth	541	18.94	Marine and alluvial, worked in past
Chongoene	?	10	Shoreline and Aeolian
Massoro	19.8	1.39	Shoreline and Aeolian, abandoned mine
Xai-Xai	?	?	Beach and dune deposits
Maxecane	?	2	Aeolian
Ponta Zavora	?	0.3	High cones on beach and coastal dune
Jangamo	33	2.64	Abandoned shoreline and Aeolian deposit
Baia de Inhambane	?	?	Deposit in Pliocene? Dunes
Praia Morrungulo	?	?	High HMC in beach sand
Inhassoro	29	1.74	Abandoned Aeolian placer mine
Total	734.8	40.25	At average of 5.5% HMC
Centre and Northern Mozambique			
Micuane and Deia	259	50	Aeolian and beach deposits
Quelimane	24.9	2.5	Aeolian and beach-ridge deposits
Zalala	15	1.5	Shoreline and dune placer
Raraga Gorai	59	29?	Very high HMC on beach and beach ridges
Pebane and Idugo	?	2.74	Aeolian placer
Moebase	1253	47.58	Pleistocene-Holocene beach and dune placer
Moma	6.24	0.42	Shoreline deposits
Angoche	207	9.11	Aeolian
Congolone	167	5.34	Aeolian and shoreline placer
Quinga	1246	23.44	Abandoned shoreline and Aeolian deposit
Total	3237.14	142.63	At an average of 5.3 % HMC

(Beiersdorf et al 1980), cited by (Wright, 1998), described potential of the offshore of Mozambique in heavy minerals sands associated with past low sea level; heavy minerals are distributed along the outer and middle shelf of Zambezi River delta with approximately 4.415 Mt of continental shelf sands and 214 Mt of economic heavy minerals sands however these deposits are sub economic due to hostile environment and logistic problem for mining.

Recently the offshore mining technology combined with the local harbors can make these deposits economically viable in the future. Figure 9 shows combination of ilmenite, zircon and rutile resource in South Africa, Southern, Centre and Northern, and offshore of Mozambique.

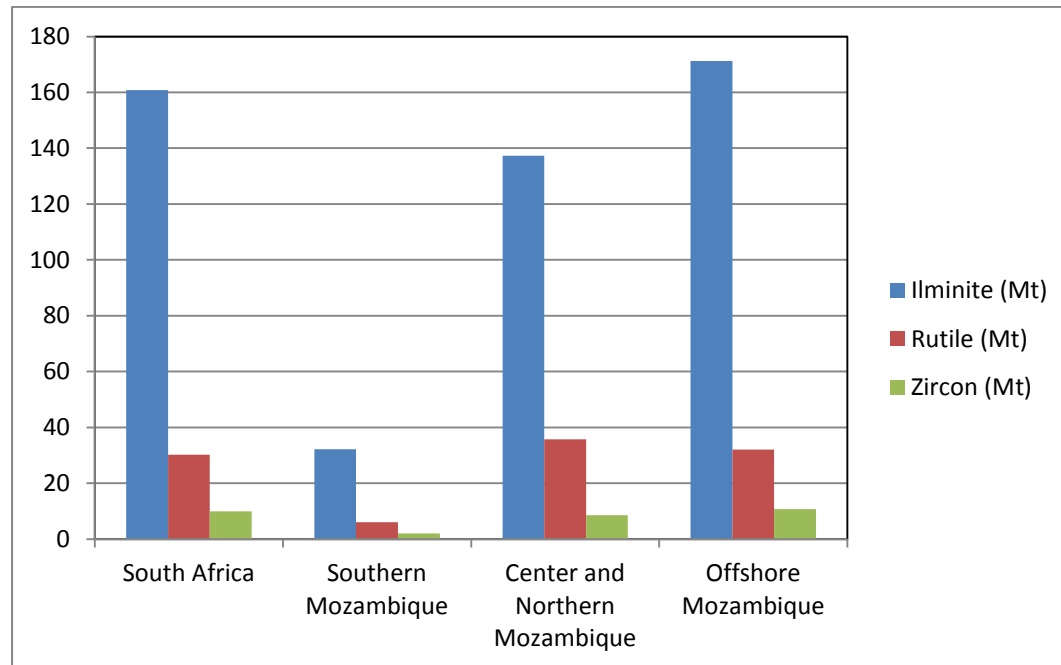


Figure 9: Diagram showing tonnages of ilmenite, rutile and zircon in the South Africa, onshore and offshore of Mozambique.

The Namalope deposit is situated in the centre to north of Mozambique, in the Moma district with heavy minerals sands most of them deposited in the Pleistocene Deck sand, Holocene dune and in dune sand along Namalope shallow area. Resources and reserves from Namalope and other areas hold by Kenmare Resources are show in Table 3 and Figure 10.

Table 3: Kenmare resources and reserves in the North of Mozambique, Nampula province coastal line, after (Rothnie, 2011)

Resources	Category	Ore (Mt)	THM (%)	Ilmenite in THM (%)	Ilmenite in Ore (%)	Rutile in Ore (%)	Zircon in Ore (%)	THM (Mt)	Ilmenite (Mt)	Rutile (Mt)	Zircon (Mt)
Congolone	Measured	167	3.3	77	2.5	0.06	0.24	5.4	4.2	0.1	0.4
Namalope	Indicated	350	3.1	81	2.5	0.06	0.18	11	8.7	0.21	0.6
Pivilli	Inferred	227	5.4	80	4.3	0.13	0.35	12	9.8	0.3	0.8
Mualadi	Inferred	327	3.2	80	2.6	0.061	0.21	10	8.4	0.2	0.7
Nataka	Inferred	5,800	2.8	82	2.3	0.047	0.15	160	130	2.7	8.6
Mpitini	Inferred	287	3.6	80	2.9	0.07	0.24	10	8.3	0.2	0.7
Marrua	Inferred	54	4.1	80	3.3	0.18	0.19	2.2	1.8	0.1	0.1
Quinga North	Inferred	71	3.5	80	2.8	0.14	0.28	2.5	2	0.1	0.2
Quinga South	Inferred	71	3.4	80	2.7	0.14	0.28	2.4	1.9	0.1	0.2
Total Resources		7,400	2.9	82	2.4	0.055	0.17	220	180	4	12

Reserves	Category	Ore (Mt)	THM (%)	Ilmenite in THM (%)	Ilmenite in Ore (%)	Rutile in Ore (%)	Zircon in Ore (%)	THM (Mt)	Ilmenite (Mt)	Rutile (Mt)	Zircon (Mt)
Namalope	Proved	250	4.4	82	3.6	0.085	0.26	11	9	0.21	0.66
Namalope	Probable	174	3.8	82	3.1	0.074	0.23	6.6	5.4	0.13	0.4
Nataka	Probable	445	3.2	83	2.7	0.047	0.16	14	12	0.21	0.73
Total Reserves		869	11.4	247	9.4	0.206	0.65	31.6	26.4	0.55	1.79

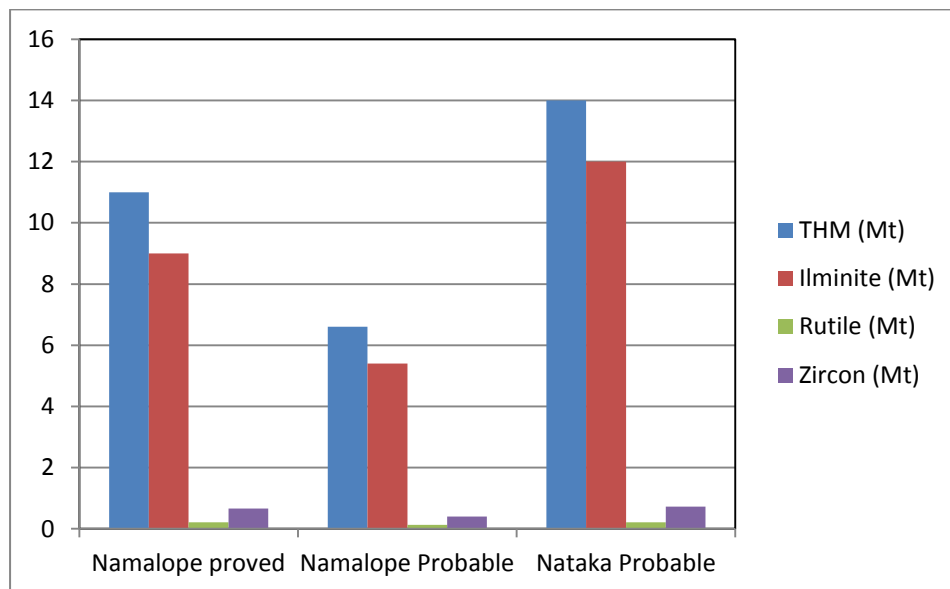


Figure 10: Diagram of tonnages of total heavy minerals (THM), ilmenite, rutile and zircon in the Namalope and Nataka, Kenmare Moma Mining.

CHAPTER 4 METHODOLOGY

A geochemical sampling program is undertaken for two main objectives of search on mineral deposit-related targets and description of geochemical variability of an area, or rock units, either statistically or spatially (Howarth, 1983). The former one is conducted by using statistical method of survey data analysis and the later one is analyzed by an interpretation of survey data using GIS.

The methodology used in this thesis consisted on literature review, identify uncovered area by 50 x 50 m drilling program in the mine paths 2014 and 2015, plan 100 x 100 m spacing infill drill program using ArcGIS and Easimine, data interpretation from cross sections generated using Easimine and generation of stratigraphy sequence of the Namalope on datamine.

The 100 x 100 m infill drill program used in this thesis consisted on plan: site selection, sample size, size fraction, field concentration, drilling, sample collection, sample storage, survey, and sample analysis.

4.1 SITE SELECTION

The fundamental concept of sampling methodology is to do target generation and analyze sample population. The target population refers to the total rock units, area, material type that sampling activities are covered and hypothesis test is meant; the sample population is sampling of materials left by target population due to logistical impossibility. During site selection it is important to have in mind clear pictures of hypothesis to be tested and geological materials, which the test will be applied (Howarth, 1983). Site selection must be done carefully and rated according to the effectiveness for the concentration of heavy minerals (Verran, 2008).

The purpose of this thesis is to identify spatial distribution and formation of heavy minerals sands using data from the infill drill program. In order to optimize recovery of the heavy minerals and delimitation of units outlines, sample site selection criteria are based on location of anomalies from previous exploration programs and location of gap left during the first exploration program along the dredge path (WCP A and B, 2014 and 2015, Figure 11).

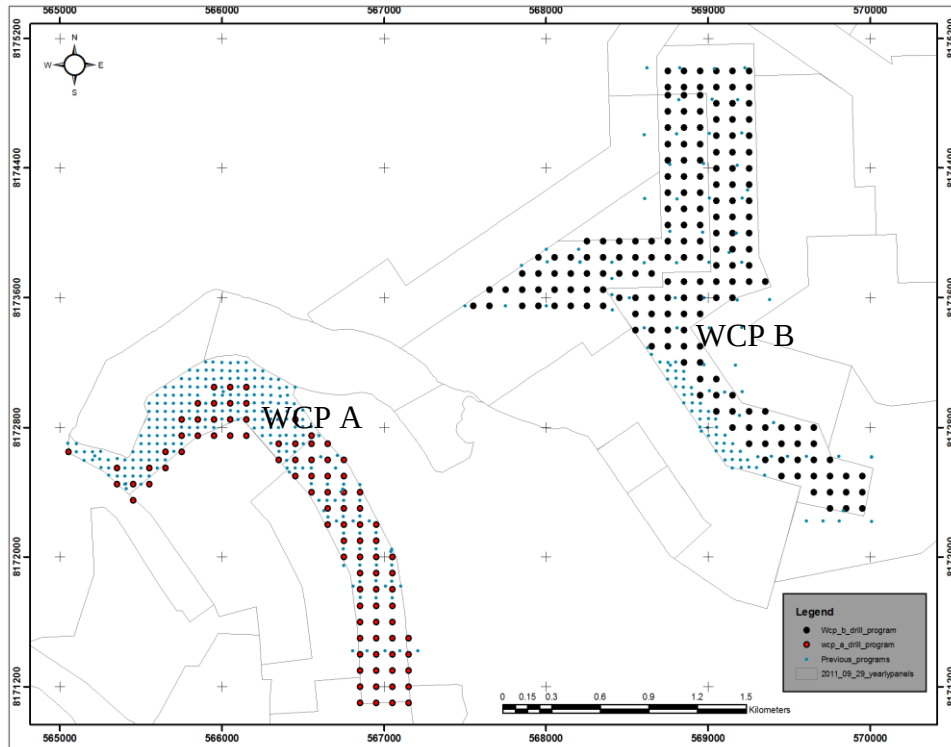


Figure 11: Map showing site selection of planned drill holes for WCP A and B 2014 and 2015 based on the previous program.

4.2 SAMPLE SIZE

Geochemical mapping programs suggested collection of sufficient quantities of sample materials to allow performance of different analytical methods. The minimum amount of recommended sample size available for analysis and references is 100 grams of fine fraction materials (Darnley et al., 1995).

The sample size used for the thesis purpose is approximately 5000 grams of soil (sand) for heavy minerals separation, 50 grams or more of composite fraction for XRF analysis, and 20 grams for field panning.

4.3 SIZE FRACTION

Collection of the optimal field fraction of heavy minerals can help for determination of sample size previously described. The field size fraction is obtained by screening sample using sieves to obtain specific size of sample material, typical size fractions of heavy minerals range from 62 micron to 2000 micron of sieve (Verran, 2008).

The size fraction used in the thesis is based on the 100 grams obtained from 5000 grams of initial weight and is classified as, oversize, slime and deslime for heavy mineral concentration.

The deslime materials consist on remove fine fraction from the weighted 100 grams using water and paint brush to push fine materials through – 0.045 mm lost during washing process; oversize is material bigger than 1 mm retained on top of the 1 mm screen; recovered oversize is dried and weighted for oversize percentage estimation same to the deslimed materials situated between 1 mm and 0.045 mm.

Oversize percentage is calculated as + 1 mm fraction divided by initial sample weight; and slime is calculated by subtracting combination of two dried fraction (oversize and deslime), from the initial fraction weight.

4.4 FIELD CONCENTRATION

The field concentration of heavy minerals is the gravity separation techniques applied to separate heavy to light material in the certain sample, common field concentration techniques used are jigging and panning (Verran, 2008). Panning and test concentrate is one of the cheap, quick and less time consumption techniques than others such as geochemical methods (Zeschke, 1961). According to (Verran, 2008), panning is very time consuming technique comparing with jigging field concentration and it uses small volume, which take long time to process; however, panning is often suitable for concentration of heavy minerals from fine grains (<500 micron). The common techniques used for heavy minerals prospecting are panning because it covers few minerals that are of economic interest in the entire samples submitted for panning process.

In this thesis, concentration technique used for heavy minerals separation is panning. Pan is broad flat bottomed dish with sloping sides, during panning collected samples are homogenized and small volume of the samples taken, usually one full spoon (20 grams), and washed; during washing light materials in suspension are removed and determined percentage of settled remaining heavier materials at the bottom of pan dish, as showing in Figure 12.

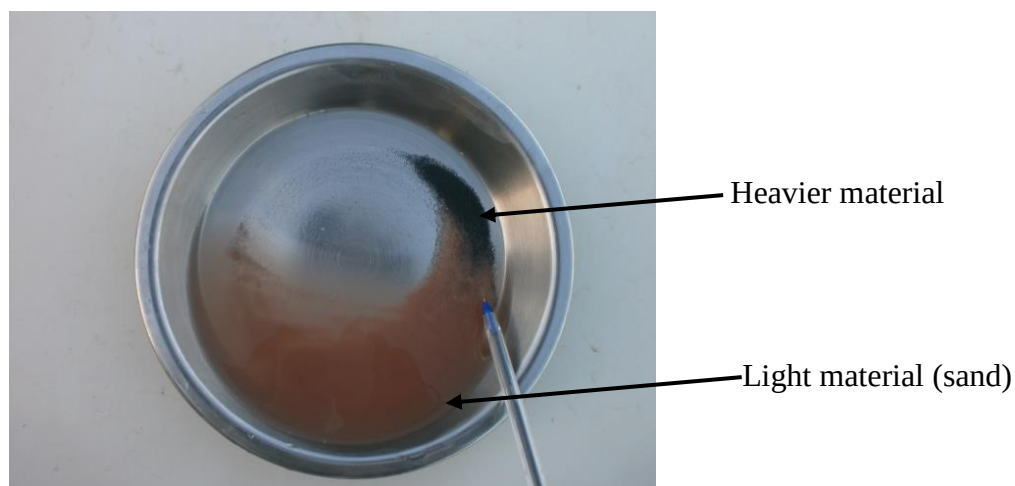


Figure 12: Pan dish with some heavier and lighter materials obtained from washed materials (sediments).

4.5 DRILLING

The design of heavy minerals drilling program, determination of optimal sample density, sample media, sampling methodology and analytical procedures used are controlled by; generated target type, the size and exposure of target and the climate, and physiography of area (Verran, 2008). Smaller target generally requires high density sampling to ensure halo dispersion, for follow up sampling such as in particular case of this thesis; density survey is determined by preceded sampling program. Usually before drilling program design some additional information is required such as landscape study (topography), orientation survey, drilling technique.

4.5.1 TOPOGRAPHY

SRTM satellite image from NASA and collar information from previous drilled holes were used to plan infill drill program collars. For determination of elevation (RL) was used Easimine software, which converts punctual RL positions from SRTM image to a plan drill program by known, X and Y coordinates.

4.5.2 PLANNING INFILL DRILL HOLES

For upgrade resources and probable reserves it is necessary and mandatory to have additional drillholes to increase the level of confidence in the resource modeling (Mohammadi et al., 2012). The total number of additional drillholes is certainly limited due to drilling cost (Soltani-Mohammadi and Hezarkhani, 2012). To locate additional drillholes some statistical methods are applied to the block modeling such as kriging variance, which characterizes local dispersion. Reducing of an average kriging variance is a usual method used for planning additional drillholes (Mohammadi et al., 2012). The disadvantage of this method is focused on two dimension points of view (Soltani-Mohammadi and Hezarkhani, 2012).

(Soltani-Mohammadi and Hezarkhani, 2012), using three dimension points of view, suggest that location of additional drillholes is related to optimization problem. To solve this problem it requires an algorithm and a software that can carry out and incorporate two evaluating mechanisms such as selecting the coordinates of infill drilling, based on generic probabilistic approach optimization algorithm, until the optimal points are reached, and find a value of depth after the proposed additional infill drillholes are specified based on equation, many softwares are not able to determine additional drill hole positions.

In the thesis were used ArcGis to plan XY positions in the desired drill sites and Easimine to plan Z position (depth) using SRTM satellite image from NASA, and surrounding pre-existent drilled holes depth.

The planned infill drill program, showed in Figure 13, was carried out in Mozambique consisted on drill around 280 drillholes along the mining paths at wet concentrate plant A and B for years 2014 and 2015. According to the purpose of drill program, sampling interval is 1 x 1 m and 100 x 100 m spacing. The thesis is focused in the mine path B, while mine path A will be developed for kenmare mining business. The infill drill program and respective duplicate (mining path B) are showed in Figure 13.

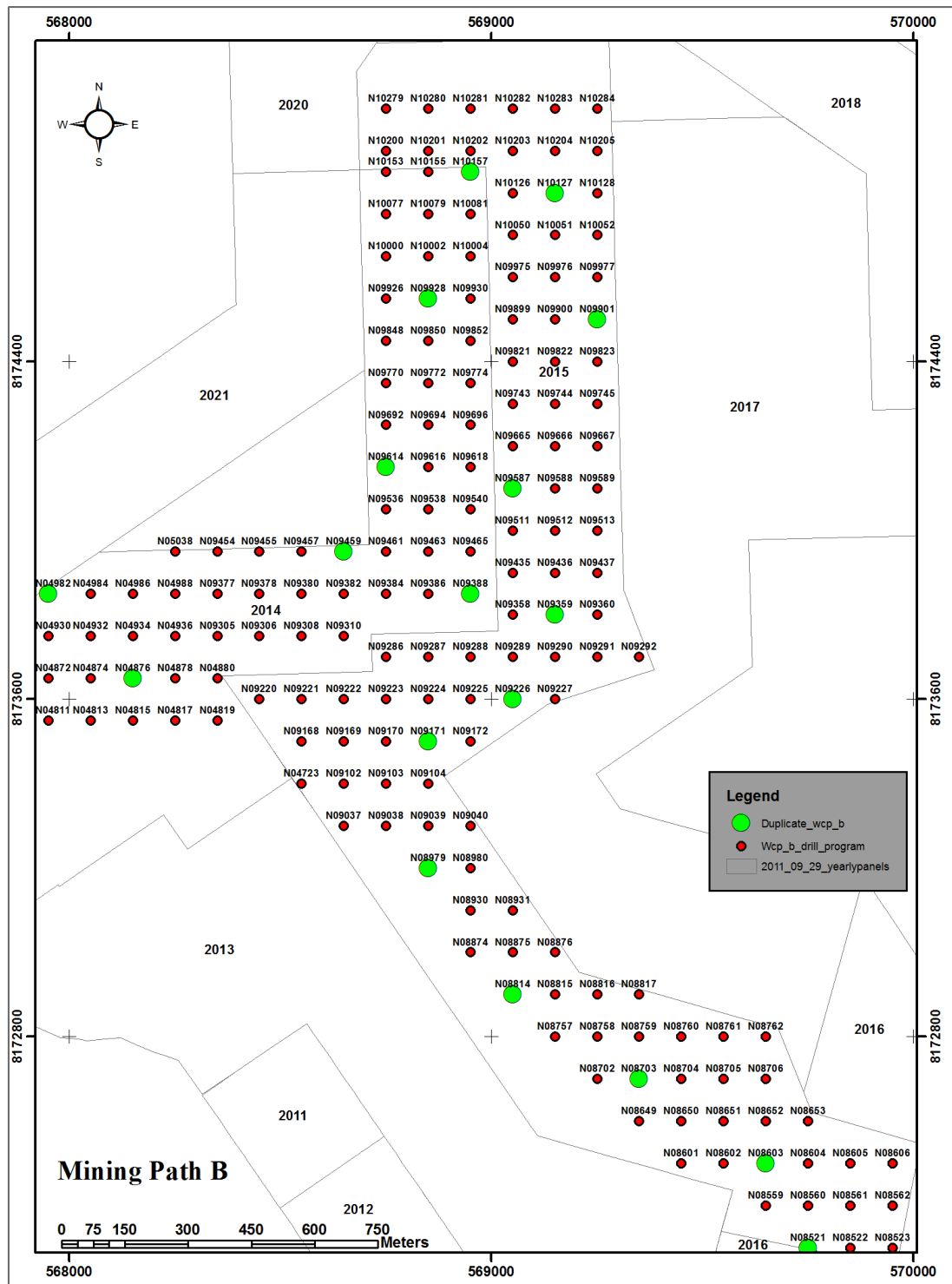


Figure 13: Map showing planned infill drillholes and field duplicates, for thesis propose, in the mining path B of Namalope deposit.

4.5.3 DRILLING TECHNIQUES

The drill rig used in this program is air core reverse, locally known as Muskeg drill rig, machine designed and built by EVH Drilling in Western Australia, Figure 14. This machine uses power to driver its compressor, drilling head and pull down ram. All components of drill rig are mounted on Carmoplast Muskeg, which is a low ground pressure machine with wide rubber based tracks; water tank is usually carried out by truck.

The drilling activity was conducted using NQ drill rods (50 mm core diameter) of the dual tube type having a male and female end pieces at opposite ends with a floating inner tube concentrically situated; inner tube has longitudinal freedom movement (Moss, 1990). The compressed air or liquid such as mud fluid is forced down along cylindrical space formed between outer rod and inner tube, and drill bit grindings together with air or fluid are brought to the ground surface at cyclone for sample collection via flexible hose.



Figure 14: Picture showing the air core reverse drill rig used during the infill drilling in the Namalope deposit for thesis purpose.

4.6 SAMPLE COLLECTION

Original and duplicate samples were collected using 1 x 1 m sampling. The samples are collected from cyclone via flexible hose, which is connected to inner tube via swivel spindle. All drillholes were drilled clean without liquid mud (chemical fluid) injection, using water and air. Sample bags and aluminum tags were pre-labeled correctly.

All collected samples in the field were logged by the Author in term of the heavy minerals, and clay contents, grains size, colour, water level and others relevant remarks. In order to determine these parameters, the collected samples were homogenized and submitted to the panning process. Replicate sampling is part of this thesis consisted on resubmit three to four assayed samples from same drillhole by change the label.

PROBLEMS WITH SAMPLE COLLECTION

The sample collection in the mining paths 2014 in the Namalope deposit was susceptible to problems such as; the wet samples collected during drilling lost slime through sample bag, and the dry samples are also susceptible to same loss where slime losses from sample bags as dust, using plastic bags surrounding sample bags can help minimize slime losses.

Saturated and dry samples are susceptible to segregation of heavy minerals due to slowly rising heavy minerals along drill rods than other light minerals, which will affect the grade and exactly location of heavy minerals depth.

The sample contamination in heavy minerals sand is rare, but it can happen by two ways either during sample transport along drill rods below groundwater level, where heavier materials are deposited at the bottom of hole at the end of drill rods, when new rod is connected to the last usually first materials, which will come out is the remains from previous drill rod, or change of the drilling injection method, where moisture materials when added more water and high air pressure is pumped to the ground surface becoming difficult to identify right depth and will come out at the first flow, with high clay content and sand, usually this material is not included into the drill sample.

4.7 SAMPLE STORAGE AND LABORATORY ANALYSIS

The sample storage is one of the last steps of drilling program where samples collected from the field are transported, stored, submitted to sample preparation and consequent submission to laboratory for analysis. The samples collected were transported to Exploration camp for storage. Before sample storage, the wet samples are dried by sun shine, during the rainy season, the wet and moisture samples are dried in the oven at certain temperature

4.8 SURVEY POSITION OF DRILLHOLES

Drilled holes collars were surveyed using real time kinematic global position system (RTK-GPS) for ore body delineation, which is a technique based on use of GPS with single reference (base) station providing real time correction, with centimeter level accuracy (+/- 10 cm) (Rothnie, 2011).

After drilling campaign all drilled holes were surveyed by trained technician and trainee geologist from Kenmare. The survey activity can be accurately conducted when drilled holes remain undisturbed whereas surveyors will measure the actual positions from visible drilled holes by using collar drilled coordinates. Disturbed drilled holes in most of cases result in mobilization of drill rig after drilled holes or long time waiting for survey where drilled holes can be covered by surrounding sediments (sands), both result in survey error. In order to minimize this error the survey activity was conducted in one to two days after drilling.

4.9 SAMPLE ANALYSIS

The Laboratory samples analyses for heavy minerals sands consisted in extracting of concentrate from the field samples, and provide quantitative and qualitative analysis from the concentrate. In order to provide good qualitative and quantitative analysis, collected samples were submitted to the following Laboratory procedure (Figure 15):

1. Sample preparation;
2. Heavy mineral separation; and
3. Mineral compositional analysis.

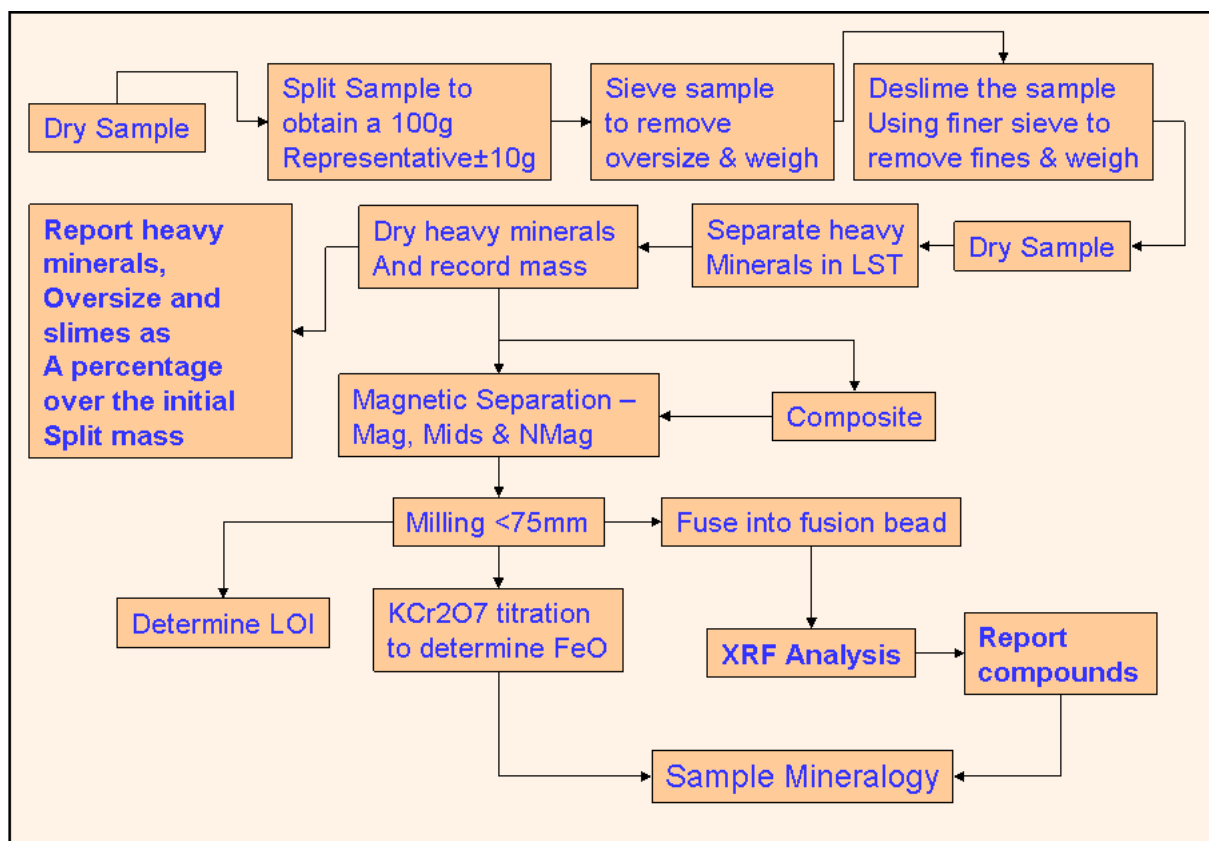


Figure 15: Flow sheet used by internal laboratory for preparation of field samples, analysis of samples for heavy minerals and reporting process.

4.9.1 Sample Preparation

Samples submitted to the laboratory before analysis were subject to sample preparation, which consists of dry samples in the oven at 110°C (+/- 5°C), the dried samples are disaggregated in the bags using rubber mallet to break down and crush dried lumps,.

After disaggregation and crushing all samples are passed through 2 mm screen to ensure that all lumps are totally broken down, grain size bigger than the screen mentioned above are put back into sample bags. The screened samples at 2 mm is split using two types of splitter first by rotary splitter and secondly by riffle splitter to obtain 100 g sample weight, which will then be submitted for analysis (Figure 16).

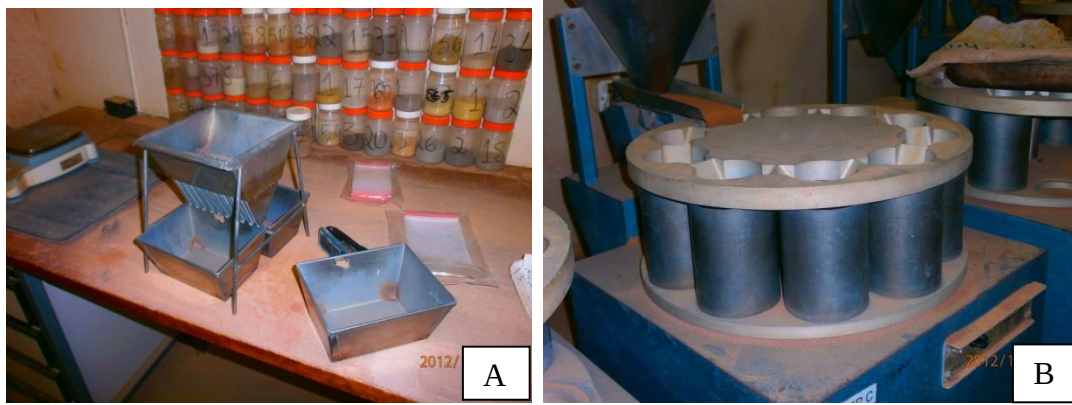


Figure 16: Pictures show riffle splitter used in the first phase of sample split in A and rotary splitter used in the second phase to make 100g sample for analysis in B.

The rotary splitter is used to reduce sample size to approximately 500 g and the riffle splitter to reduce to approximately 100 g, the remaining samples is put back into the original sample bag and stored in a long term for further use, the dried 100 g fraction is weighted to get accurate sample weight.

4.9.2 Heavy Minerals Sand Separation

The heavy liquid separation is a method used for separation of particles by density whereas the particles can float or sink during separation process according to their densities relative to the density of liquid used. The particles less than 100 micron are eliminated from fraction prior to its processing (Gent et al., 2011).

Separation of heavy minerals in sand includes desliming, removing oversized materials and recovering heavy minerals, which can be magnetic or non-magnetic.

The deslimed fraction is submitted to Lithium heteropolytungstates (LST), heavy suspension separation liquid, developed by Australian Mineral Industry Research Association (AMIRA), project sponsored by De Beers, Rio Tinto and Iluka Resources due to toxicity of other heavy suspension liquids for gravity separation between lighter and heavier materials (Koroznikova et al., 2008).

The deslimed materials are then put into 500 ml separating funnel containing 150 ml of LST tested by hydrometer to ensure densities of between $2.81 - 2.89 \text{ g/cm}^3$, the lighter materials float and the heavier ones sink, and this process is repeatable until no further HM is evident in LST. After complete separation the heavier materials are decanted onto pieces of filter paper previously labeled with the drill hole ID, washed using dionised water and dried at 105°C (Figure 17) (Rothnie, 2011).

The heavy minerals percentage from this process is calculated by dividing weight to the original mass and multiplies by 100 (Table in appendix 10).



Figure 17: LST heavier liquid separation with heavier material at the bottom of funnel and lighter at the top in A and washing process of separate materials using paint brush in B.

4.9.3 Mineral Composition Analysis

The mineral composition analysis is determined using XRF technique, from magnetic and nonmagnetic separation of heavy minerals; the heavy minerals fraction submitted to XRF analysis is obtained by combination of drill holes from same unit (lithology) in one geological cross section that is composited as single sample and submitted to separation method to obtain oxide concentrations.

The composited fraction usually is not less than 50 g, to ensure that enough sample fractions is present for magnetic separation, and it is placed into plastic bags and sent to laboratory for XRF analysis.

4.9.4 Magnetic Separation

The magnetic separation is a technique used to reduce density volume of concentrate to be analyzed for IMs by eliminating irrelevant fractions from samples.

The magnetic fractionation is determined using induced roll magnetic separator with initial intensity magnetic of 2.2 amps and roll speed of 150 RPM. The non-magnetic fraction is obtained from progressive cleaning by increasing amps from 2.2 to 3.6 amps in order to remove entrapped materials by magnetite particles and re-passes multiple times the nonmagnetic fraction. The combination of split setting of non-magnetic fraction and the multi passing process are designed to give non-magnetic fraction generally less than 1% of Fe_2O_3 (Figure 18).

The magnetic fraction typically comprises 80 – 85 % of HM, and the second magnetic fraction (paramagnetic) is obtained after the first phase of separation comprises 3 – 8 % of HM and the non-magnetic fraction has 10 – 13 % of HM. The common magnetic fraction is dominated by ilmenite, and alumino silicate minerals such as tourmaline and staurolite and the non-magnetic fraction comprises rutile, zircon, kyanite, tourmaline and spinel. The second phase of magnetic separation contains ilmenite with high TiO₂ content than in the first phase, and trash minerals such as staurolite, tourmaline, chromite and monazite (Rothnie, 2011).



Figure 18: One of the magnetic separation machines used at Kenmare for magnetic and non magnetic separation of heavy minerals for XRF analysis.

After separation the fractions are submitted to XRF analysis in order to determine quantity and quality of oxides present in each fraction (Tables in Appendix 11 and 12).

4.9.5 XRF Analysis

The technique is used to reproduce results from X-ray diffraction analysis of heavy minerals samples; some important variables are determined and minimized such as uniformity of gridding, uniformity of mounted mineral particles, mass absorption, fluorescence and textural character of heavy mineral grains (Pryor and Hester, 1969). During XRF analysis grains obtained from magnetic and nonmagnetic separation are grounded and pestle and then mounted on glass slides; the grounded sample must have uniform size of less than 4 micron.

The Common problems with XRF analysis are related to grinding sizes, which can result in missing of many peaks or show various intensities from one grind to another:

mounting ground material as many of heavy minerals have well developed cleavages, there is tendency for ground particles to orient themselves when mounted on glass slide or packed in a sample holder; size sorting and hydraulic sorting of heavy minerals cause density and size differences of various minerals.

Some precautions in order to avoid mentioned problems are necessary such as avoiding size and hydraulic sorting variations, using proper grinding techniques, obtaining randomly oriented particles mounts, and reducing mass absorption fluorescence (Pryor and Hester, 1969).

(Thomas and Haukka, 1978), describe that one of the problem with XRF analysis is contamination during grinding and accidental surface contamination of powder pallets, which were considered more seriously than that resulted from glass slide preparation.

CHAPTER 5 DATA ANALYSIS AND VALIDATION

The importance of quality control and quality assurance was emphasized recently due to generation and publication of erroneous data produced during exploration activity. In order to develop acceptable exploration work is necessary to develop QA/QC protocols applied not only in the laboratory but in the initial planning activity as well, and throughout the life of project (Nicholas and Mark, 2011).

Field sampling techniques are a major source of uncertain in exploration geochemistry, which include discrepancies in sampling specific horizons either by no recognition, by sampling bias or by field related factors such as topography slumping or wind-borne transport surface sediments, sample transport and stored in order to minimize this problems and as field activity requires time prior to sampling, and collecting samples, the researcher must ensure that samples collected will appropriately address the scientific objectives of study.

In the field sampling, the QA/QC samples are important to collect such as field duplicates, replicates, blanks, standards, and tips for sample submittal.

5.1 COLLAR DATA ANALYSIS AND VALIDATION

In order to comply with QA/QC requirements, the drilled holes were surveyed and corrected between planned and surveyed collars, which are useful for determination of the accurate current collar positions of drilled holes and modeling the ore grades in the right manner. The correlation graphs are showing in Figure 19.

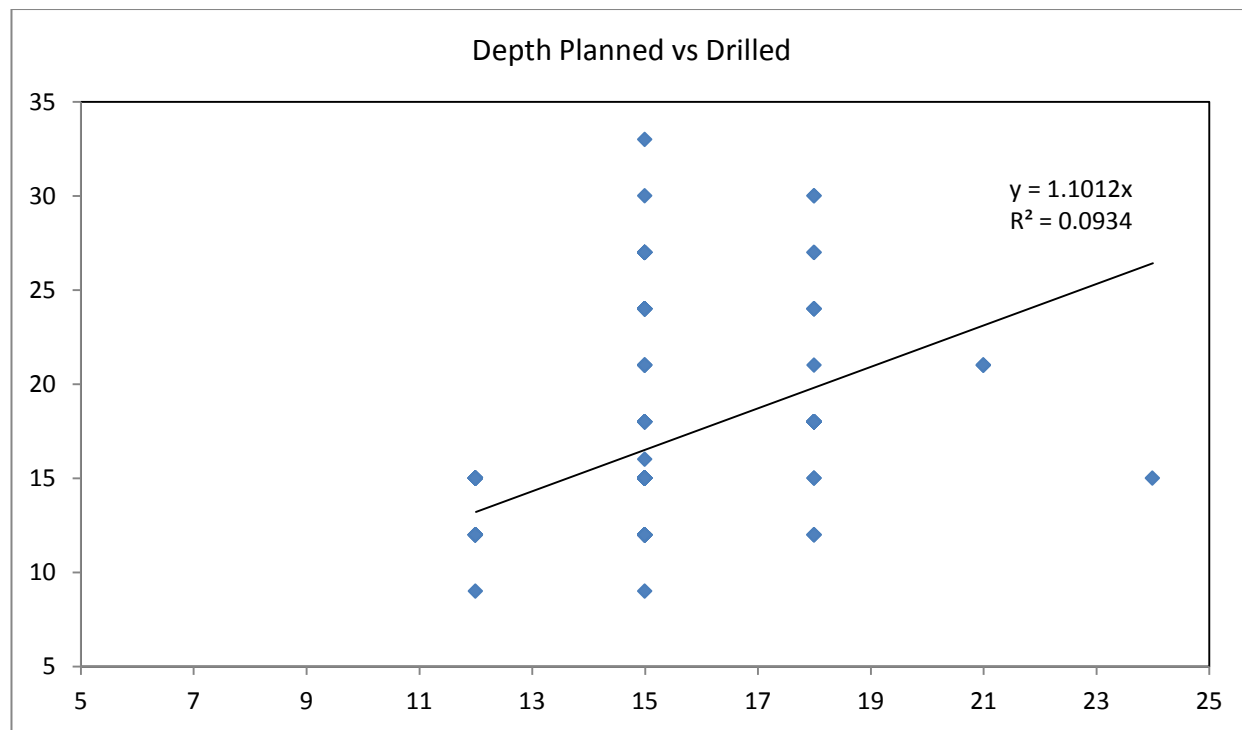
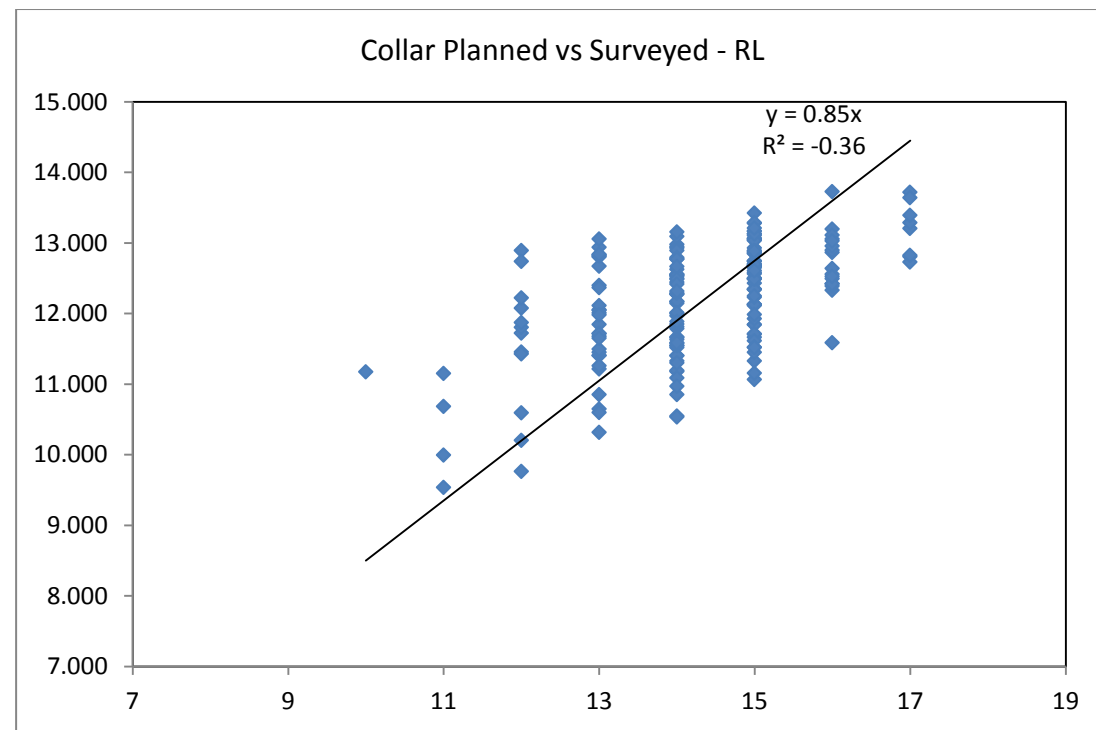
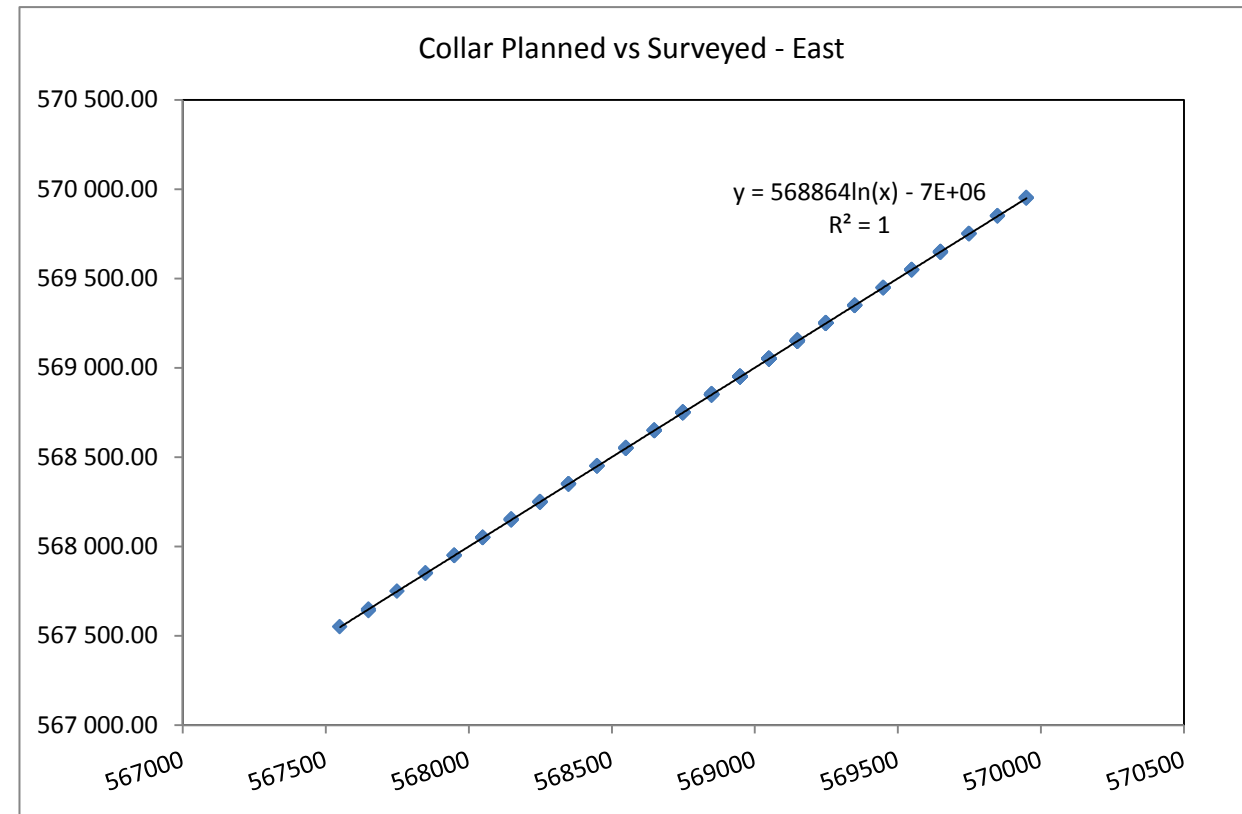
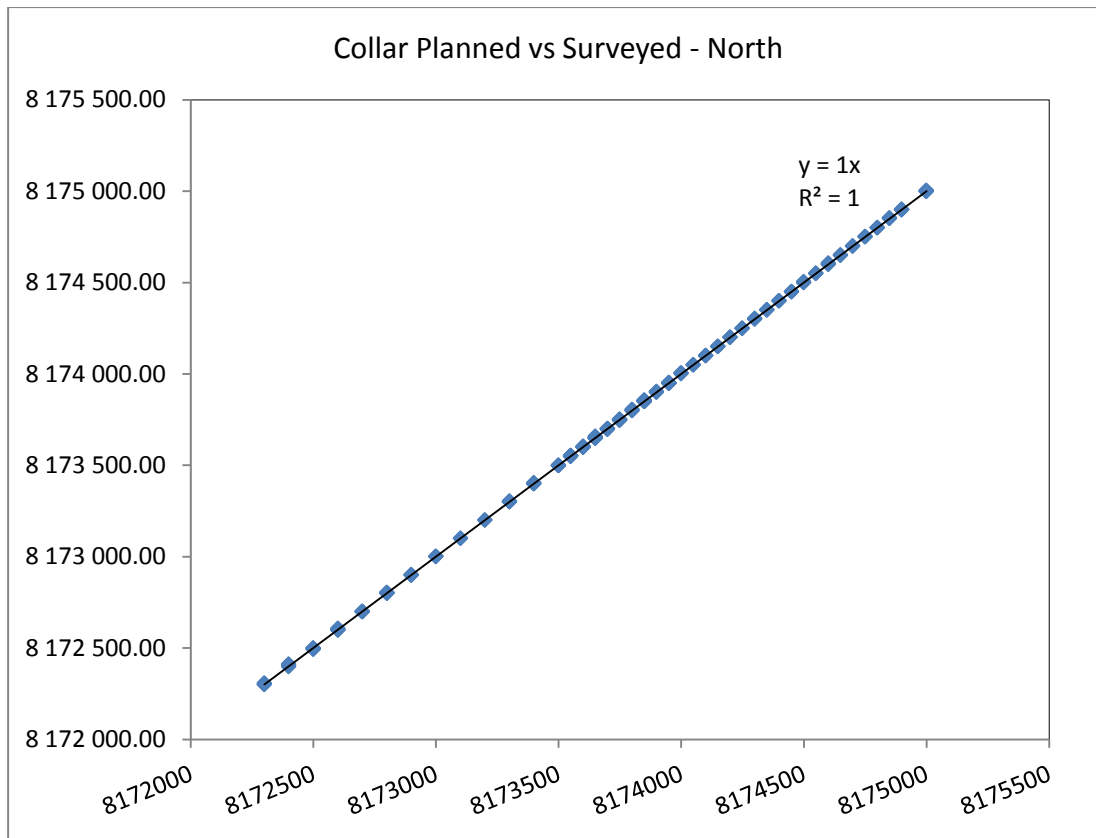


Figure 19: Graphs showing correlation of quality control and quality assurance for planned and surveyed collars of drill holes in the east, north and RL positions.

The collars planned and drilled in the 2D view shows good correlation, which means that the hand GPS and RTK-GPS used for delineation of ore body are well correlated in the plan view (2D).

The elevation (RL) for collars planned and drilled shows poor correlation, which suggests that the SRTM satellite image used to create planned RL is not accurate and shows high variance compared to the surveyed RL, more accurate in 3D view (Figure 20). The data from the SRTM satellite image cannot be used to generate ore body delineation whereas in plan view this may be possibly as its shows good correlations with the surveyed data.

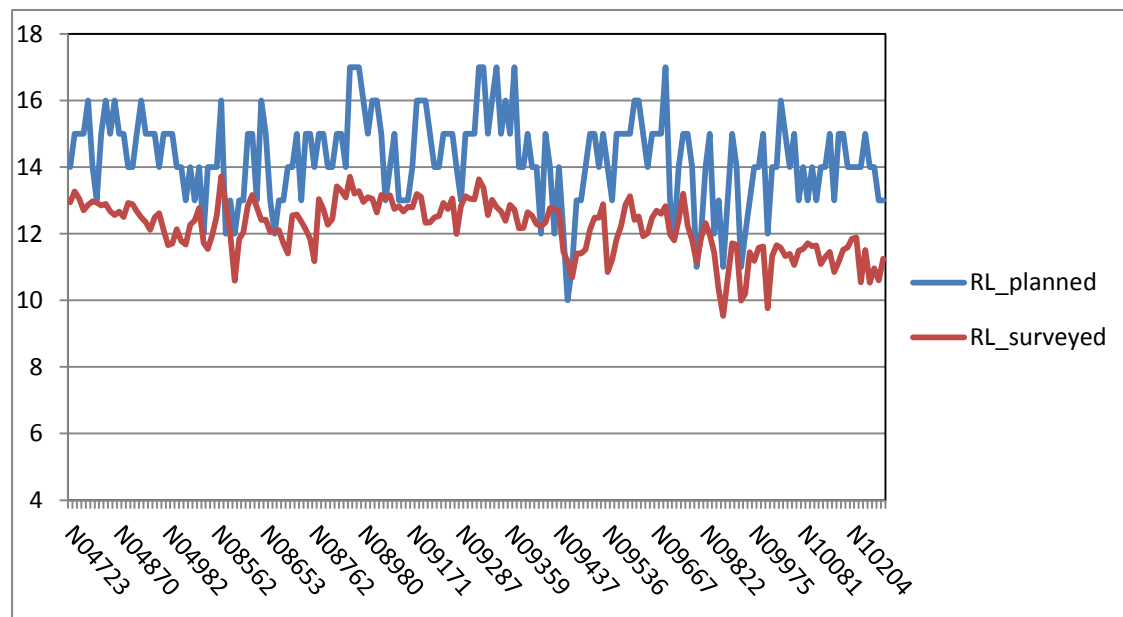


Figure 20: Plot showing elevation variance between planned and surveyed drill holes.

The plot in Figure 20 suggests that the surveyed RL is always lower than the planned ones, few drilled holes show surveyed RL higher than the planned data, and the average variance between them is 2.0 meter. Thus, that the surveyed RL and the RL extracted from SRTM satellite image have an average 2.0 meter of variance.

The depth between drilled and planned drill holes shows poor correlation as well due to the planned depth being obtained from RL adding 3 meters, in order to increase recovery of ore body mineralization, and ceil the results by 3 as drill rods have 3 meter long, Figure 21 shows plot of drilled and planned depth.

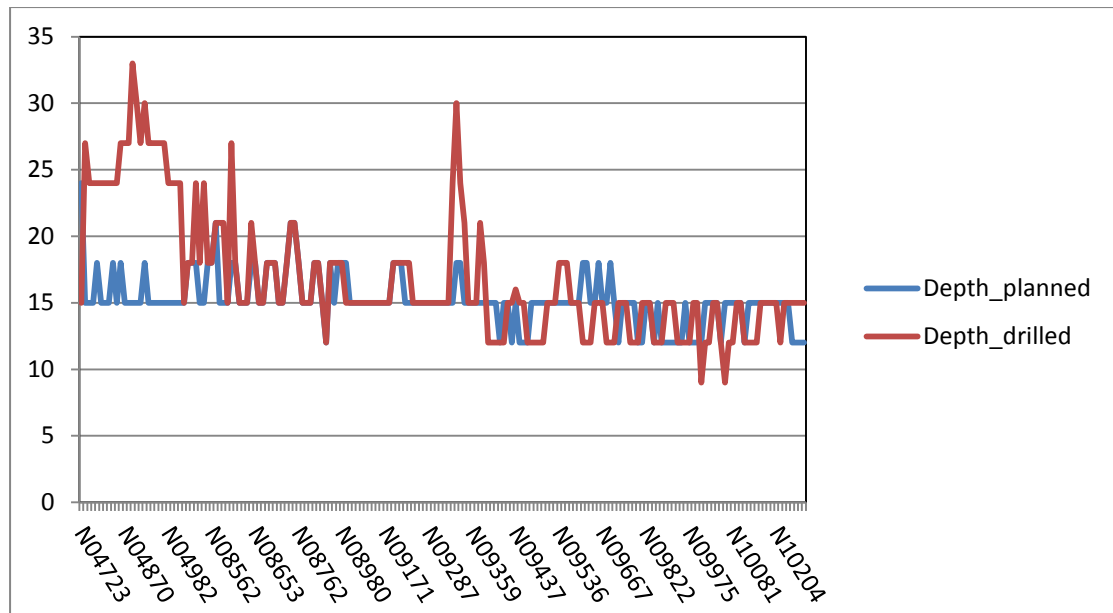


Figure 21: Plot showing depth variance between planned and drilled depth

Plot in Figure 21 suggested that some planned depth are shallower than drilled which means that 3 meters of estimated value to add to the RL is not accurate for some situations where ore body mineralization units are not being uniform and prior drill program intervals used to determine mineralized surface was large (100 x 100 m). In general the planned depth must be higher than the drilled ones, and according to the plot above all the drilling activities require geologists on site to guide driller to drill correctly for accurate delineation of ore body.

5.2 FIELD DUPLICATE ANALYSIS AND VALIDATION

The validation of field duplicates is developed by acquisition of assay results from LIMS (laboratory information management system) and loads into excel sheet, removing incomplete and suspicious assays from batches, plot correlation graph of original and duplicate samples which show strength of linear relationship between the original value and duplicate ones, the plot shows absolute difference (HAD) to the pair mean and HARD percentage against HARD percentage for HM and slime. HM graphs from the field duplicates and original samples are showing in Figure 22.

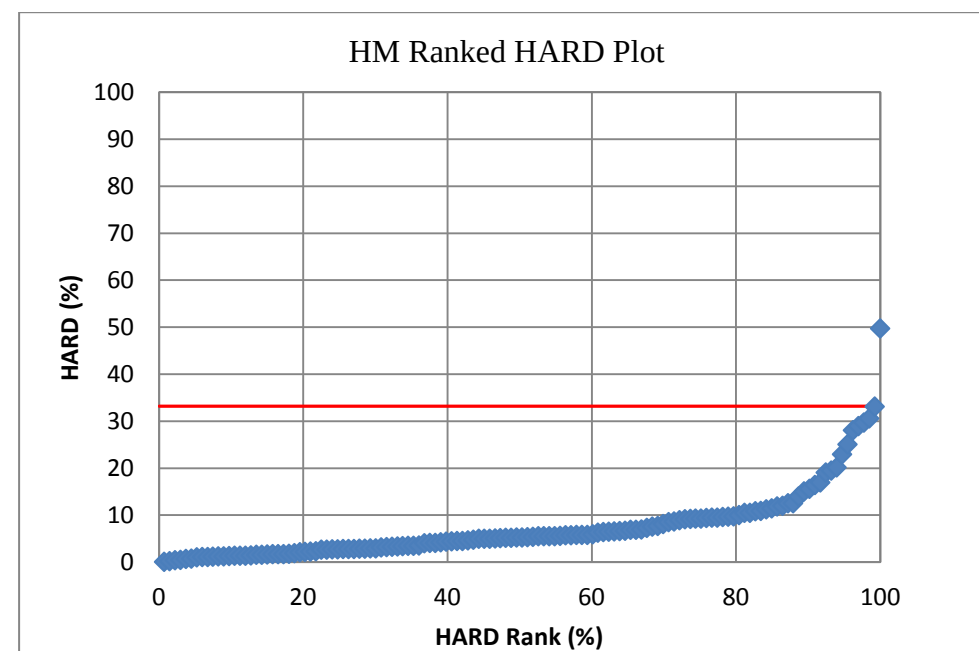
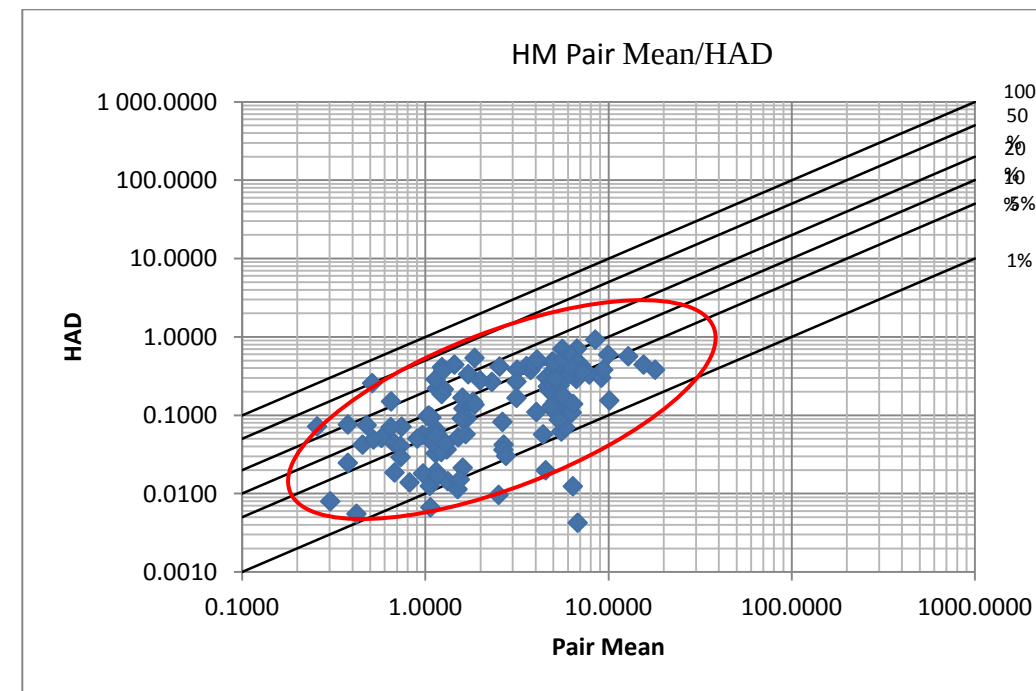
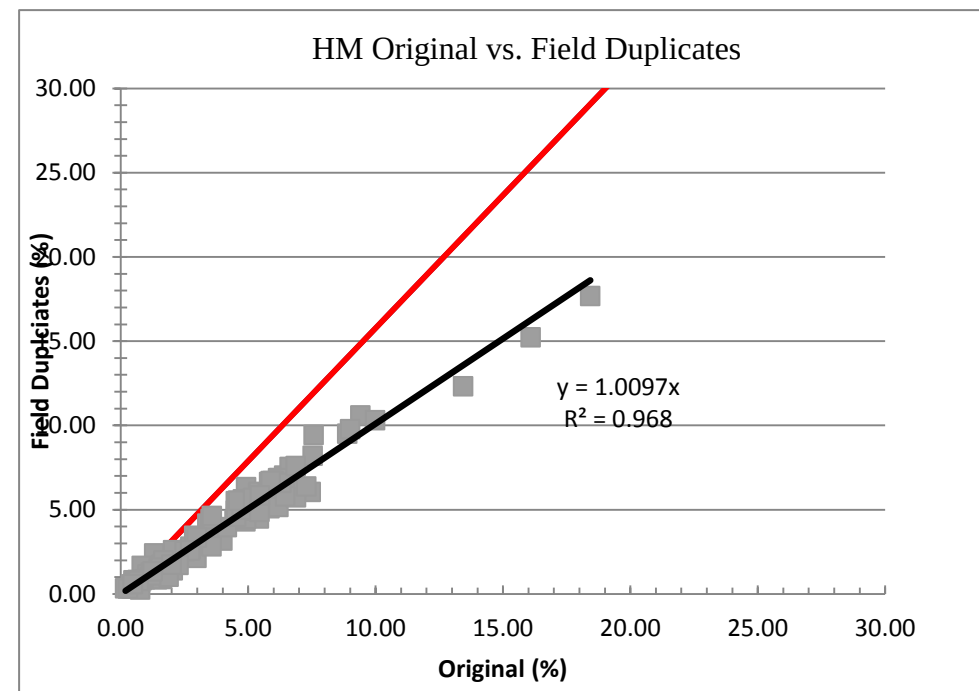


Figure 22: Graphs show data validation from correlation between original vs. duplicate, pair mean vs. HAD, HARD Rank (%) vs. HARD (%) of heavy minerals sand in the Namalope deposit.

According to the original vs. duplicate graphs of correlation in Figure 22, for heavy minerals (HM) analysis, from 170 collected duplicate assays, 38 shows high bias variance, which corresponds to 22.3 % of total duplicate samples.

If more than two samples from the same batch present high bias variance all the related original batches are dropped out from assays to be interpreted and are resubmitted to internal Laboratory for analysis. Following this procedure around 52 original samples related to these duplicates were removed from the data to be interpreted.

The maximum lower and upper limit used for acceptable variance to the mean is 10%, the duplicate assays closer to this limit were considered to be acceptable. The HARD/ranked HARD plot shows that 40% of the data have HARD less than 60% which can be seen from HAD/pair mean graph, 17,7% assays were acceptable by proximity to lower and upper limit.

5.3 LABORATORY SAMPLES ANALYSIS AND VALIDATION

Laboratory duplicates are obtained by re-analyzing randomly two or three samples from the same drill holes, depending on depth of drill holes. The result of the samples are submitted to the same procedures of field duplicates by generate graphs of correlation with the original vs. duplicate ones, pair mean vs. HAD and HARD vs. ranked HARD for HM and slime (Figure 23). The oversize plot was not performed due to lower values.

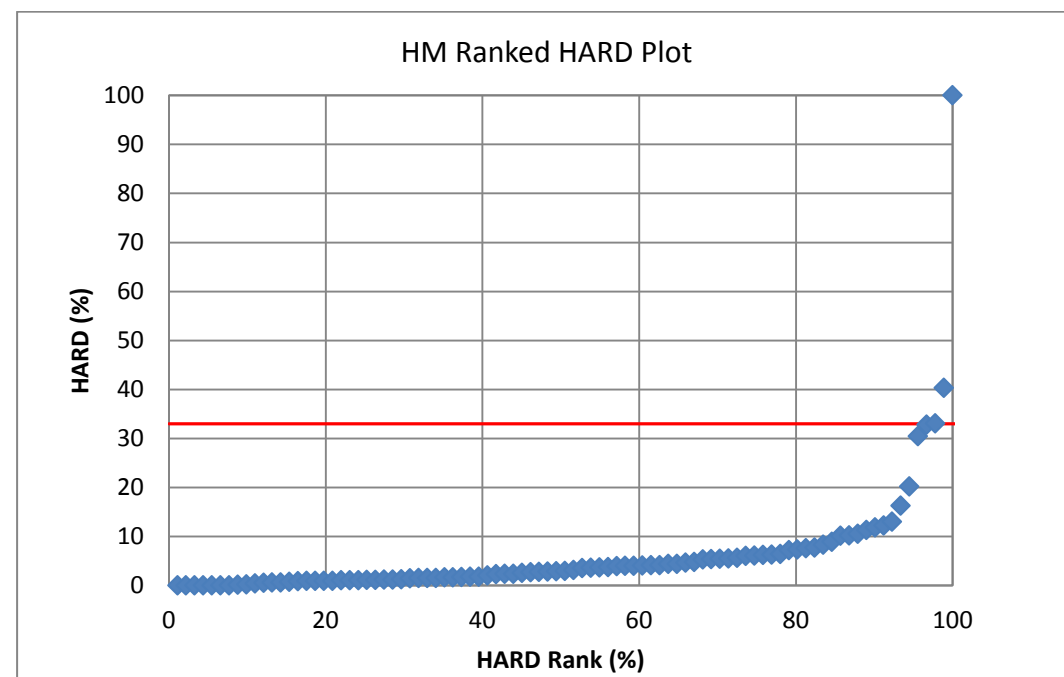
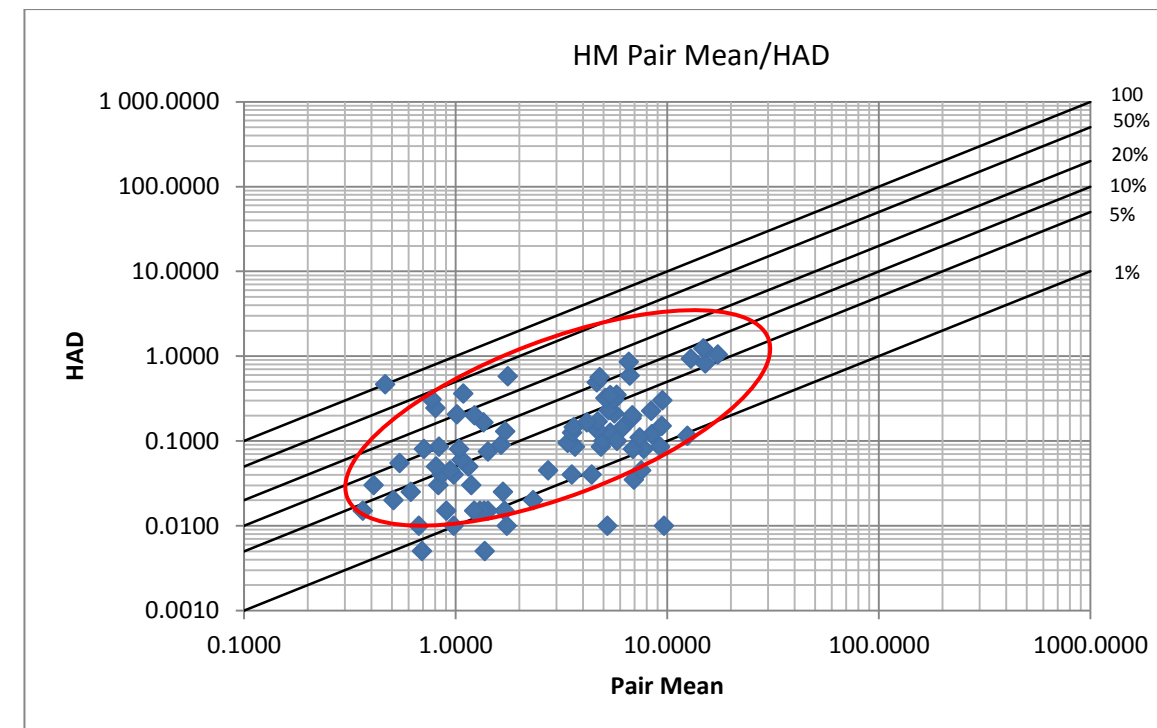
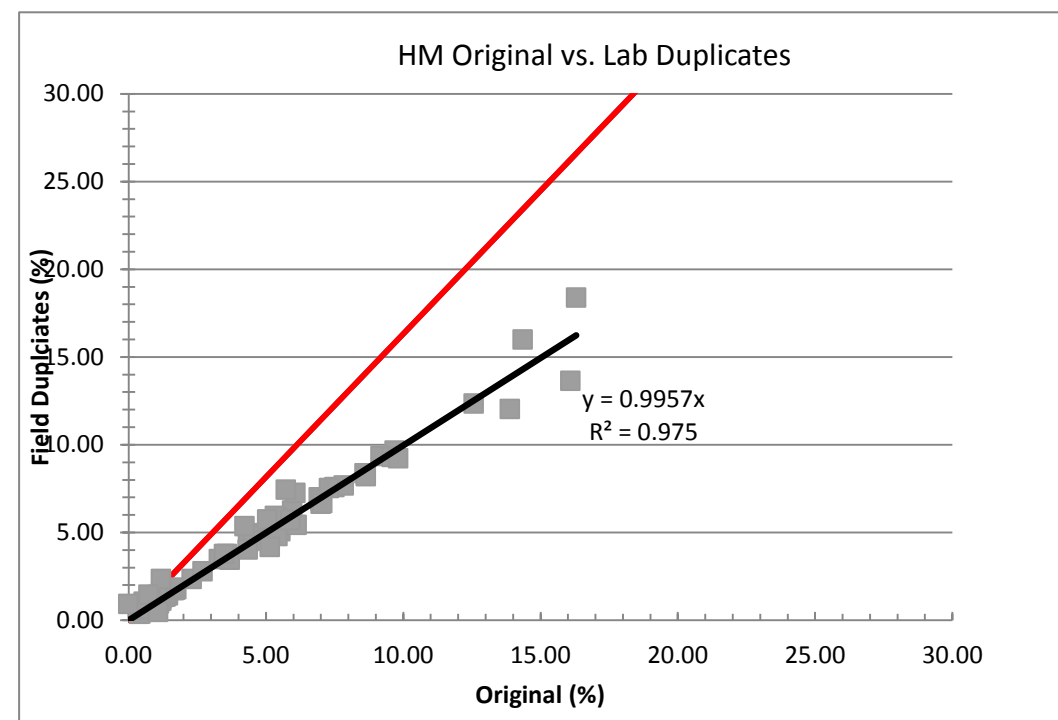


Figure 23: Graphs showing laboratory data validation from correlation between duplicate vs. original, pair mean vs. HAD, and HARD Ranked (%) vs. HARD (%) for heavy minerals concentrate

The good correlation between laboratory duplicates vs. original values in Figure 23 results in removing 18 assays from the total 91 laboratory duplicate assays due to high bias variance.

The correlation coefficient between the original vs. laboratory duplicate assays after removing 18 samples is good with 65% of the data showing HARD less than 35% which can be seen from HAD/pair mean plot in figure 23. The upper and lower limit of variance from the mean is 10% as a maximum error and 5% minimum error, respectively.

5.4 SPATIAL ANALYSIS

After problematic assays data have been removed from the load batches for interpretation, some basic statistic data are performed to determine processing parameters such as percentile, mean, standard deviation, skeweness. The histogram analysis is performed to evaluate population and processing parameters such as percentiles that apply specific elements based on population breaks, normal QQPLOT is performed to discriminate background to the threshold values. Figures 24 and 25 show the basic statistic and spatial analysis, and QQPLOT with the same components as shown in the histograms respectively, these graphs were created in ArcGIS.

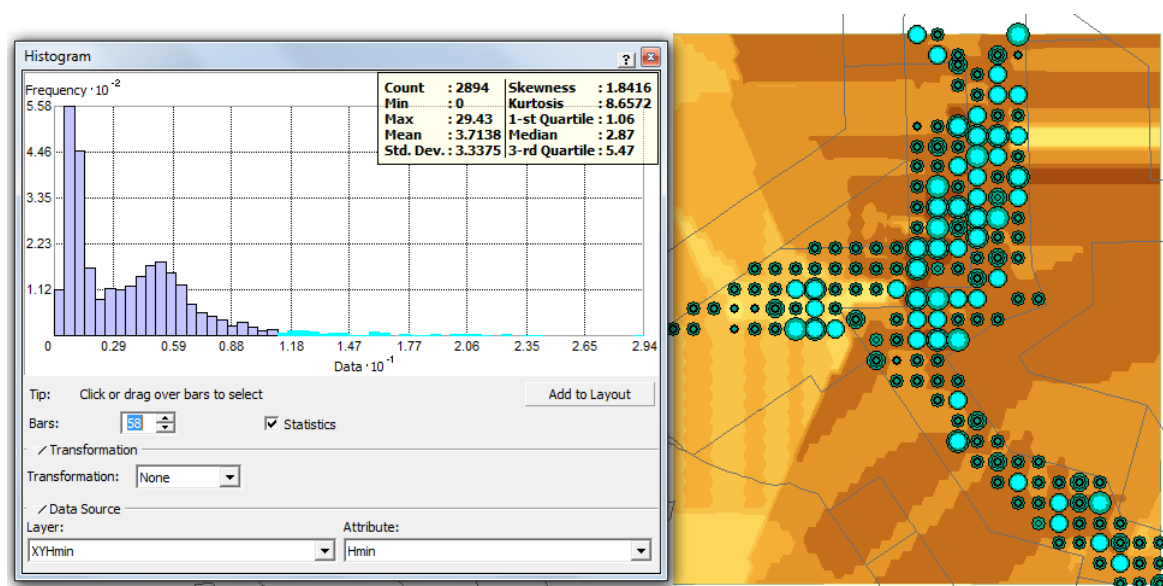


Figure 24: Histogram of basic statistics and spatial distribution of heavy mineral in the mine paths 2014 and 2015, WCP B at Namalope deposit.

Histogram of Figure 24 shows positive skewness with two populations, frequent values are less than 0.29% for most data from the east of the mine path 2014 and south of the mine path 2015, the threshold value is at 1.18, the values above the threshold limit are considered as anomalies values and most of them are in the northern part of both mine paths; the anomalies values range from 1.18 to 29.43, considered as a maximum value in the load batches (Figure 24).

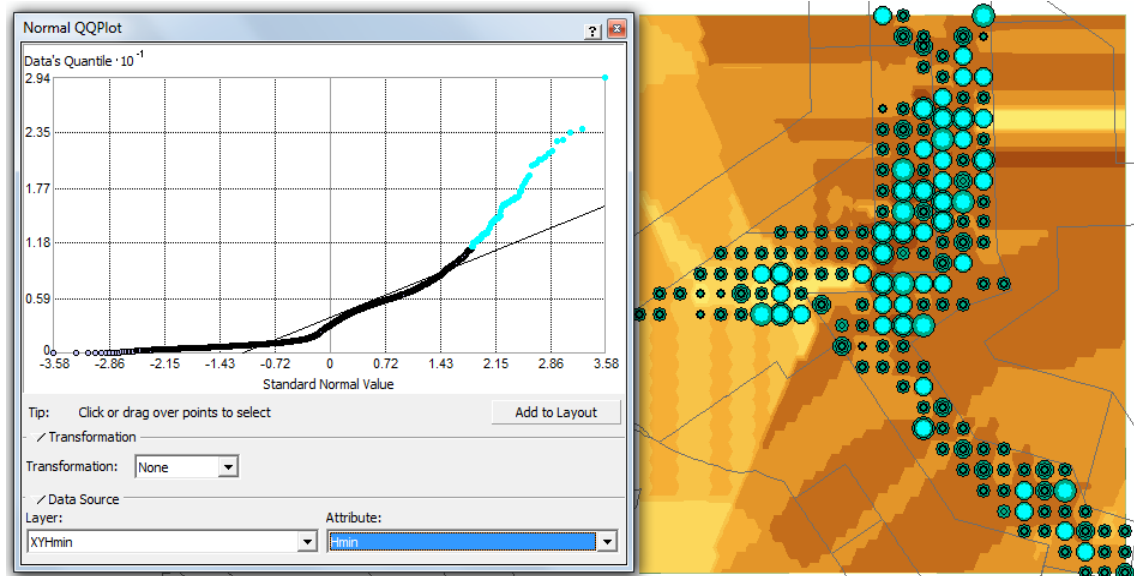


Figure 25: Normal QQPLOT and spatial distribution of heavy minerals sands in the mine paths 2014 and 2015, WCP B at Namalope deposit.

The QQPLOT graph shows approximately the same value of threshold obtained from the histogram with anomalies values of 1.8 to 29.43 and all the data are concentrated in the northern part of both mine paths (Figure 25).

In order to determine frequency occurrence and distribution of slime was applied the same principle and software as heavy minerals concentration by histograms with respective spatial analysis and QQPLOT (Figure 26 and 27).

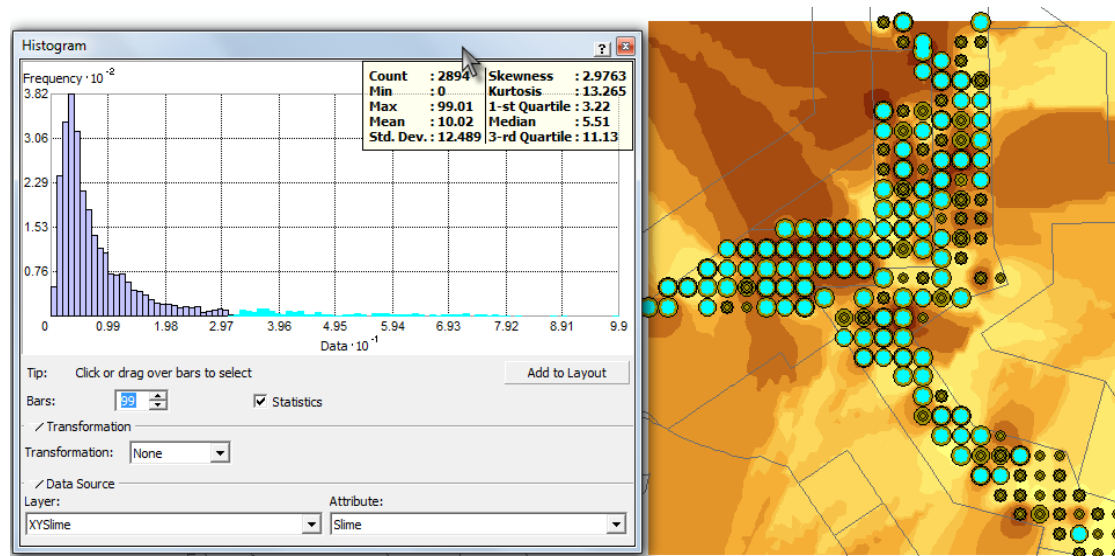


Figure 26: Histogram and spatial plot for slime contents in the mine paths in the wet concentrate plant B.

The histogram in Figure 26 shows positive skeweness with one population, frequent values extend from 0.1 to 0.99% of slime content and are situated in the southern part of mine path 2015. The high slime content of 3.2 to 99.01% occur in all the mine paths except in the south of mine path 2015 were is recorded one drill hole with high slime content (Figure 26).

In order to confirm histogram threshold, the QQPLOT graph shows in Figure 27 was generated.

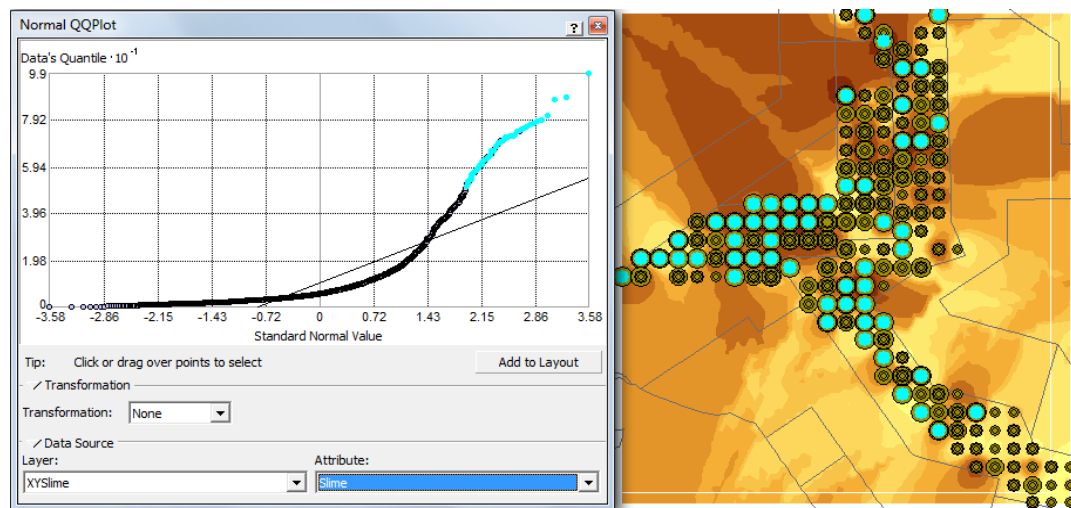


Figure 27: QQPLOT threshold and spatial distribution of slime content in the mine paths.

The QQPLOT in Figure 27 shows the threshold value of approximately 2.0% slime with high slime content values of $> 2.0\%$ in the east of mine path 2014, some high slime contents are recorded in the north of both mine paths but not with much frequency. The south of mine path 2015 has low slime contents ($< 2.0\%$).

The correlation analysis applied to the dataset for HM, slime and oversize in Figure 28 shows poor correlation, which suggests different environment of deposition and probable different rock sources.

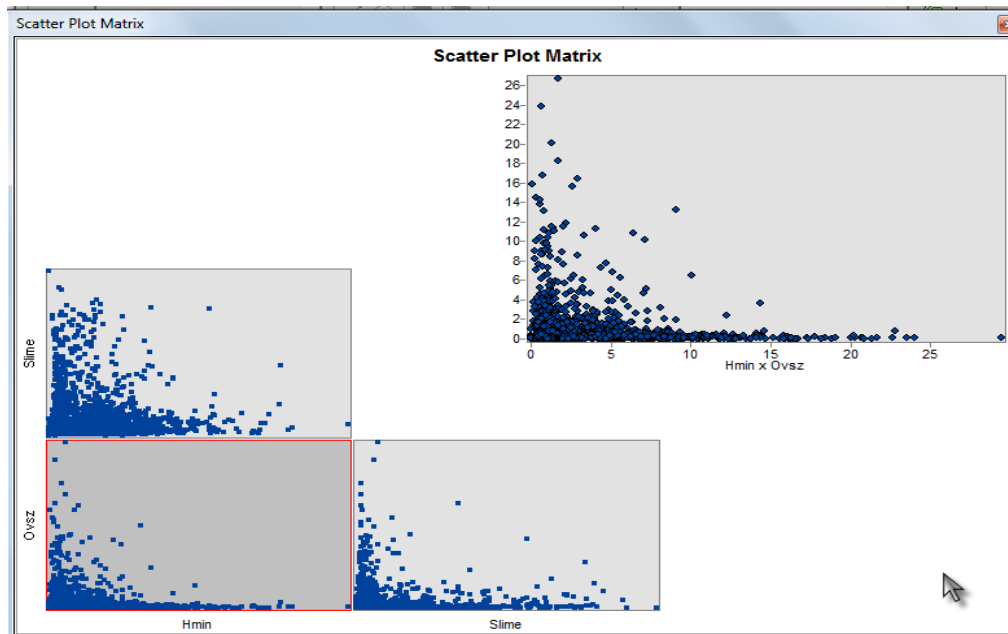


Figure 28: Correlation between HM, slime oversize in the both mine paths at the wet concentrate plant B.

CHAPTER 6 RESULTS

After validation, the data were interpreted based in assay load batches from the data validation, which integrate the collar information and assays results. For the interpretation was used Datamine to generate cross sections and digitalization of different units (zones, lithologies) from the assays data. Before interpretation, during de-survey some data overlaps were detected and deleted from the load batches. The geological interpretation focused on identification and delimitation of different geological units according to heavy minerals and slime contents. Three representative cross sections were used for each mine paths 2014 and 2015 at WCP B as showed in Figure 29.

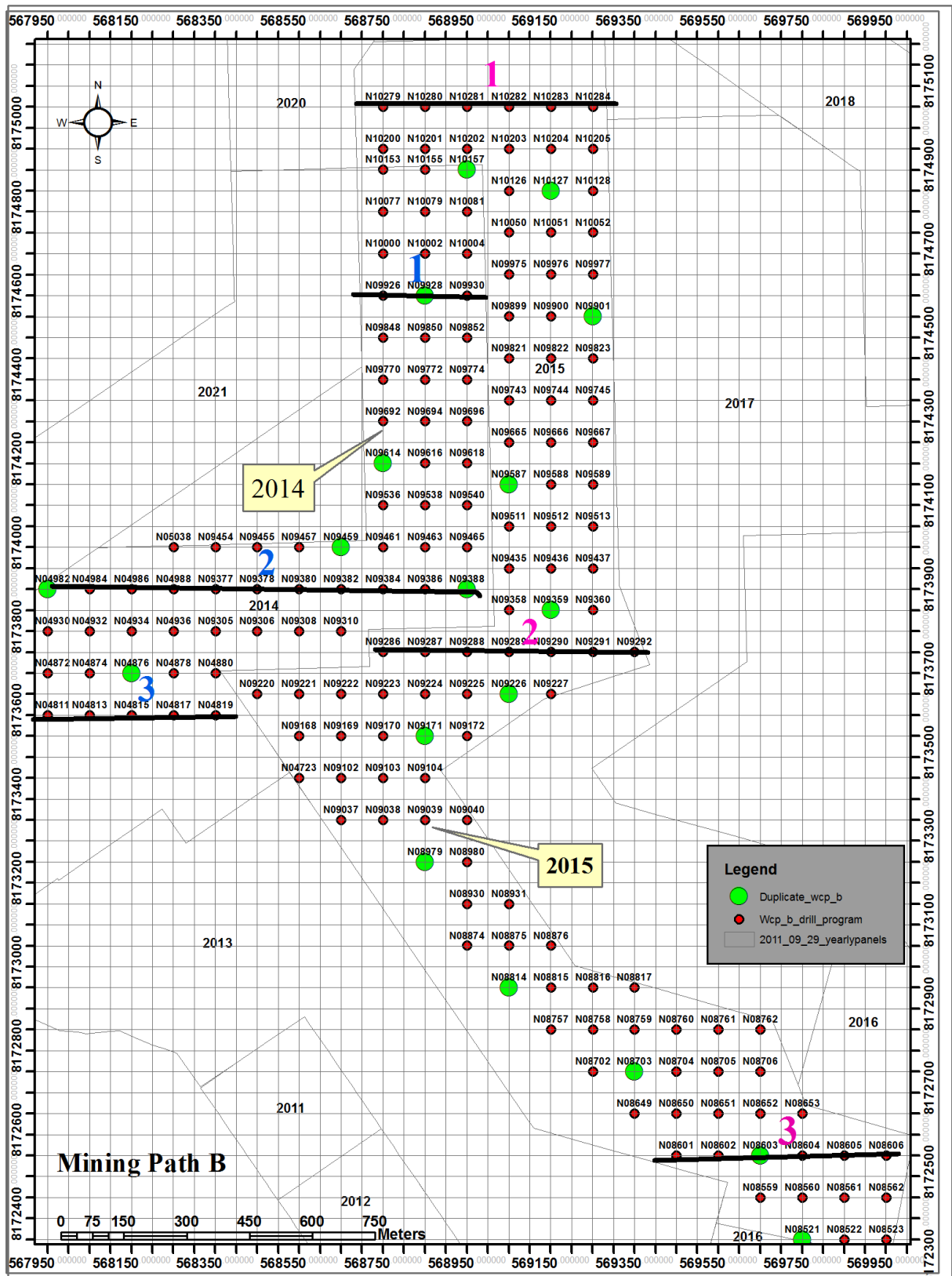


Figure 29: Map shows planned east-west cross sections in the 2014 and 2015 mine paths at Namalope deposit.

The plotted cross sections of the wet concentrate plant B in appendices 10 to 12, show shallow area of the Namalope deposit (maximum 30 m depth) dominated by units 6 usually on top, units 81, 7, 82, 9 and in some cases unit 4, considered as the basement of Namalope deposit (GREIG, 2001).

6.1 MINE PATH 2014

The mine path 2014 is adjacent to the mine path 2015 in the east, and it is dominated by occurrence of the same units as in mine path 2015, in Namalope flat area.

6.1.1 Unit 6

It is dominated by high grade heavy minerals concentrations, between 3 to 22 % with an average thickness of 8 m, increasing northward with tendency to the east into the line as shown in sections (Appendix 10 and 11). The slime content generally varies between 0 to 6 %, and increases with depth the same as showed in heavy minerals concentration.

The spatial distribution of heavy minerals concentration (Appendix 2), shows the same tendency as cross section with high grade heavy minerals increase northward and variable distribution of slime with tendency to increase southward in the deeper area.

6.1.2 Unit 7

Commonly dominated by high grade of heavy minerals concentration, the same to unit 6 with ore grade varies from 2.0 to 22 % and average thickness of 4 m; the slime content varies between 5 to 15 % (Appendix 10 to 12).

The spatial distribution of heavy mineral concentration and slime content (Appendix 3) shows variable distribution, where heavy minerals concentration shows tendency to increase northward and slime content southward. The heavy minerals concentration increases with depth.

6.1.3 Unit 81

Characterized by low heavy mineral concentration and high slime content, the heavy minerals concentration ranges from 0 to 3%, some drillholes show high grade of heavy minerals concentration probably due to error during sampling by mixing samples from upper unit

(Appendix 10 to 12), and the slime content on average varies between 24 to 60% and it increases toward north, average thickness of unit 81 is 2 m.

The spatial distribution of heavy minerals concentration and slime content (Appendix 4), shows a decrease in slime content northward and westward in the mine path and an increase in heavy minerals concentration southward and eastward.

6.1.4 Unit 9

Occurs at the bottom of all units according to cross sections produced from drilled holes in this area, (Appendix 10 to 12), characterized by low heavy minerals and often high slime content; the slime content on average is less than 45% and heavy mineral concentration is less than 2%. An average thickness varies between 7 and 13 m or more, depending on depth of drill holes.

6.2 MINE PATH 2015

The mine path 2015 occurs in the east of mine path 2014 and around 500 m east of the current mine pond in the wet concentrate plant B (Figure 29), dominated by units 6, 81, 7, 82 and 9.

6.2.1 Unit 6

The mine path 2015 in Figure 29, shows average heavy mineral concentrations of 3 - 12% with an average depth of 6 m; in the cross section 8172500 appendix 11, the average depth tends to increase to 7 m, heavy minerals concentration in this unit tend to increase with depth same to mine path 2014.

The slime content varies between 0 - 5% in average and it usually tends to be constant with some intercalation of high slime content up to 7%. The unit 6 map (Appendix 2), shows the spatial distribution of heavy minerals concentrations in both mine paths increasing toward north. In the south concentrations are variable, the centre-south show lower concentrations, and increase of thickness layers.

The thickness of unit 6 decreases toward the centre and generally is associated with low heavy mineral concentrations. The top of unit 6 (1- 2 m thick), is dominated by low grade of heavy minerals. Appendix 2 map shows slime contents increasing with depth toward south and north-east of mining path.

6.2.2 Unit 7

The heavy mineral concentration in unit 7 is variable with grade of 0.5 to 12 %, and further east of cross section 8172500 and 8173700 (Appendix 12), heavy minerals occur on the surface, unit 6 is missing, which was probably being eroded.

The slime content ranges from 5 to 16%; generally increases with depth, its thickness increases seawards in the south of mine path 2015 with average thickness of 7m. The spatial distribution of the heavy minerals concentrations in the mine path 2015 (Appendix 3), shows tendency to increase toward north and decrease seawards in the south. The slime content is more variable with tendency to increase toward south. The low grade of heavy minerals concentrations and high slime content in the deeper area are associated with proximity to units 82 and 9, showing medium to low heavy minerals concentrations.

6.2.3 Units 81 and 82

The heavy minerals concentration in units 81 and 82 is commonly low, but some medium to high grade in this units are probably associated with unit 6 for high grade heavy minerals occur in unit 81 and unit 7 for unit 82, which are mixed with units 81 and 82 by error during sampling; the slime content is high between 20 to 60 % with an average thickness of 2 m and 7 m deep from the surface.

The spatial distribution map of unit 81 and 82 (Appendix 4), shows occurrence of low grade heavy minerals concentration associated with high slime content northwards; southwards the slime content tends to decrease and heavy minerals increase probably due to proximity of the area of changing in depositional environment. The southward of mine path 2015 unit 81 and 82 is missing, which suggest different environment of deposition.

6.2.4 Units 9

The mine path 2015 is characterized by heavy minerals concentrate of less than 1.8 % and variable slime contents. From the cross section it is impossible to estimate thickness of this unit due to shallow drill holes as the drilling target is units 6 and 7.

Generally the wet concentrate plant B in the mine paths 2014 and 2015 is formed by units 6 on top, 7, 81, 82 and 9 at the bottom of sequence. Unit 7 shows high grade of heavy minerals concentration with an average grade of 7 %, and medium slime content with an average of 9 %; the slime content and plasticity of materials contain in this unit become often difficult for mining; unit 6 has slightly the same concentration of unit 7 but with low slime content of maximum 5 % on average. Unit 81 and 82 is dominated by high slime content and low heavy minerals concentration, same to unit 9 but differs in slime content whereas the slime content in unit 9 is variable and low (Figure 30).

Drill hole N09377 was ignored during interpretation due to suspicious assays results, which probably have errors during sampling or laboratory analysis. Figure 4 in Appendix shows good correlation between oversize and thickness, high oversize content is recorded in the deeper area of units 6 and 7 in the south of mine path 2015.

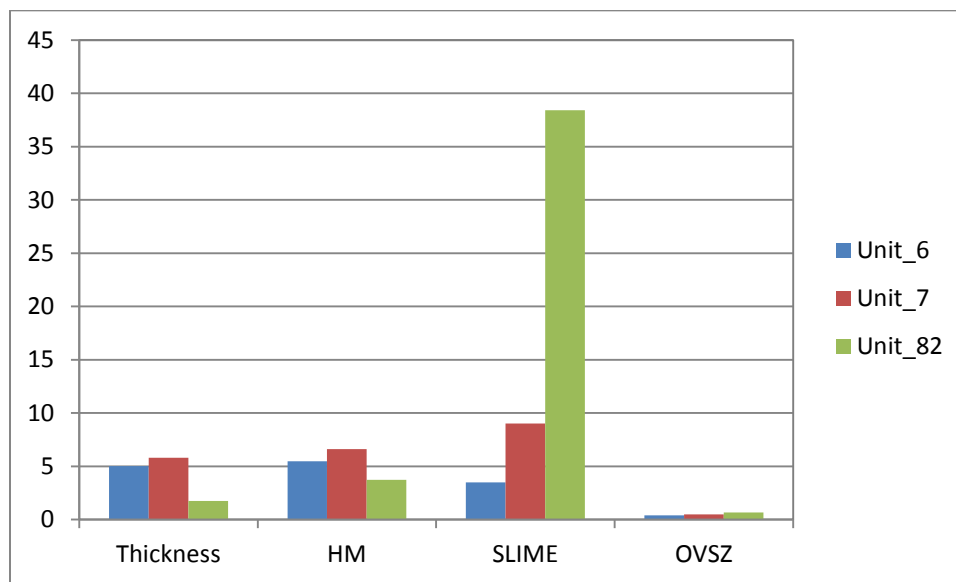


Figure 30: Occurrence of HM, slime, and oversize with thickness of units 6, 7 and 82 (81 and 82) in the mine paths.

6.3 MINERAL ASSEMBLAGE

The heavy mineral assemblages are not controlled only by mineralogical compositions of source rocks; overprinted processes can cause homogeneity in sandstones derived from one single source, which result in heterogeneity of heavy mineral assemblage. The heavy mineral assemblages in general are affected by three main processes such as physical sorting resulted from hydrodynamic conditions during transport and deposition, mechanical abrasion during transport, where sediments are fractured and rounded resulting in reduction of grain size; and dissolution, which result in partial or total losses of heavy minerals from parent sediments during sedimentation phases (Morton and Hallsworth, 1999).

Determination of mineral assemblages is based on heavy mineral concentrations, slime contents and oversize. From the cross section based on heavy minerals concentration, the concentrate is composited and submitted to the laboratory for XRF analysis.

The XRF analysis of these fractions provides reliable information for estimation of oxides containing in each fraction analyzed. Results from XRF analysis are submitted to theoretical calculation model to determine mineralogy of concentrate analyzed, which is commonly formed by ilmenite type, rutile, zircon as valuable heavy minerals, which also include monazite but not produced enough at the mine, and some accessories minerals such as chromite, kyanite, staurolite, tourmaline epidote, spinel and quartz.

In the thesis 17 composite samples were collected and analyzed for XRF analysis, oxides resulted from XRF analysis submitted to theoretical calculation model in order to determine mineralogy of concentrate in the 17 fractions, Table 4.

According to the theoretical model used for mineral assemblage estimation, the guide error values vary from 10% to 52%, which are considered to be good to moderate for magnetic and non-magnetic fractions. The poor guide error value were recorded in sample RBS10 by high Fe_2O_3 (110%), probably due to low total mass value 97%; the guide error values of more than 60% are considered as poor.

Table 4: Results of 17 mineral assemblage samples from 2014 and 2015 mine paths at wet concentrate plant B in the Namalope deposit.

MA_ID	Ilm Lo	Ilm Hi	Rut	Zir	Mon	Chr	KYA	Sta	Tour	Epi	Spin	Qtz	Avg Ilm TiO2
%	%	%	%	%	%	%	%	%	%	%	%	%	%
RBS02	44.8	35.2	1.89	5.87	0.44	0.31	2.4	3.6	4.7	0.27	0.12	0.4	55.4
RBS01	40.4	43	1.93	6.22	0.6	0.3	2.8	3.8	0.4	0.23	0.08	0.3	54.94
RBS03	41.3	40	1.83	5.48	0.45	0.28	3.1	2.8	4.6	0.23	0.06	0	55.06
RBS05	36.2	42.4	1.94	5.67	0.36	0.3	3.3	3.6	5.9	0.34	0.07	0	56.29
RBS08	35.1	45.7	1.89	6.53	0.53	0.33	2.2	2.5	4.5	0.27	0.06	0.3	55.36
RBS13	32.6	48.3	1.98	6.09	0.48	0.32	2.9	2.6	4.4	0.23	0.05	0.1	55.75
RBS12	32.9	49.2	2.38	5.58	0.47	0.3	3	2.2	3.4	0.29	0.07	0.2	54.09
RBS14	32.4	48.8	1.89	6.29	0.46	0.33	2.9	2.2	3.8	0.34	0.06	0.5	54.68
RBS15	35.1	44.9	1.83	6	0.55	0.32	3	2.4	4.8	0.3	0.06	0.7	54.68
RBS16	26.5	55.3	1.85	6.66	0.72	0.41	2.6	1.8	3.1	0.7	0.04	0.3	56.24
RBS17	43.5	37.6	1.04	5.07	0.53	0.34	0	2.9	8.5	0.46	0	0	54.65
RBS11	43.5	40	1.56	5.65	0.58	0.29	3	2	2.6	0.26	0.17	0.4	54.59
RBS10	43.9	40	1.76	6.88	0.85	0.3	2.1	1.7	1.8	0.21	0.14	0.5	53.21
RBS09	25.6	57.3	1.91	5.88	0.76	0.34	2.3	0.8	3.7	0.26	0.18	0.9	55.58
RBS07	49.9	33.1	1.92	6.31	0.8	0.3	1.8	2	3.1	0.22	0.12	0.6	55.99
RBS06	35.4	46.4	2.01	5.86	0.72	0.35	2.1	1.7	4.3	0.27	0.19	0.6	56.8
RBS04	38.9	44.1	1.69	6.14	0.73	0.3	2	1.6	3.7	0.23	0.14	0.6	55.36
Average	37.53	44.19	1.84	6.01	0.59	0.32	2.44	2.36	3.96	0.30	0.09	0.38	55.22

The valuable heavy minerals (VHM) are high ilmenite with high grade of TiO₂ (>53%) and low ilmenite with low grade of TiO₂ (<53%) balancing, with an average percentage range from 30% to 60%, and zircon is the second abundant heavy mineral with an average of 6 % while rutile has the lowest grade of all VHMs, about 2 % on average (Figure 31).

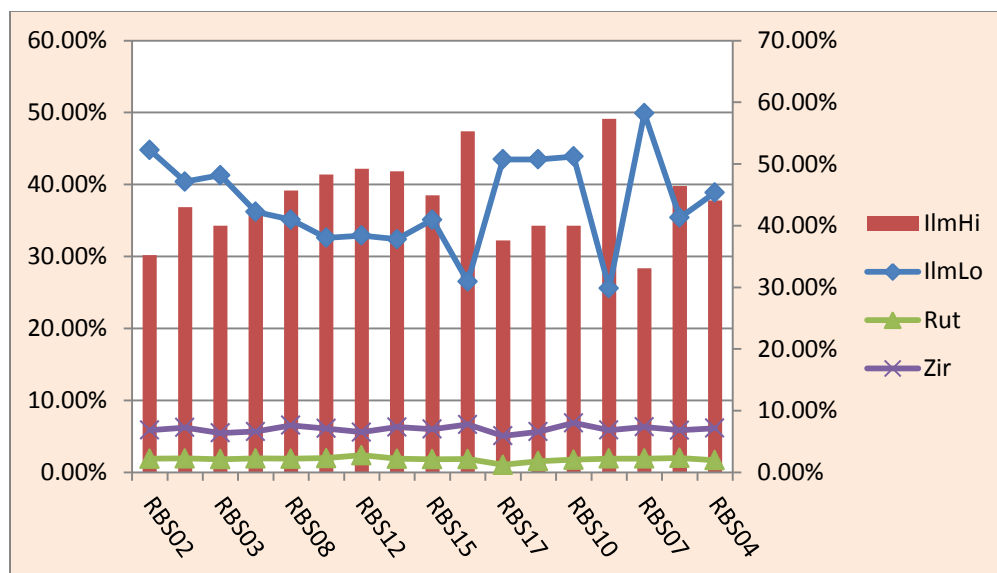


Figure 31: Occurrence of valuable heavy minerals. Ilmenite is the most abundant, followed by zircon and rutile in the mine paths 2014 and 2015 at WCP B of the Namlope deposit.

The accessory minerals in Namalope deposit are these associated with valuable heavy minerals. Tourmaline is the most abundant of all accessory heavy minerals with an average grade of 3% to 6% as showed in the secondary axis of graph chart in Figure 32; spinel is a mineral with lower grade of all accessory heavy minerals 0.1% on average.

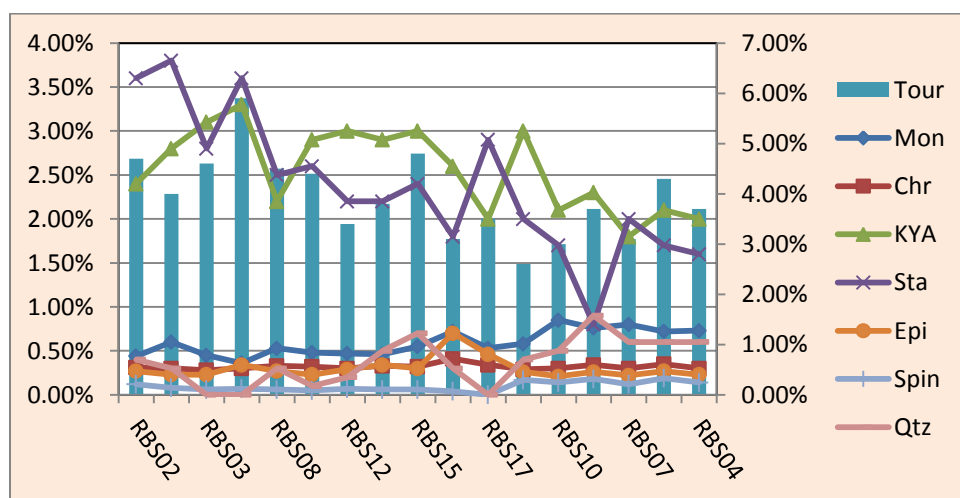


Figure 32: Occurrence of accessory heavy minerals such as tourmaline, chromite, kyanite, staurolite, epidote, and spinel; quartz is a part of lighter minerals in the mine paths 2014 and 2015 at Namalope deposit. Monazite is associated to this group due to low grade comparing to others VHM.

6.3.1 Spatial Distribution of Heavy Minerals at the Wet Concentrate Plant B

The heavy minerals are a group of minerals present in certain type of sedimentary rocks in a minor amount comparing to the light sediments forming the same rock, and are associated with silicates, sulfates, sulfides, oxide and phosphates while the light sediments are associated with minerals such as quartz, feldspar, carbonate, and mica groups (Hollyer et al., 1999; Dill and Klosa, 2011). Liberation of heavy minerals from their parent rocks by weathering of resistant minerals show relative concentration and those less resistant to weathering decrease in abundance or disappear completely (Dryden and Dryden, 1946).

The heavy minerals in sedimentary environment occur as high grade and low grade; the high grade heavy minerals are characterized by coarse grained beach placer deposits with well sorting sandy on the shoreface while the low to moderate grade heavy minerals are dominated by irregular occurrence of fine to relative coarse grain heavy minerals in clay rich, less well sorted sandy sediments in dune or washover deposits behind shoreface; and disseminated deposits of fine to very fine heavy minerals occur in clay rich sandy sediments adjacent to shallow marine environment (Roy et al., 2000).

The spatial distribution of heavy minerals was determined by plotting results of mineral assemblage calculation from selected composite samples in the mine paths, and it is divided into three different group, the valuable heavy minerals include ilmenite low ($< 53\% \text{ TiO}_2$) and high ($> 53\% \text{ TiO}_2$), zircon, rutile and monazite; the medium grade accessory heavy minerals are those with medium occurrence (Figure 32), such as staurolite, tourmaline, and kyanite, and low grade accessory heavy minerals these with low occurrence such as chromite, epidote, spinel and quartz; monazite is included into this group due to low grade occurrence but according to (Cilek and Duda, 1989) it is considered to be of the valuable heavy minerals.

Valuable Heavy minerals

The valuable heavy minerals constitute the principal group of heavy minerals at the mine, show high grade and high abundance, in all mining areas. Description of the spatial distribution of this group is shown ahead.

Ilmenite

Ilmenite is generally characterized by TiO_2 grade range between 35% and 45%, fresh ilmenite is commonly intergrowth with iron or chromium oxide minerals resulting in less ilmenite composition than expected; leaching of iron from ilmenite during weathering process may result in poor crystalline mineral grains residually enriched in TiO_2 . The common ilmenite concentrations are $\text{TiO}_2 < 50\%$ dominated by unweathered ilmenite and $\text{TiO}_2 < 60\%$ altered ilmenite (Roy et al., 2000).

The Ilmenite characteristic in the mine paths suggests that is altered, with TiO_2 concentration in a range of 52% to 56 %. According to the theoretical model used by the Author for mineral assemblage estimation ilmenite is divided into ilmenite high and low. The occurrence of ilmenite low and high in the entire area shows low variation with ilmenite high declining toward west and south, and increasing toward east and centre. The Ilmenite low shows low variance with tendency to increase southward (Appendix 6).

Rutile

Rutile is commonly dominated by impurities such as SiO_2 , Cr_2O_3 , Al_2O_3 , FeO , which invariably; reducing the TiO_2 content from 100% as described by many literatures to 94% and 98%.

Rutile constitutes the most important heavy mineral into group of TiO_2 and is the premium commercial titanium mineral (Roy et al., 2000).

In the mine path at Namalope the rutile concentration range from 1% to 2%, occurs in the entire mine paths with low variability but has tendency to decrease southward to the mine path 2015, (Appendix 6 and 7).

Zircon

Zircon is the most stable mineral found in rocks such as granites and pegmatite, and it is able to survive in erosion, transport, deposition and diagenesis with much less alteration than other accessories minerals (Owen, 1987); and it is the most frequent minerals found in zirconium ore in heavy minerals sands where it is extracted as co-product of ilmenite and rutile. Currently industry is facing challenge to recover premium zircon due to impure separation such as Fe_2O_3 , Al_2O_3 , and U + Th; in generally the presence of minerals such as sillimanite, kaolinite, corundum

and monazite with coating of iron oxide poses challenge for production of premium zircon (Murty et al., 2007).

The zircon occurrence at Namalope varies between 5% to 6%, constituting the second abundant heavy mineral in the deposit after ilmenite, the spatial distribution of zircon shows low variability in entire mine paths, (Appendix 6 and 7).

Medium Grade Accessory Heavy Minerals

The medium grade accessory heavy minerals are those heavy minerals such as staurolite, tourmaline, and kyanite show medium grade in the entire area.

Tourmaline is the most abundant accessory heavy mineral in this group, with concentration of 0.4% to 6%. The tourmaline concentration is variable with tendency to increase toward south in the mine path 2015 and decrease toward west in the mine path 2014. The low concentration of tourmaline is observed further north, considered to be anomaly and probably suspicious data, (Appendix 8).

Staurolite is the second abundant accessory heavy mineral after tourmaline into the group, characterized by concentration of 1% to 4%; the spatial distribution of staurolite shows low variability with tendency to increase toward south and decrease toward north. Further north is observed high concentration of staurolite, which is probably associated with suspicious data or wrong results as described in the tourmaline section, (Appendix 8).

Kyanite is the lower abundant accessory heavy mineral into the group with concentration of 2% to 3%; the spatial distribution of kyanite shows low variability with tendency to slightly increase toward west and south in the mine path 2014. The sample RBS01 further north and RBS17 further south show suspicious data.

Low Grade Accessory Heavy Minerals

This group of accessory heavy minerals includes monazite, chromite, epidote, spinel and quartz, and they occur in the entire area with very low grade of less than 0.8%.

Monazite

Monazite is the one of valuable heavy minerals in the Namalope deposit, described as principal thorium mineral in mineral deposit containing up to 30% thorium and variable amount of rare earth elements (cerium and lanthanum as common), as well as yttrium and uranium (Roy et al., 2000).

Monazite is included to this group due to low grade but it is considered as a valuable heavy mineral, it shows low variability in the entire area probably due to high resistance to weathering (Dryden and Dryden, 1946). The monazite concentration in Namalope deposit varies between 0.4% to 0.8%, and the high concentration increases toward north-east and decline seaward in the south of the mine path 2015, (Appendix 9).

Chromite is the first abundant accessory heavy mineral with concentration range from 0.3% to 0.4%. The chromite concentration shows low variability in the entire mine paths with tendency to decrease toward west of the mine path 2014 (Appendix 9).

Epidote is the second abundant low grade accessory heavy mineral with concentration of 0.2% to 0.7%; the epidote concentration tends to increase southward and declines northward (Appendix 9).

Spinel is the third abundant low grade accessory heavy mineral with concentration range of 0.04% to 0.2%; the spinel concentration tends to increase toward north and decreases southwards, further south it is missing, (Appendix 9).

Quartz is the lowest abundant mineral in the study area, due to low occurrence but it is part of lighter minerals, which is incorporated into heavier with concentrations of 0% to 0.9%. The quartz concentration are variable with tendency to increase in the centre of both mine paths and decrease northwards and southwards, further south quartz is missing, (Appendix 9).

CHAPTER 7 DISCUSSION

The spatial distribution of heavy minerals in the mine paths 2014 and 2015 of the wet concentrate plant B, at the Namalope shows high variability with tendency to increase with depth and grain sorting, and is divided into different areas according to units, of which each unit has specific of heavy mineral concentration, slime and oversize content. The high grade heavy minerals occur in the unit 7 with an average grade of 7% and slime 9%, and the heavy minerals concentration in the entire area increases northwards and decrease seawards in the south, the slime content increases southwards.

The unit 6 is characterized by slightly the same concentration in heavy minerals of unit 7, 5% in average; the difference between them is in the slime concentration with unit 6 showing low slime content of a maximum of 5%. Unit 81 and 82 is dominated by high slime content, an average content of 38% and low heavy minerals concentration with an average of 3%, further south of the mine path 2015, the slime content is missing probably due to proximity to the shoreface where all light materials were washed out to the offshore. The oversize content increases toward south in units 6 and 7, according to the cross section in Appendix 10 to 12, probably due to active shoreface in that area, the waves and longshore currents removed the light materials.

(Frihy and Komar, 1993), described that the longshore sediment movement is selective transport involving different minerals with different density and grain size where light minerals having highest advection rates and dense opaque minerals having low rates tend to remain behind as lag within the lag erosion. This explanation support idea the author's idea on affirmation of light materials from south of the mine path 2015, probably former shoreface was eroded thereafter the unit 81 and 82 is missing. (Frihy and Dewidar, 1993), also suggested that the wave swash on the beach can selectively concentrate fine grained heavier minerals by separating the lighter from the coarse grained minerals.

(GREIG, 2001), propose that the unit 7 hold the same grade of heavy minerals with unit 6, according to the data interpreted by the author, there is slightly difference on average grade between units 6 and 7 with unit 6 having an average heavy minerals of 5% and unit 7, 7%. The slime content is according to (GREIG, 2001) explanation (5% to 15 %). The author realized that there are low grade heavy minerals lens in the unit 7, which dilutes the heavy minerals concentration. This fact was registered in the 6 as well. Some sections show low grade of heavy

minerals near the surface probably due to porous spaces between grains where fines pass through coarse grains and settle in the deep area according to their shape, grain size and density. (Rubey, 1933) proposed that factors such as difference in density and hardness, difference in grain sizes from source rocks, abrasion, settling velocity and degree of sorting cause large variations in relative abundance of various heavy minerals, e. g. the abrasion and sorting tend to concentrate heavy minerals in the fine fractions.

According to (GREIG, 2001), the unit 81 is located at the bottom of unit 6 and unit 82 between units 7 and 9. This evidence was found in this thesis as well where unit 81 is on top of unit 7 and at the bottom of unit 6 and unit 82 between unit 7 and 9. Slime content in both units (81 and 82) varies between 20% to 70% with an average thickness of 3 meters and heavy minerals concentration of 3% on average.

The results obtained in the thesis compared to these obtained by (GREIG, 2001) show low variability; according to (GREIG, 2001), the slime content of unit 82 varies from 40% to 70% and 81 from 20% to 60% which is slightly different. The average thickness of units 81 and 82 is 2 m, according to (GREIG, 2001) the average thickness of unit 82 is 3 – 6 m, which is slightly different. The high grade of heavy minerals in the unit 81 and 82 is probably from errors during sampling by mixing the lower part of unit 6 or 7 and to the upper part of unit 81 or 82 during sampling.

The mineral assemblage estimation in the entire area suggested that the occurrence of valuable heavy minerals such as ilmenite can be divided into ilmenite low and high, zircon, rutile, and monazite. The ilmenite high, rutile and monazite tend to increase northwards while the ilmenite low increases southwards. The zircon concentration shows low variability in the entire area.

The ilmenite averages is 82%, zircon 6%, rutile 2%, and monazite 0.6%. The optical mineralogy and QEM*SEM techniques described by (GREIG, 2001) show close similarity with determination of mineralogy by estimation techniques used in this thesis in the same area, however the optical mineralogy shows low occurrence of leucoxene of approximately 1%, which was not found by the estimation proportion technique. Data used for comparison of two techniques are from the same area of Namalope deposit at the flat area, however composition techniques is different; the optical mineralogy determined mineralogy by units while in this

thesis, the mineral compositions were determined from unit 6 to unit 7 as both units have slightly the same heavy minerals concentration.

The occurrence of valuable heavy minerals in the Namalope deposit is divided in three groups according to their concentrations, valuable heavy minerals such as ilmenite, zircon; rutile, and monazite; medium grade accessories minerals such as staurolite, tourmaline, and kyanite; and low grade accessories heavy minerals such as chromite, epidote, and spinel. Quartz is one of the lighter minerals in the mine paths shows high variability.

The spatial distribution of heavy minerals in the mine paths is divided in two groups according to heavy mineral variability: those with high variability such as spinel, epidote, and tourmaline; and others with low variability such as zircon, rutile, chromite, kyanite, monazite and staurolite. The heavy minerals with low variability in the mine paths suggest relatively high resistance to alteration during transport and diagenesis; and those with high variability suggest susceptibility to alteration during transport and diagenesis.

(Peterson et al., 1986) studied Oregon beach and suggested that maximum segregation and heavy minerals occurs in the backshore basin and at shoreline inflection points, the decline flow velocity produce gradient stress of fluid shear stress, allowing light minerals to winnow from more stables heavy minerals. (Cilek and Duda, 1989) described that the presence of higher content of kyanite in placer deposits along northern part of Mozambique coastal line suggests source rock within Mozambique belt (granite gneiss).

7.1 HEAVY MINERALS SAND FORMATION

The sedimentary basin is depression capable to trap sediments by subsidence of upper surface of crust, generally mechanism involved to generate this depression are crustal thinning, mantle lithosphere thinning, sedimentary and volcanic loading, tectonic loading, subcrustal loading, thenospheric flow and crustal densification (Dickinson, 1993) cited by (Boggs, 1995).

According to (Tanner, 1995), the sand beach ridge occurs in four categories such as Swash built, Settling lag, Aeolian and Storm surge. The swash ridge and settling lag tend to be geometrical regular while the last two don't have these characteristics and are not suitable for detailed historical studies.

The beach ridge sand commonly progrades with abundant sediments and low offshore gradient; the sea water level change don't determine the beach ridge growth but determine orientation and elevation in the beach ridge plain; in general the orientation and shape of younger beach ridge depend on the sea level fluctuation, climate and sediment supplier histories in the area of formation (Taylor and Stone, 1996).

The vertical differentiation of valuable heavy minerals and others non valuable in beach in combination with marine transgression, which result in beach barrier migration determine the distribution of heavy minerals such as ilmenite, rutile magnetite monazite and zircon and move these materials to landward specially in narrow shelf with moderate terrigenous sediments; the high terrigenous influx results in large body of disseminated placers (Kudrass, 1987).

Abundance of heavy minerals in beach sands don't reflect composition of source rocks, but they are heavily influenced by sedimentation processes such as transport, deposition and diagenesis, nevertheless the heavy minerals assemblages contain some features that reflect source materials (Morton and Hallsworth, 1994).

The description of basin formation and heavy minerals concentration in the mine paths 2014 and 2015 at Namalope is based on cross sections from drilled holes plotted in map showed in Figure 33; both cross sections are from flat area of Namalope deposit.

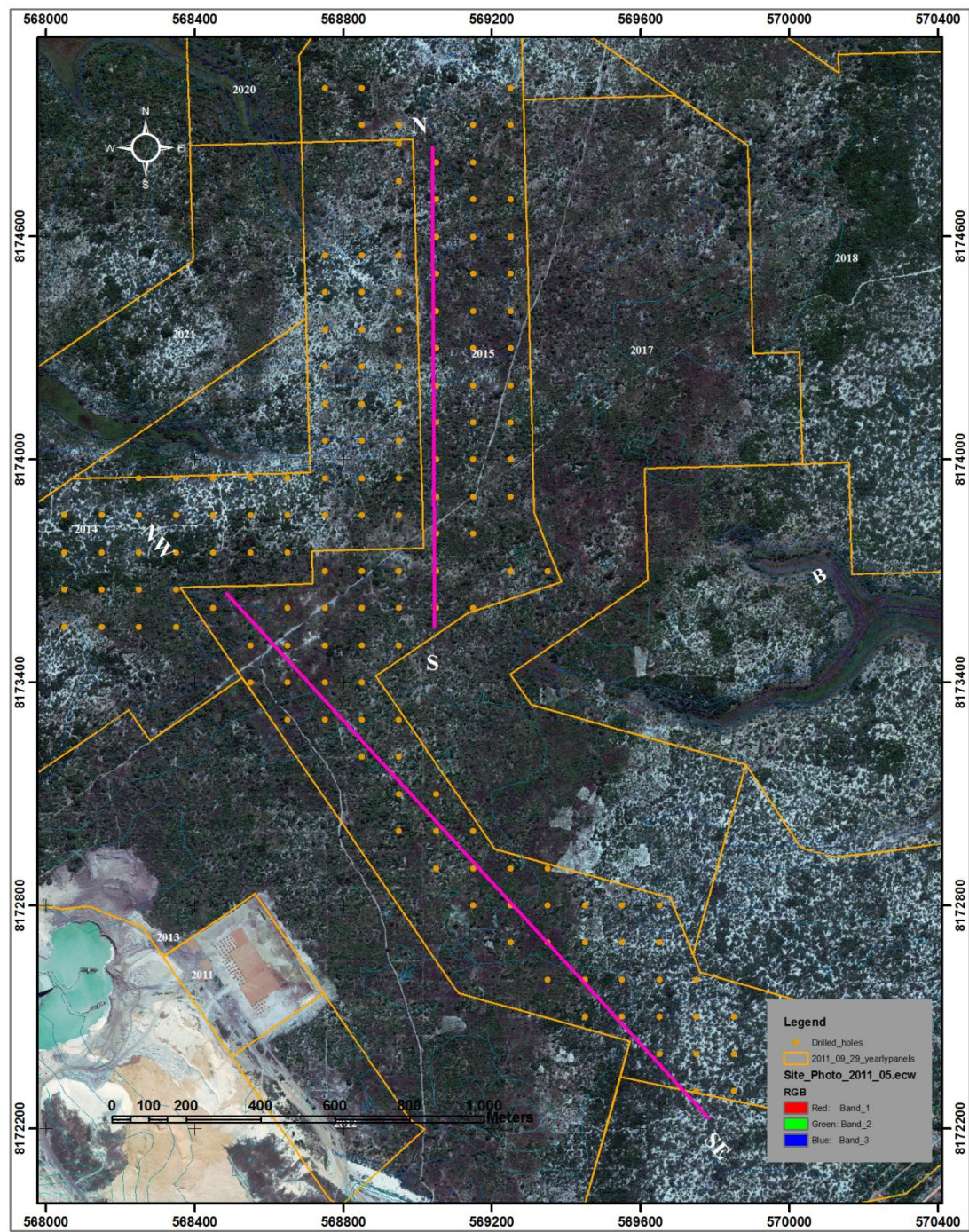


Figure 33: Satellite image shows cross sections of NW – SE and N – S directions in the mine paths 2014 and 2015 at the wet concentrate plant B, Namalope deposit.

Based on the interpretation of heavy minerals concentration, slime and oversize content, the criteria used by the author to distinguish different units (zones) in the stratigraphic sequences, suggested a deposition model for the mine paths, which may probably affect all the Namalope at flat areas. The oversize content usually is uniform with content less than 5% in most of the cases, except in the south of mine path 2015 that can be approximately 30% (Appendix 5). The plotted cross sections for deposition model in figure 35 and 36 suggest two scenarios:

7.1.1 Section North – South

Section N to S is plotted into the mine path 2015 due to large data availability in this area. The plotted cross section suggests horizontal stratigraphic sequences with all units showing undulation of sand crest (Figure 35). The description of stratigraphic sequence is based on shallow holes, approximately 30 m at maximum depth, the cross section of the entire areas based in the oversize content suggest coarsening upward deposition with coarse materials usually being deposited in the unit 9 bottom of the sequence, which decrease upward to unit 6 dominated by fine to medium grain (Figure 34).

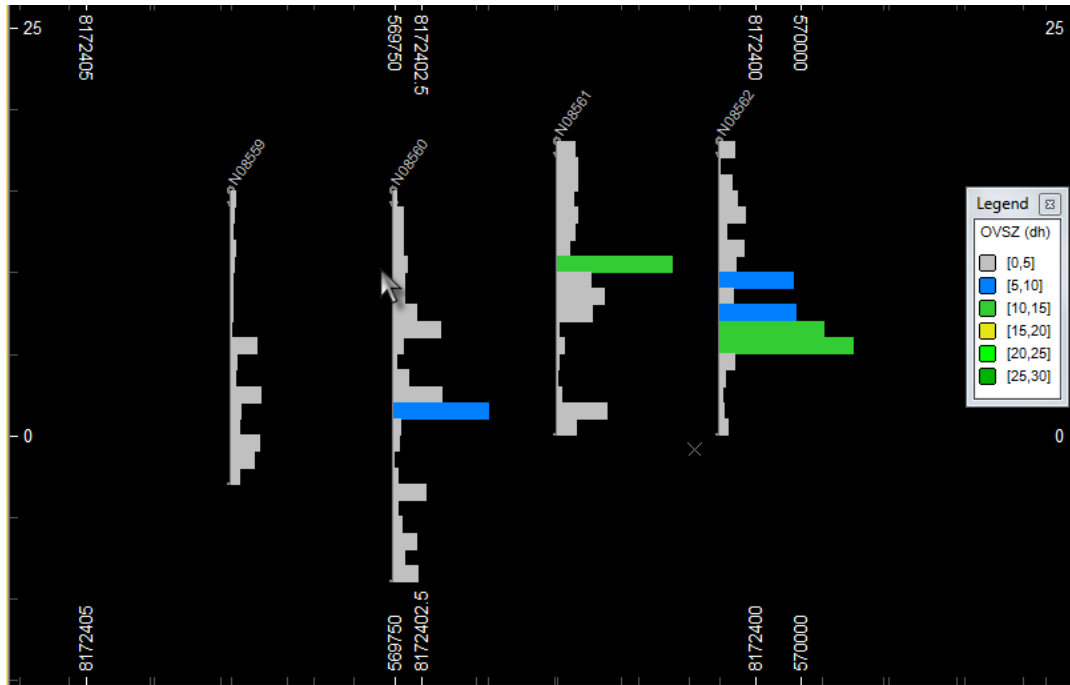


Figure 34: Downhole distribution of oversize with depth, all drillholes in the section show coarsening upward with units 9 at the bottom and 6 on the top of stratigraphic sequences.

The stratigraphic sequences of this area suggest shallow marine environment deposition of terrigenous sediments along continental shelf. The terrigenous sediments are supplied to the continental shelf by uplifted continental region from inland and some sediment from Old Red Dune (high dune area) adjacent to the flat area of the Namalope deposit transported by rivers.

The deposition of heavy minerals depends on various factors such as differences in density and hardness of minerals, original size of source rocks, and amount of abrasion during transport, settling velocity of sediments during deposition and degree of sorting. The abrasion and sorting tend to concentrate heavy minerals in the fine grained sediments fractions (Rubey, 1933), less dense minerals or platy minerals are concentrate in coarse tails (Komar et al, 1984), cited by (Garzanti et al., 2009).

Unit 9 is considered as the bottom of both mine paths according to the drilled depth and suggests deposition by low to medium energy marine regression environment due to presence of terrigenous coarse materials and coarse grains than other units; the high slime content showed in this unit, is probably associated with weathered materials from inland such as feldspar and clay minerals, which are mixed with coarse materials resistant to weathering; geomorphology feature on the top of this unit suggest erosion and consequent creation of shallow basin where unit 82 is deposited; further north suggest levee of shallow river.

Units 81 and 82 was deposited in the short period time with low energy environment and high sea water level, where few suspended terrigenous sediments from uplifted continental origin and some sediments from the sea are deposited, associated with marine transgression and climate factor. The geomorphology of this unit suggests deposition into the basin created by erosion in the unit 9 bellow. The high concentration of organic matter made this unit very dark grey or black colour (Nichols, 2009). Deposition of clay layer in the shallow area suggests absence of tidal currents and more bioturbation; the deposition of units 81 and 82 ceased due to storm action or clay moves along the coast in decrease waves and sand beach development (Clifton, 2005).

Unit 7 was formed during marine regression in the shallow water resulted in deposition of terrigenous sediments from inland associated with feldspar and clay minerals, whereas fine materials are fitted into porous space during settling. The climate condition was relevant to

deposition of these materials due to water availability. The heavy minerals concentration increases with depth in this layer probably due to increasing of slime content downwards, whereas heavier and fine material passed through porous spaces and trapped via cementation from slime. The geomorphology of unit 7 suggests erosion in upper part whereas in the centre, level of erosion was slightly high resulting in formation of small scale palaeochannels.

Unit 6 is formed from the same deposition environment of unit 7 by shallow water marine regression and probably with low clay mineral content, whereas in the settling fine materials passed through porous spaces and deposited in unit 7. The geomorphology of entire sequences suggests a long erosion period that can be visualized in the south of cross section with exposure of unit 7.

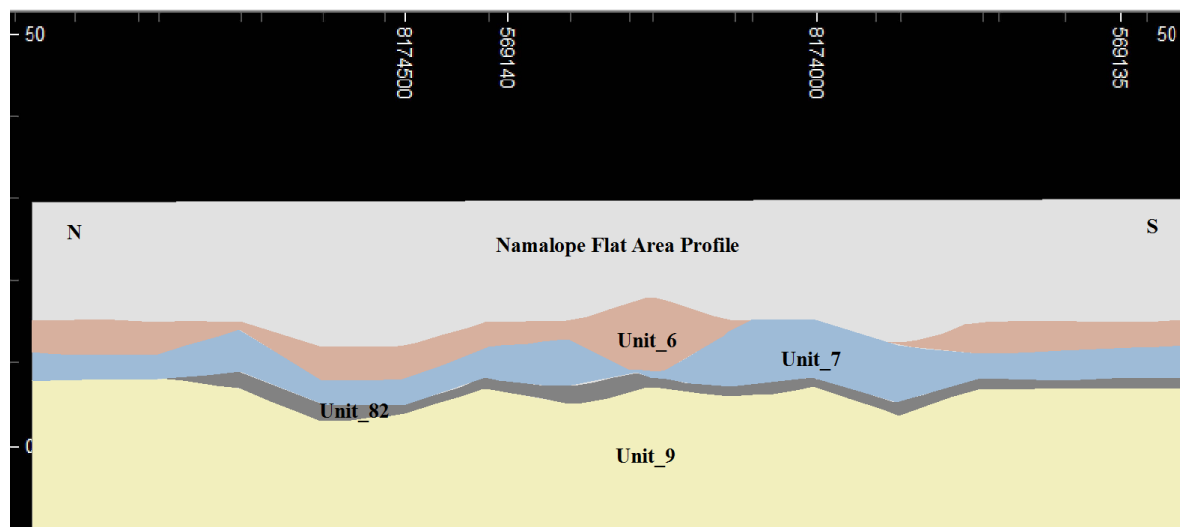


Figure 35: Cross section N – S shows stratigraphic sequences along mine path 2015, which will be used for 2014 as well due to proximity and low data variability into the closed space of mine paths.

7.1.2 Section NW – SE

The cross section NW–SE (Figure 36), was planned in the south of section N–S with some intersection between south of N-S section and north of NW – SE section, in both mine paths (Figure 33).

Deposition of all units in this section was submitted to the same processes of previous section with unit 9, deposited in the shallow marine environment during regression; unit 82 during low energy of shallow marine environment and high sea water level (marine transgression) associated with the climate factor and few load of terrigenous sediments supplied to the shallow basin

created in the unit 9, probably by erosion; the units 6 and 7 were deposited during regression by low to medium energy depositional environment.

The geomorphology of units in this section is influenced in most of cases by erosion level and formation of channel in the units. The unit 7 shows incised area in the section, suggesting small scale palaeochannels.

Further to SE the scenario has changed with slope of units 9 and 7, dipping toward offshore and absence of unit 82, suggesting high energy of deposition during marine regression in that particular area as fine grained sediments lost their cohesion when eroded and debris are transported offshore as suspended load.

Unit 9 probably forms shoreface with unit 7 forming parallel layer to the slope, which suggests waves are dominated by sandy beach environment. The unit 9 geomorphology in the SE suggests prograding ridge formed as beach shoreline; the upper shoreface is characterized by coarse material while the lower shoreface is dominated by scattered pebbles (Clifton, 2005). According to the cross section, unit 6 was deposited in the inner shelf basin during regression.

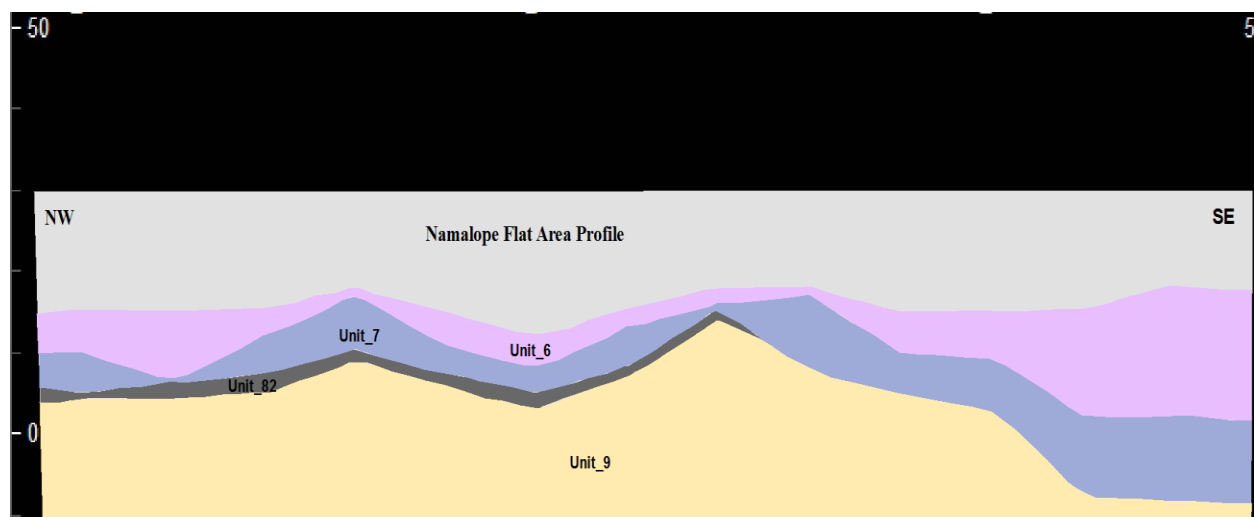


Figure 36: Cross section NW –SE shows stratigraphic sequences and deposition model for units 9 at the bottom, 82, 7 with incised area in the NW direction and unit 6 on top of sequence.

The Namalope deposit at the wet concentrate plant B in general and in the mine paths 2014 and 2015 in particular, was deposited in the shallow marine environment dominated by regression for formation of unit 6, 7 and 9, and transgression forming the unit 82. The stratigraphic sequence

indicates that the unit 9 was deposited first during regression of shallow marine environment and constituted the bottom of the sequence as maximum depth is 30m determined by drill holes.

The deposition of unit 9 was followed by a long period of erosion in the entire area, resulted in opening shallow basin on the top surface of unit 9. During transgression few suspended loads from inland were deposited in a short period time in the low energy marine environment to form unit 82. Further south, the unit 82 is eroded away by storms and wave currents during formation of unit 7. Units 6 and 7 were formed during a long period of regression and deposition of materials from inland.

(GREIG, 2001) considered that the flat area of Namalope deposit was formed under transitional to fluvial conditions; BHP geologists suggested that during the Pleistocene epoch, the sea water level dropped due to glaciations, sediments from rivers were dry, thereafter the sea water level rose and incised valleys formed during regression, which were filled by fine silt sediments. This event resulted in formation of unit 82 in the flat area of Namalope deposit.

(Macey et al., 2006) suggested that dissected sediments from river were from Molocué River and adjacent catchment. The seaward slope of coast sand ridge was confirmed by (Macey et al., 2006), where it has been incised by stream to form valleys that have blocked along eroded eastern slope by raised beach ridge. The Northern part of ridge is truncated by Larde River and steeply incised seaward is flanked and undulated coastal plain topography (Figure 36).

(Taylor and Stone, 1996) by differentiation of beach ridge to cheniers, suggested that the beach-ridges are deposited by swash during high or low wave energy condition, which may emerge through aggradations of offshore bar.

7.2 Limitations

The drilling activity for purpose of this thesis was well planned; however, care must be taken during sampling, some areas of units 81 and 82 show high grade of heavy minerals concentration, which becomes difficult to interpret due to the units 81 and 82 known that has low heavy minerals concentration and high slime content.

During the interpretation was found that the unit 7 has lens of around 2 to 3 m thick with low grade heavy minerals of less than 2%, while the unit 7 is dominated by high grade of heavy minerals, same situation is registered in unit 6.

The low sampling availability due to internal Laboratory used for data acquisition not analyzing standard and blank samples frequently, unfortunately during sample analysis coincided with the period of not analyzing standards and blanks, which could help for data validation and confidence.

Determination of mineralogy in the study area focused only the data from XRF analysis, which made determination of mineral assemblages completely dependent on that technique.

During data interpretation, some drillholes were ignored due to suspicious assays such as high slime content comparing to the vicinity drillholes, the same situation happened with the mineralogical data, with mass balance less than 98% in the samples with suspicious data quality.

CHAPTER 8 CONCLUSIONS & RECOMENDATIONS

The quality control and quality assurance performed, detected high bias variance related to accuracy between handle GPS and RTK – GPS used to survey drilled holes; and poor accuracy between field duplicates to the original samples, and laboratory duplicates to the original samples. The accuracy between handle GPS and RTK – GPS is good in the plan view (2D) and poor in the 3D view. In the quality assurance and quality control for field duplicates and original samples were removed 22% of total samples into load batches while in the laboratory duplicate samples were removed 18% from the total samples into load batches as well due to suspicious erroneous data.

The spatial distribution of heavy minerals in the Namalope deposit at the mine paths 2014 and 2015 of the wet concentrate plant B is divided into different areas according to the units, and units themselves are divided into different sequence according to heavy mineral concentration, slime and oversize. Unit 7 shows high grade heavy minerals of 7% on average and 9% of slime, and its heavy minerals concentration increases northwards and declines seawards in the south. Unit 6 has slightly the same concentration of heavy minerals with the unit 7, approximately 5% on average, and the slime content generally less than 5%. The units 6 and 7 show the same tendency of spatial distribution of heavy minerals.

Units 81 and 82 shows average heavy minerals concentration of 3% and high slime content of 38%, the slime content declines northwards while heavy minerals increase southwards, further south the units 81 and 82 are missing due to proximity to previous shoreface where light materials were washed out and heavier materials deposited as fine to medium grained sands and pebble gravels from units 6 and 7. The heavy mineral concentrations in the mine paths increase with depth up to the bottom of unit 7, and the high grade of heavy minerals shown in units 81 and 82 is probably associated with errors during sampling processes.

The results of mineral assemblage estimation show occurrence of heavy minerals such as ilmenite, zircon, rutile and monazite, and accessory minerals such as chromite, kyanite, staurolite, tourmaline, epidote, spinel and quartz. The ilmenite is the most abundant with an average grade of 82%, divided into 38% for ilmenite low and 44% ilmenite high; zircon is the second abundant heavy mineral with an average grade of 6%, rutile 1.8% and monazite 0.59%.

The spatial distribution of heavy minerals in the mine paths shows ilmenite high, zircon and rutile with tendency to increase northwards while ilmenite low increases southwards. Ilmenite, spinel and epidote show high variability in occurrence while zircon, monazite, rutile, chromite, kyanite and staurolite show low variability. The low variability of heavy minerals is associated with high resistance of minerals for abrasion during transportation and diagenesis, while the high variability suggests high susceptibility of minerals to alteration during the processes.

The flat area of Namalope deposit shows a deposition model of shallow marine environment dominated by regression during formation of units 9, 7 and 6, and transgression during formation of unit 82. The regression is characterized by deposition of materials from hinterland such as fine to medium grain sands and pebble gravels, while the transgression is dominated by deposition of few suspended loads of sediments from hinterland and offshore in the basin created on top of unit 9, in short time period associated with low marine environment. Further SE, the deposition model suggests that the unit 82 was washed out by storms or wave currents and deposition of heavier materials from units 9, 7 and 6.

According to limitations presented in the previous chapters, the author suggests the following recommendations:

1. During sampling processes, care must be taken in order to avoid mixing samples from different depth, which can result in low data quality and confidence, thus the coordination between driller and geologist is very important regarding to drill rod cleaning and sampling;
2. Data validation, in order to keep high quality data, it needs introduce blank and standard samples into load batches frequently;
3. Mineralogy study is necessary to be carried out in order to confirm leucoxene reported by feasibility study and actual situation reporting no leucoxene by use of EDS, microprobe, XRD and optical microscope;
4. Review the stratigraphic sequence of units in the flat area of Namalope deposit and low grade lens of heavy minerals in units 6 and 7.

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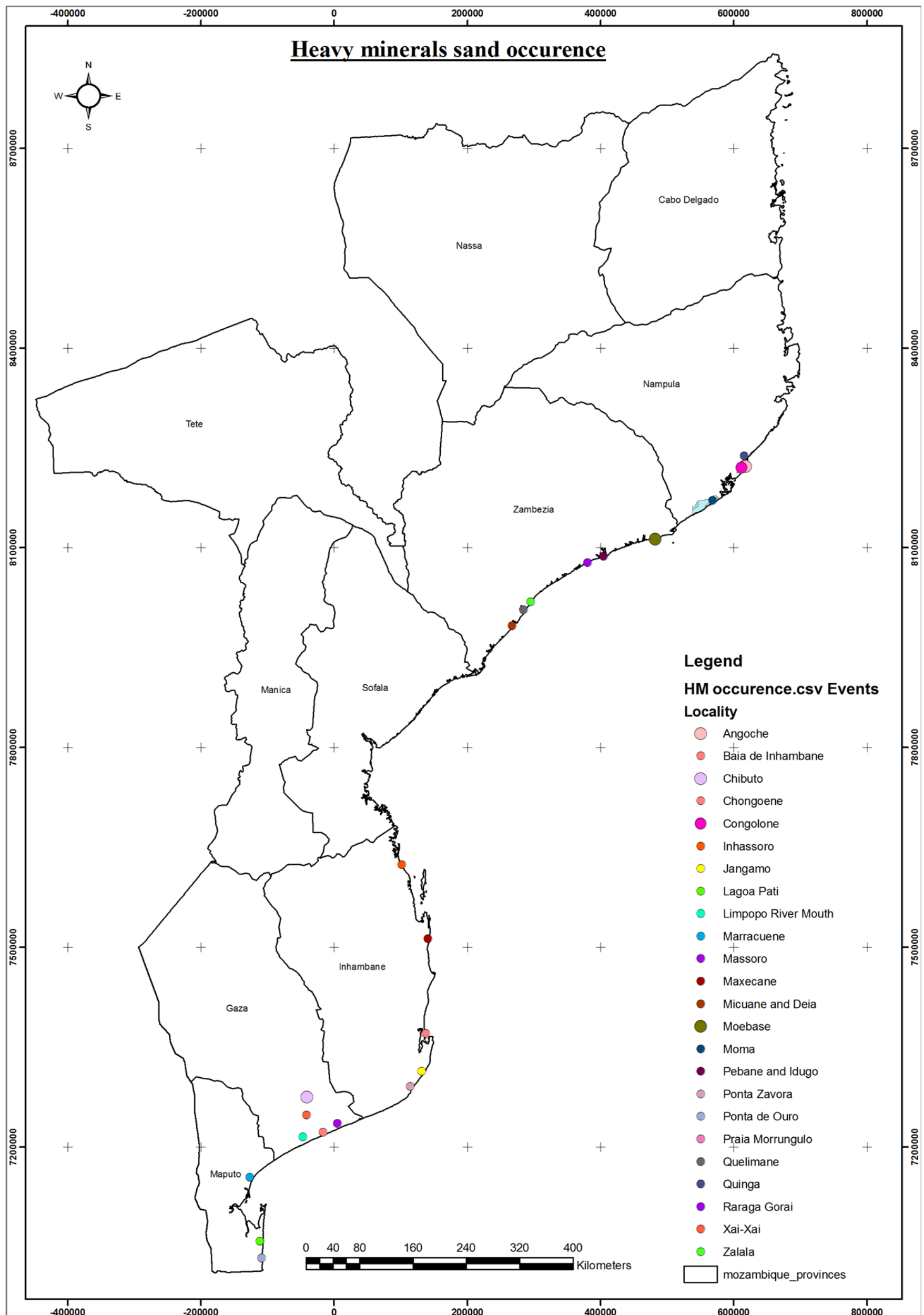
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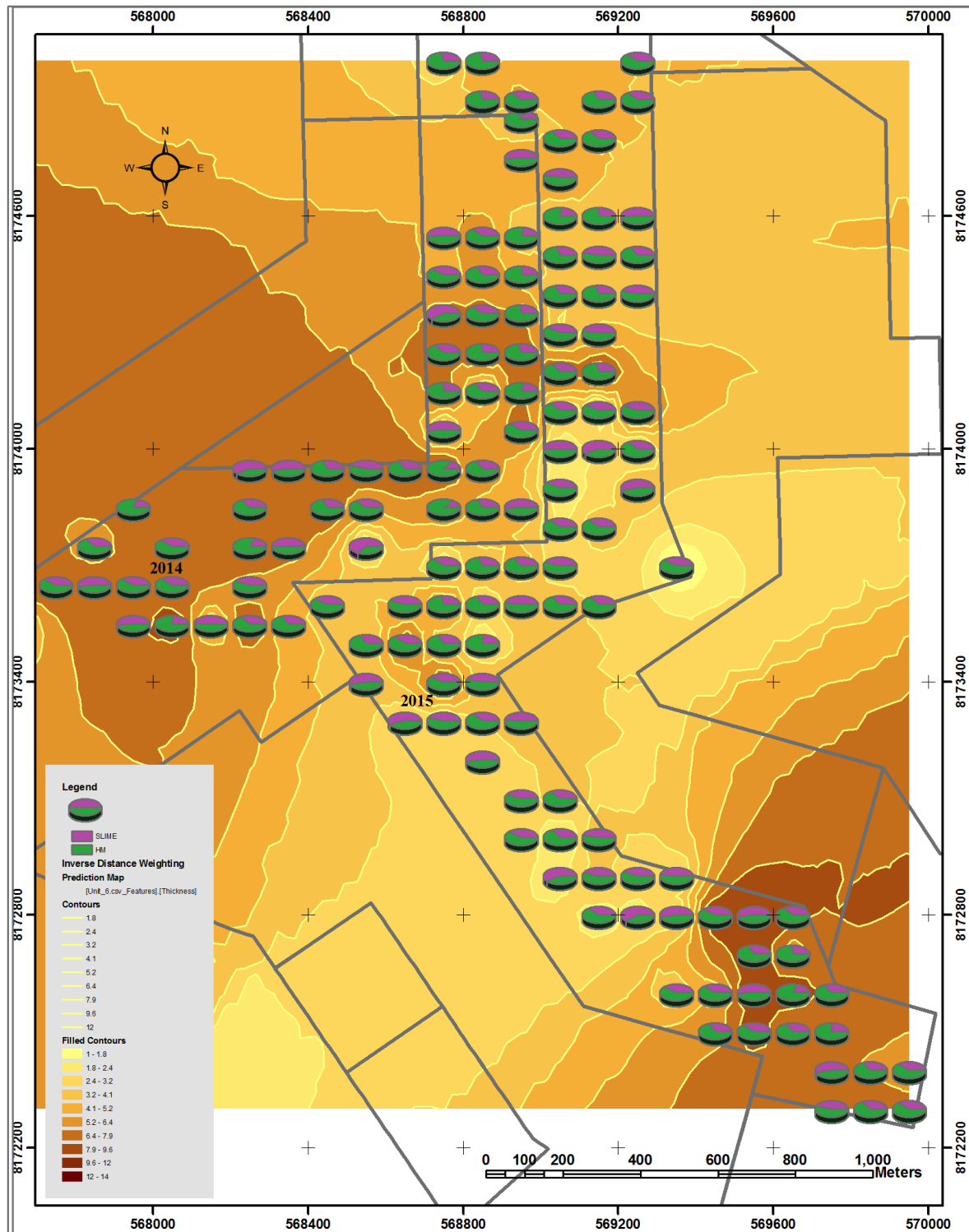
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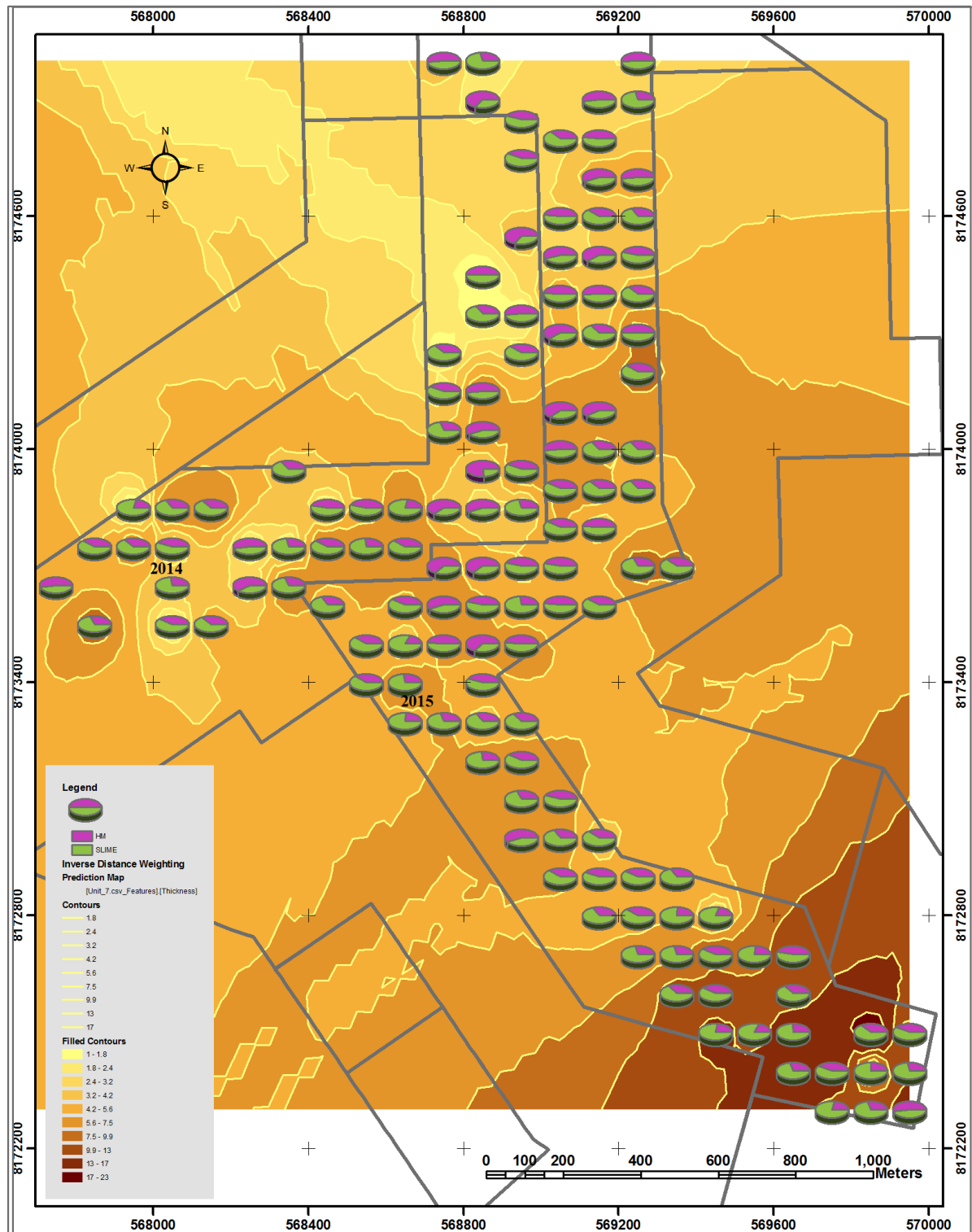
APPENDICES



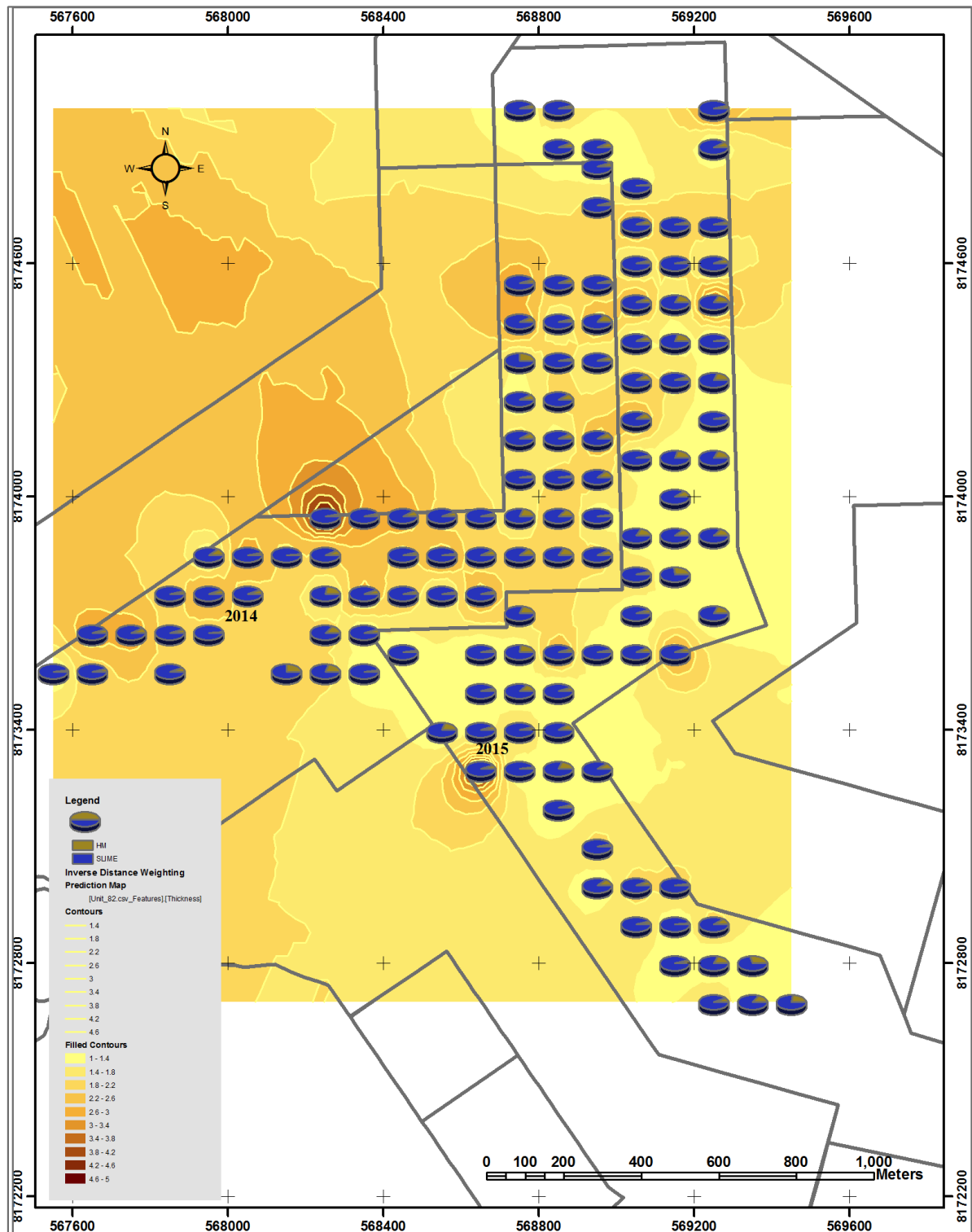
APPENDIX 1: Some localities of heavy minerals sand occurrence along Mozambique coastal line with more focus on Angoche, Moma, Moeabase and Chubuto the main heavy minerals sand deposits in Mozambique (references WGS 84, datum 37S).



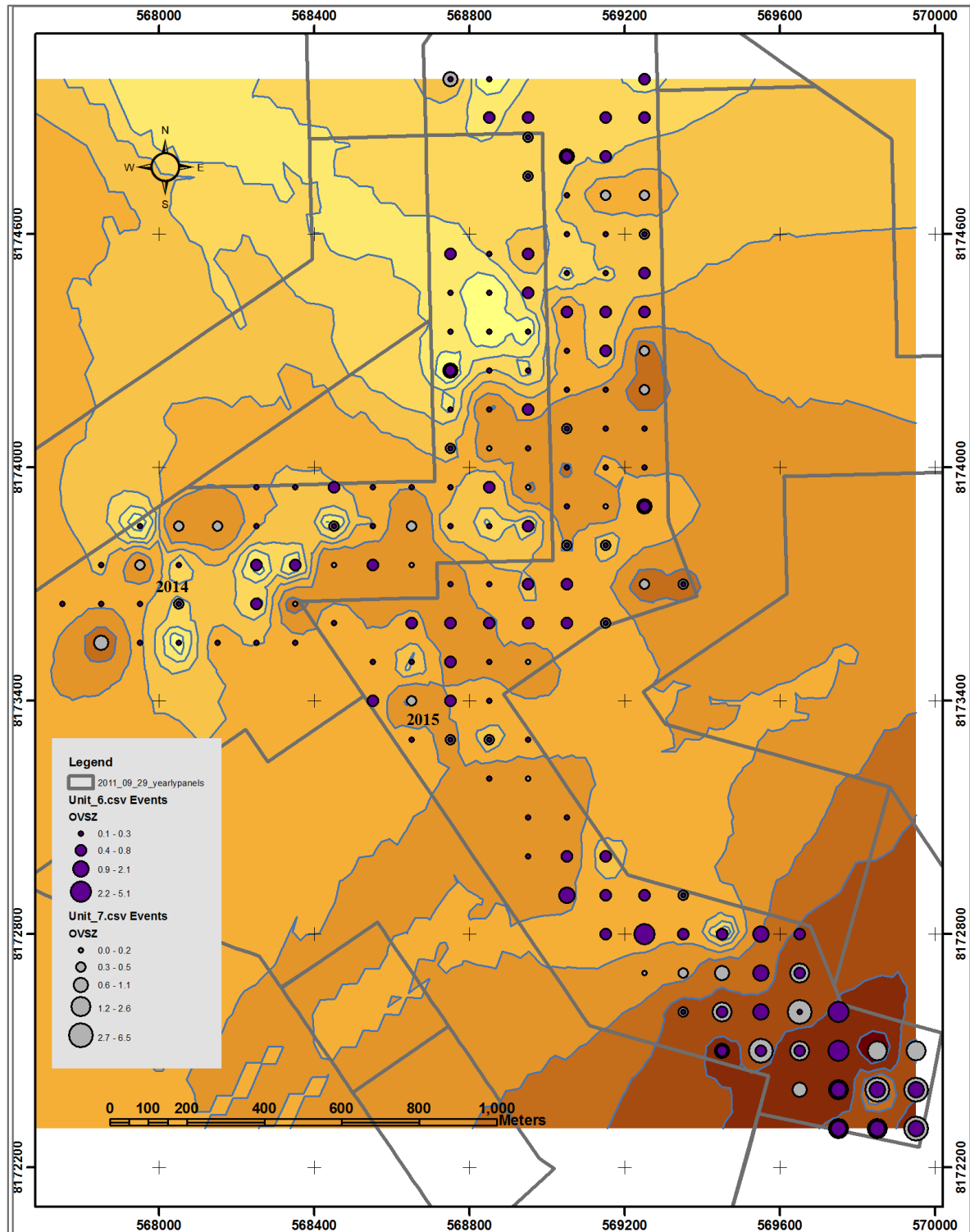
APPENDIX 2: Unit 6 map shows the spatial distribution of heavy minerals and slime content by thickness contour in the mine paths.



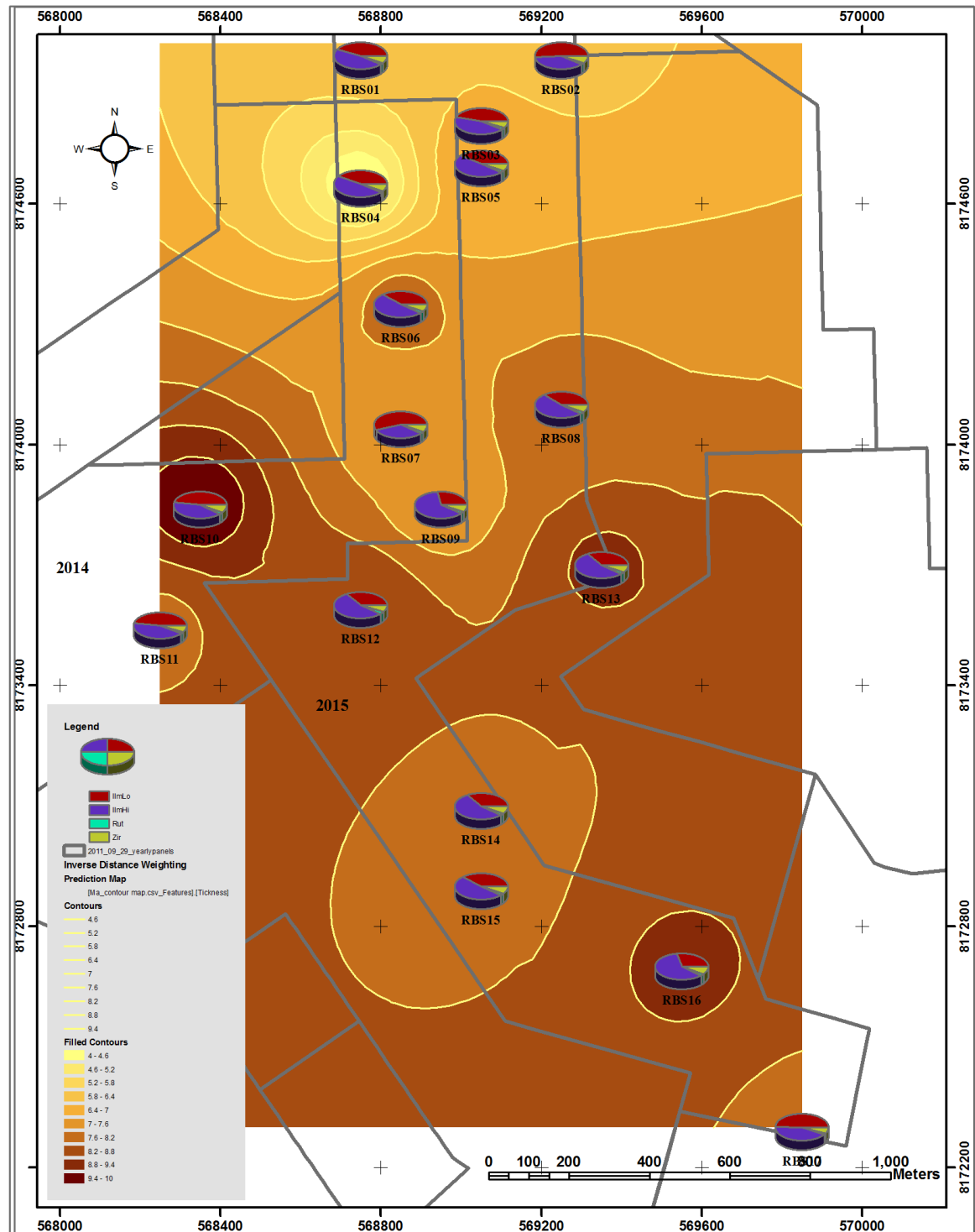
APPENDIX 3: Unit 7 map shows the spatial distribution of heavy minerals and slime contents by thickness contour in the mine paths.



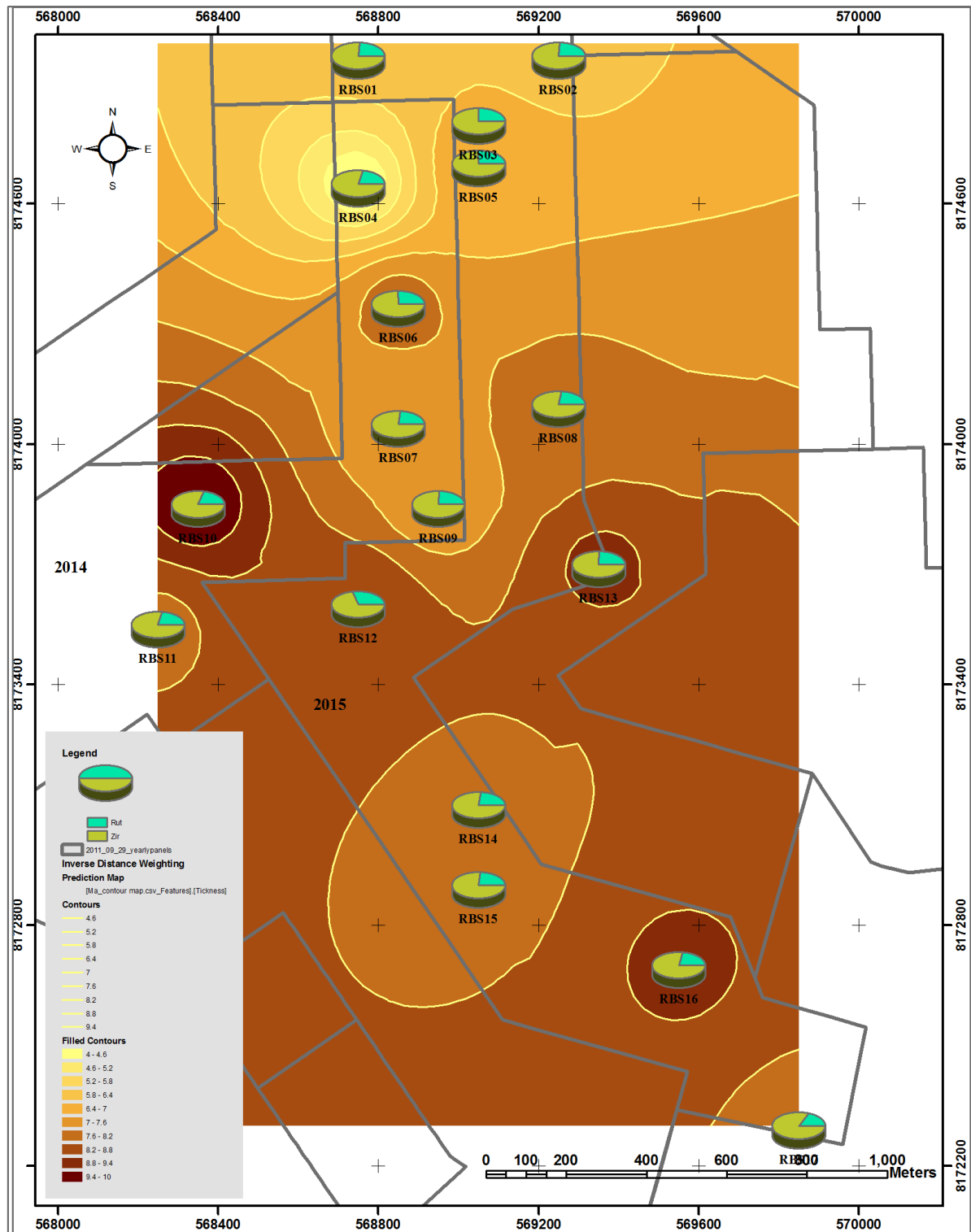
APPENDIX 4: Unit 81and 82 map shows the spatial distribution of heavy minerals and slime content by thickness contour in the mine paths.



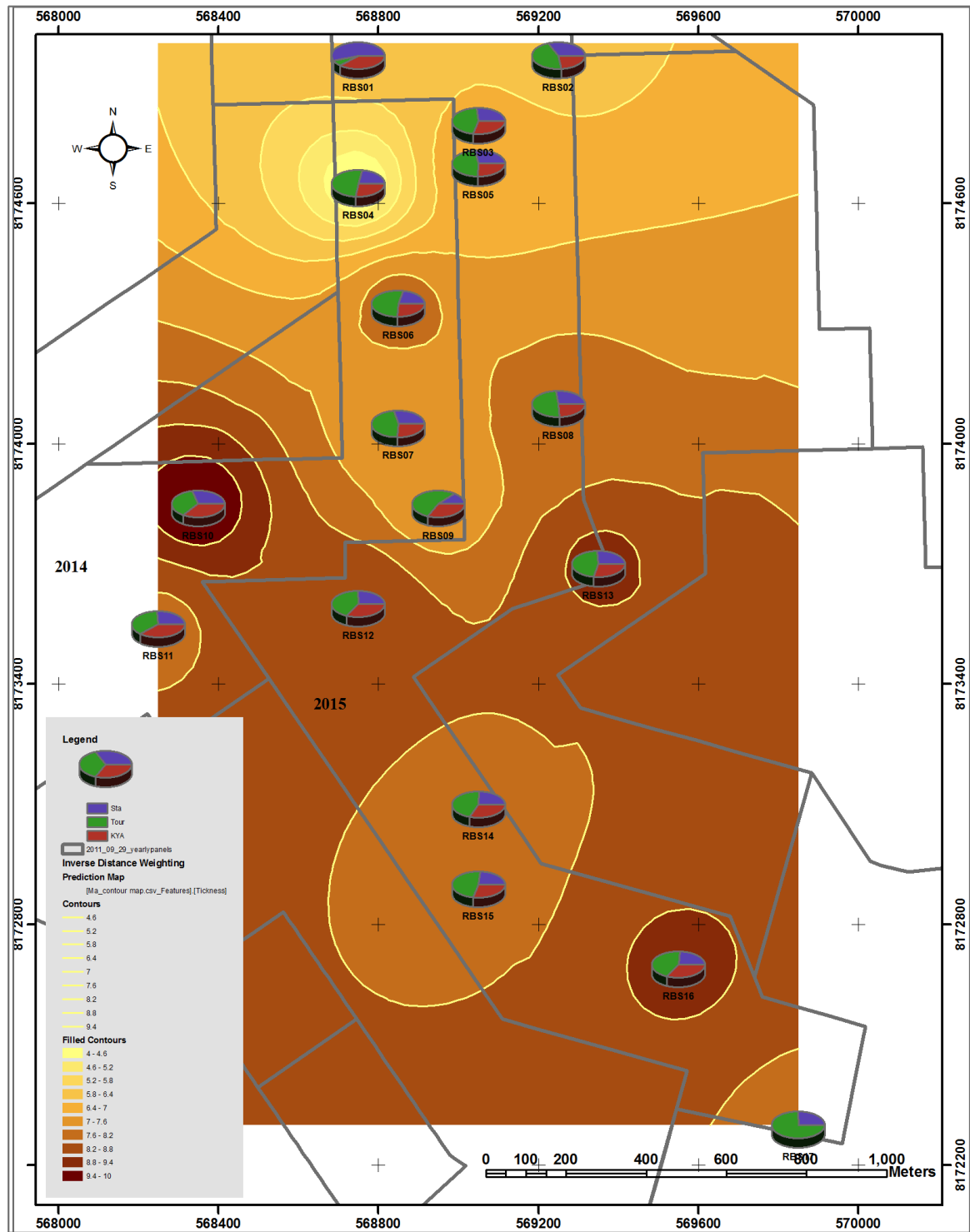
APPENDIX 5: Units 6 and 7 map show the spatial distribution of oversize in the mine paths; contour map used is from unit 7.



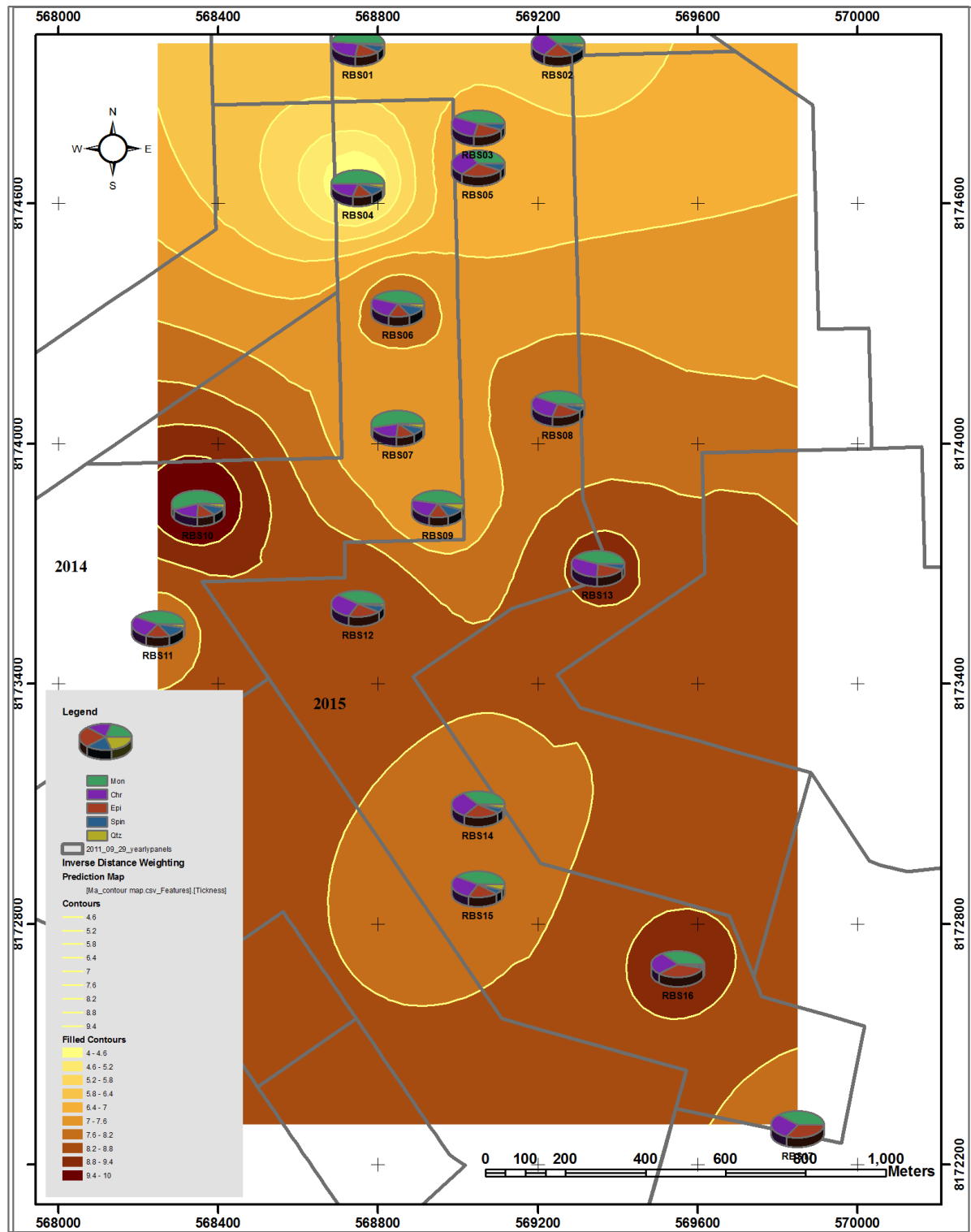
APPENDIX 6: Map shows the distribution of valuable heavy minerals with respect to depth in the mine paths 2014 and 2015 at Namalope deposit.



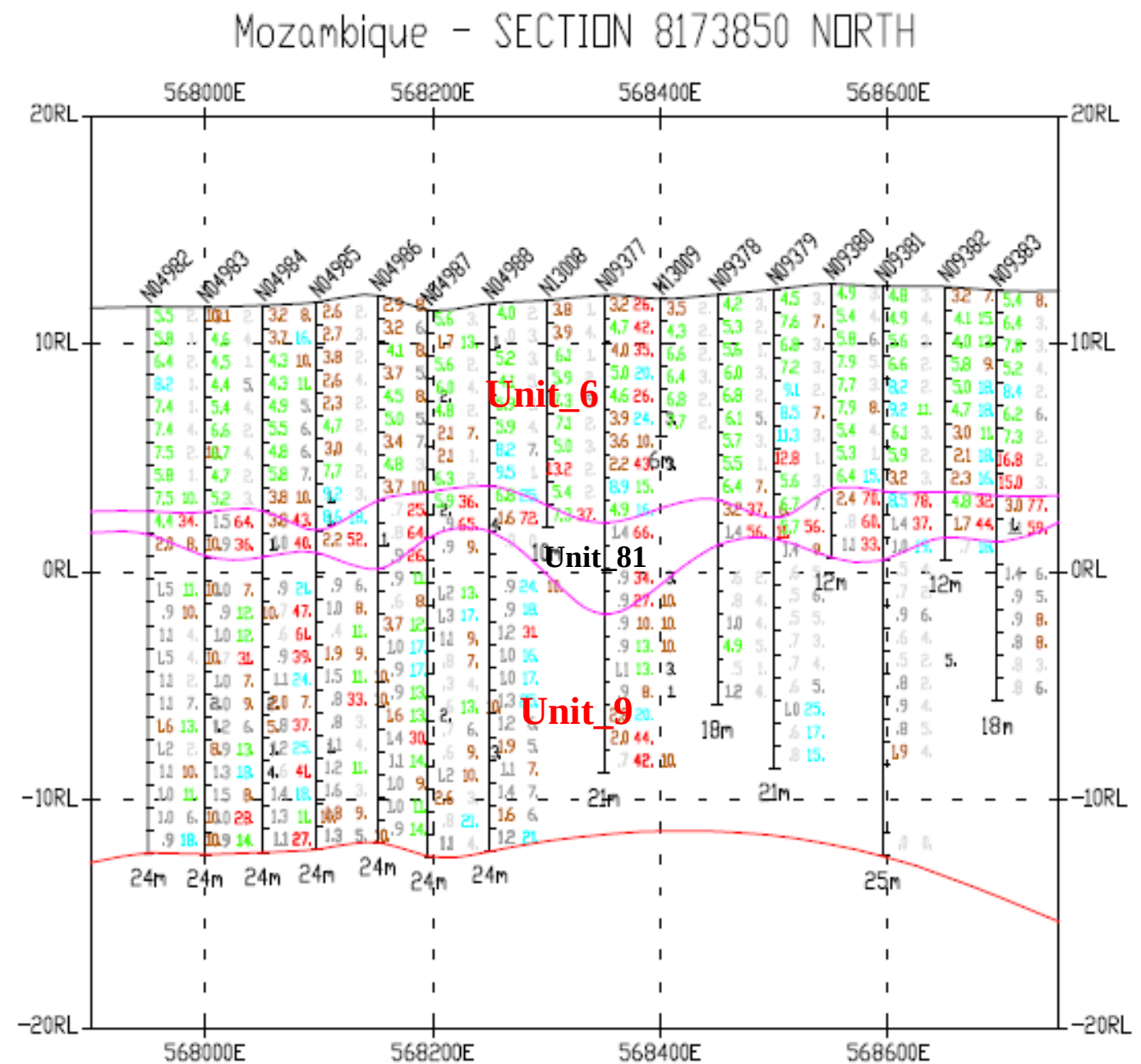
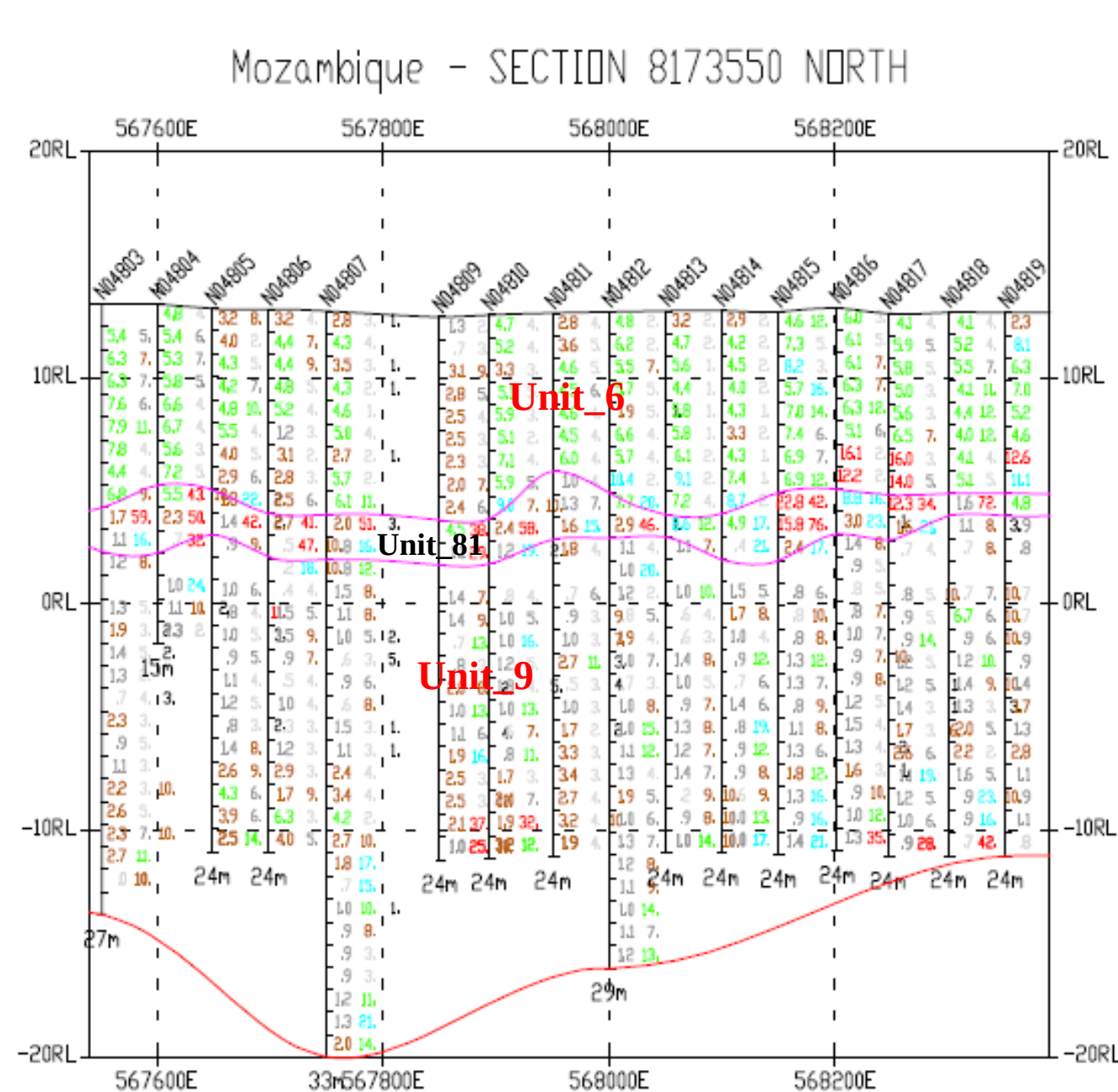
APPENDIX 7: Map shows the spatial distribution of rutile and zircon with depth in the mine paths 2014 and 2015.



APPENDIX 8: Map shows the spatial distribution of high grade accessory heavy minerals with depth in the mine paths.

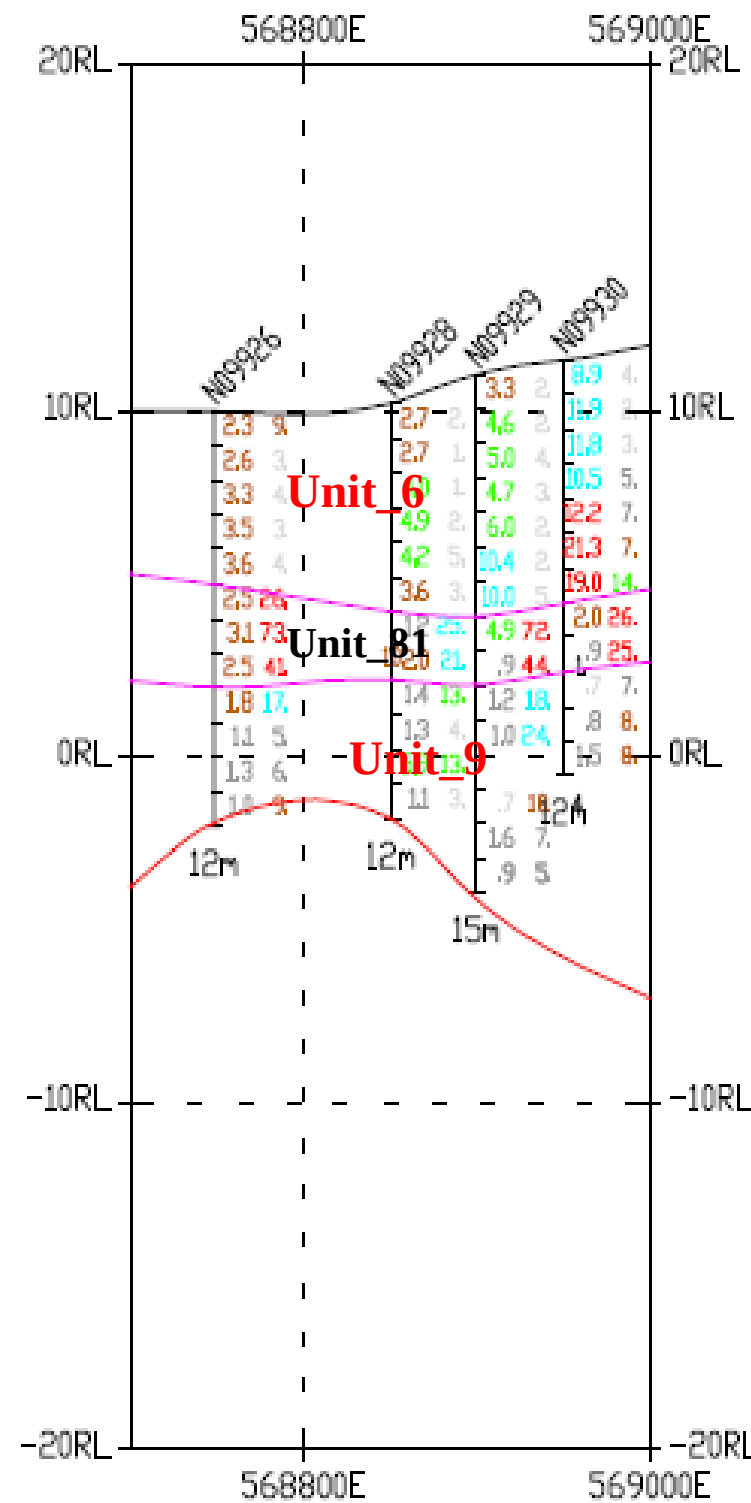


APPENDIX 9: Map shows the spatial distribution of low grade accessory heavy minerals, monazite and quartz with respect to depth in the mine paths.

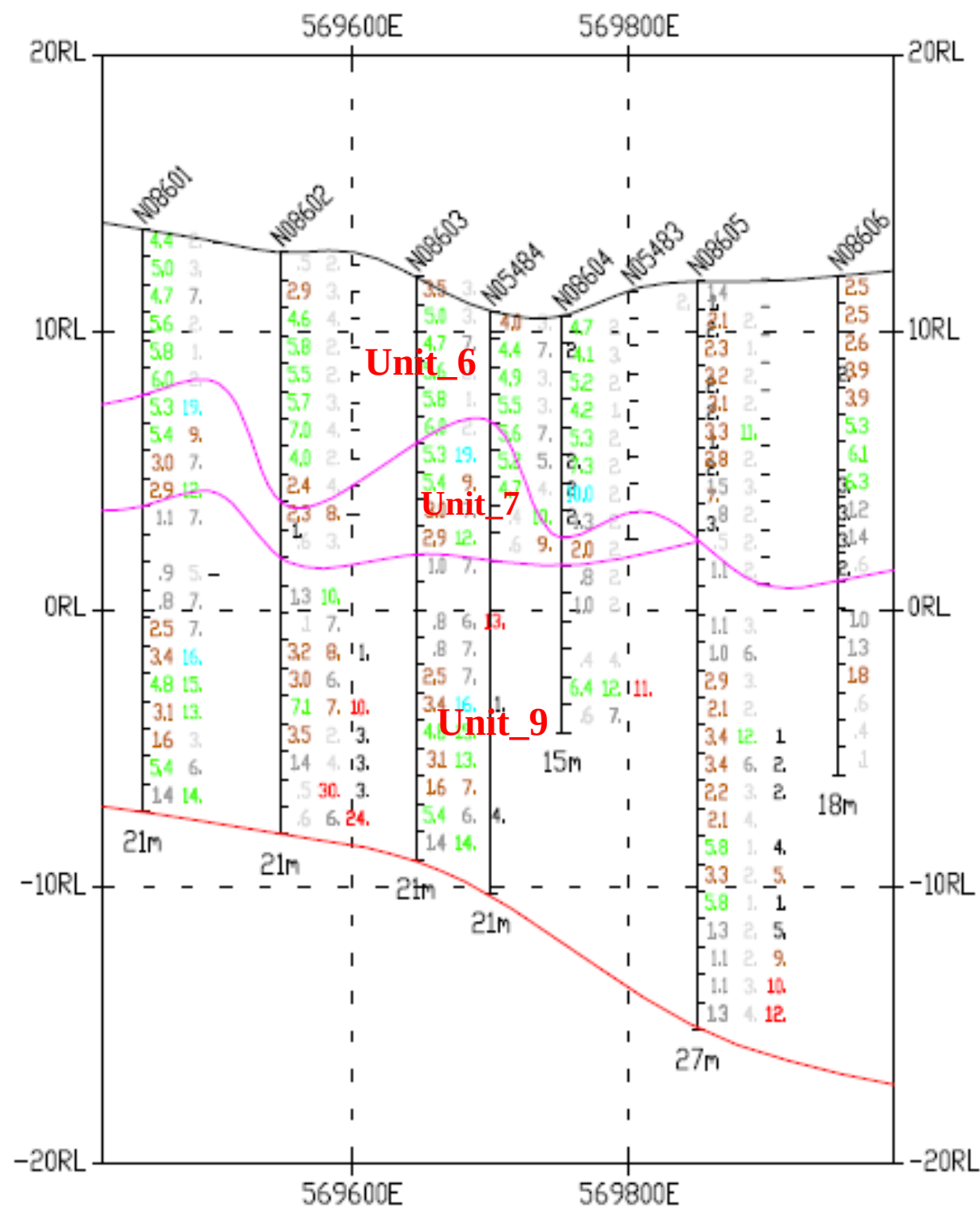


APPENDIX 10: Cross sections 8173550 and 8273850 north, along 2014 mine path at WCP B. First column shows heavy minerals concentration, second is slime and third is oversize. The sections show unit 6 on top, unit 9 at the bottom and unit 81 between the two units. The red colour shows high grade, blue medium and dark low grade.

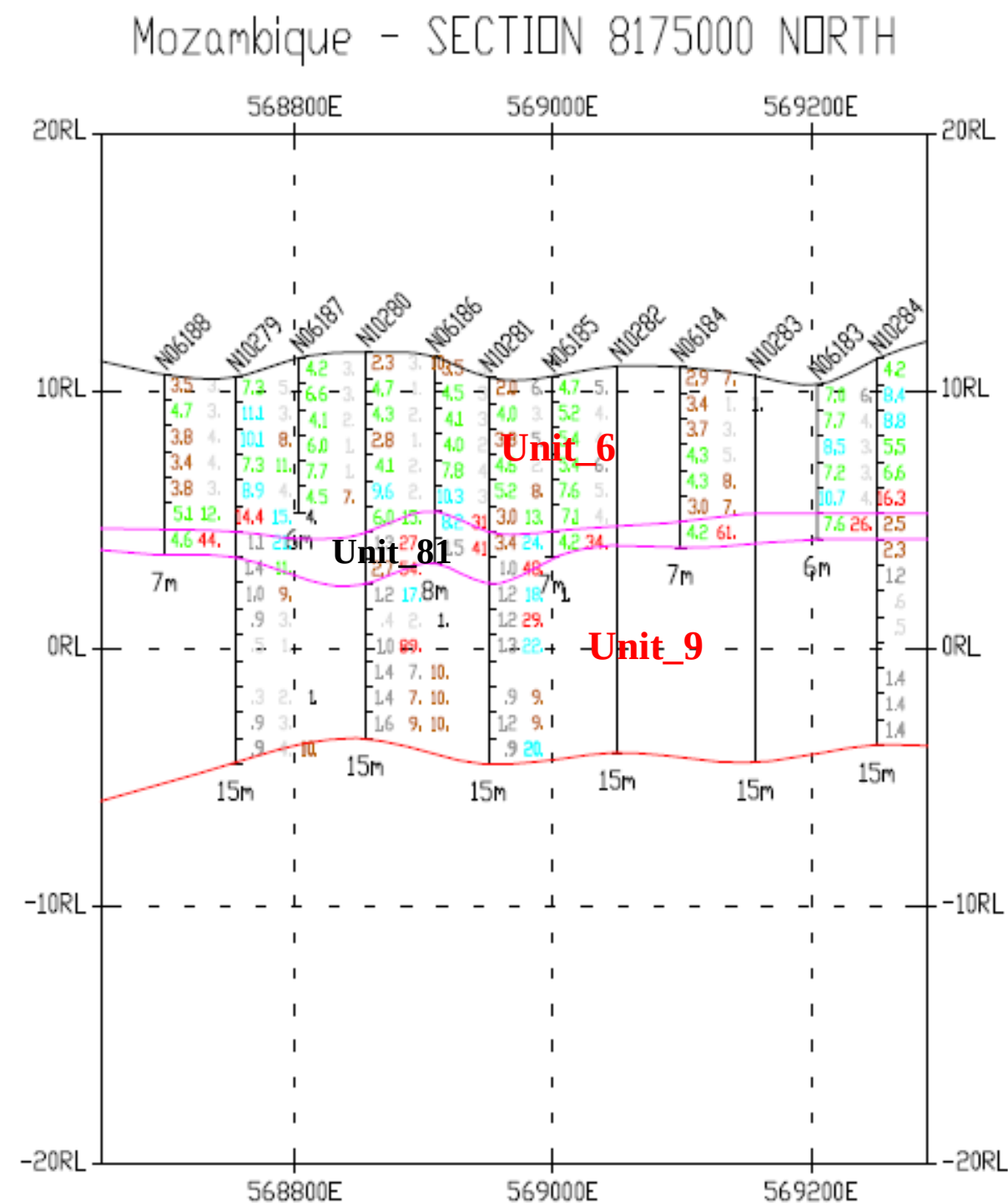
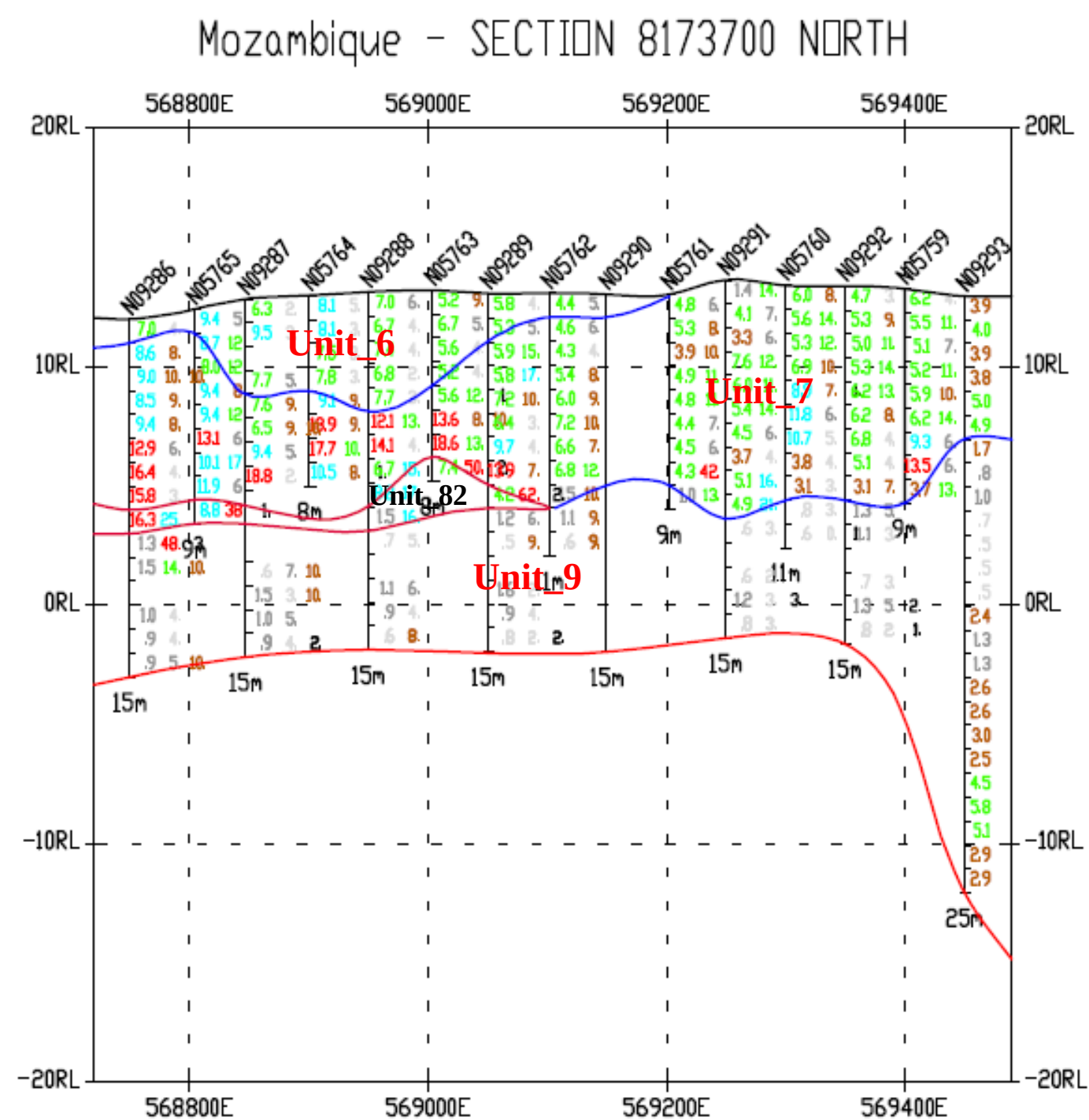
Mozambique - SECTION 8174550



Mozambique - SECTION 8172500 NORTH



APPENDIX 11: Cross sections 8174550_1 along mine path 2014 and 8172500 at mine path 2015. Both Sections show unit 6 on top, unit 9 at the bottom and unit 81 between the two units. East of section 8172500 unit 81 is missing.



APPENDIX 12: Cross sections 8173700 and 8175000 at 2014 mine path, WCP B area. The sections show unit 6 on top, unit 9 at the bottom; section 8173700 in the east unit 6 and 81 are missing.

APPENDIX 13: Table 1, Assays result for heavy minerals concentration, slime and oversize in the mine paths 2014 and 2015, wet concentrate plant B, Namalope deposit.

HoleID	Sample	Hmin	Slime	Ovsz	HoleID	Sample	Hmin	Slime	Ovsz	HoleID	Sample	Hmin	Slime	Ovsz	HoleID	Sample	Hmin	Slime	Ovsz
N08521	N08521_1	2.67	8.2	1.81	N09286	N09286_1	7.04	4.32	0.1	N10202	N10202_1	3.16	1.94	0.15	N09692	N09692_1	3.55	3.8	1.2
N08521	N08521_2	2.85	1.34	1.64	N09286	N09286_2	8.57	7.85	0.24	N10202	N10202_2	3.63	3.81	0.2	N09692	N09692_2	4.43	4.38	0.8
N08521	N08521_3	3.85	2.7	1.62	N09286	N09286_3	8.97	9.88	0.01	N10202	N10202_3	3.96	1.44	0.31	N09692	N09692_3	4.43	4.38	0.8
N08521	N08521_4	3.47	2.83	1.97	N09286	N09286_4	8.51	8.76	0.05	N10202	N10202_4	3.53	0.43	0.32	N09692	N09692_4	5.06	0.7	0.3
N08521	N08521_5	4.53	1.45	1.5	N09286	N09286_5	9.37	7.95	0.05	N10202	N10202_5	4.1	4.03	0.29	N09692	N09692_5	5.29	1.64	0.3
N08521	N08521_6	5.41	2.82	1.32	N09286	N09286_6	12.9	5.84	0.05	N10202	N10202_6	4.48	2.45	0.37	N09692	N09692_6	6.56	1.92	0.3
N08521	N08521_7	5.18	4.25	1.86	N09286	N09286_7	16.4	3.87	0.04	N10202	N10202_7	2.96	35.1	2.26	N09692	N09692_7	4.19	3.22	0.2
N08521	N08521_8	1.32	4.36	2.49	N09286	N09286_8	15.8	3.16	0.02	N10202	N10202_8	5.11	8.87	0.71	N09692	N09692_8	6.57	10.9	0.6
N08521	N08521_9	1.29	3.56	2.23	N09286	N09286_9	16.3	24.9	0.16	N10202	N10202_9	1.02	14.6	1.23	N09692	N09692_9	2.2	22.1	0.1
N08521	N08521_10	1.35	3.24	1.7	N09286	N09286_10	1.34	47.6	3.03	N10202	N10202_10	1.08	12.9	0.12	N09692	N09692_10	4.39	12.6	0
N08521	N08521_11	1.14	2.36	1.05	N09286	N09286_11	1.53	13.8	0.01	N10202	N10202_11	1	4.03	0.68	N09692	N09692_11	0.77	5.55	0
N08521	N08521_12	1.2	3.51	0	N09286	N09286_12	1.67	8.41	0.01	N10202	N10202_12	1.08	3.32	0.73	N09692	N09692_12	0.95	5.42	0.1
N08521	N08521_13	1.36	2.48	4.58	N09286	N09286_13	1.01	4.05	0.15	N10202	N10202_13	1.31	8.14	0	N09694	N09694_1	6.1	2.03	0.2
N08521	N08521_14	3.04	9.97	1.91	N09286	N09286_14	0.87	4.21	0.05	N10202	N10202_14	1.29	4.79	0.17	N09694	N09694_2	6.95	4.24	0.2
N08521	N08521_15	5.32	11.6	0.65	N09286	N09286_15	0.87	5.24	0.01	N10202	N10202_15	1.06	5.67	0	N09694	N09694_3	5.81	4.85	0.1
N08521	N08521_16	3.85	16.7	1.75	N09287	N09287_1	6.34	1.94	0.07	N10204	N10204_1	3.76	2.06	0.4	N09694	N09694_4	5.36	2.22	0.1
N08521	N08521_17	1.54	9.31	0.08	N09287	N09287_2	9.49	3.36	0.05	N10204	N10204_2	5.9	1.6	0.23	N09694	N09694_5	7.5	2.92	0.1
N08521	N08521_18	1.18	14.7	0.24	N09287	N09287_4	7.72	5.09	0.11	N10204	N10204_3	5.35	3.04	0.25	N09694	N09694_6	5.31	5.72	0.2
N08522	N08522_1	2.59	3.38	0.5	N09287	N09287_5	7.64	9.18	0.13	N10204	N10204_4	4.93	5.64	0.34	N09694	N09694_7	16.3	2.68	0
N08522	N08522_2	3.52	2.3	2.16	N09287	N09287_6	6.46	8.83	0.01	N10204	N10204_5	9.31	1.8	0.23	N09694	N09694_8	16.6	1.76	0
N08522	N08522_3	1.42	1.49	1.79	N09287	N09287_7	9.35	5.39	0.05	N10204	N10204_6	9.55	11.4	0.33	N09694	N09694_9	6.21	44	1.7
N08522	N08522_4	5.27	1.46	1.28	N09287	N09287_8	18.8	1.9	0.02	N10204	N10204_7	10.9	7.49	0.1	N09694	N09694_10	2.42	28.8	0.9
N08522	N08522_5	5.1	1.37	1.76	N09287	N09287_12	0.56	6.85	0.01	N10204	N10204_8	1.6	15.7	0.05	N09694	N09694_11	0.97	3.64	0.4
N08522	N08522_6	5.58	4.97	1.39	N09287	N09287_13	1.49	3.16	0.01	N10204	N10204_9	1	2.67	0.61	N09694	N09694_12	1.18	4.31	0.1
N08522	N08522_7	9.08	3.35	1.91	N09287	N09287_14	0.99	5.27	0.97	N10204	N10204_10	0.7	3.16	0.31	N09696	N09696_1	5.5	2.29	0.3
N08522	N08522_8	5.6	4.18	6.34	N09287	N09287_15	0.95	3.65	2.16	N10204	N10204_11	1.04	2.93	0.28	N09696	N09696_2	6.55	3.12	0.2
N08522	N08522_9	1.23	2.12	5.21	N09288	N09288_1	7	6.06	0.45	N10204	N10204_12	0.89	4.58	0.36	N09696	N09696_3	6.51	3.22	0.3
N08522	N08522_10	2.44	1.66	0.77	N09288	N09288_2	6.73	4.16	0.14	N10204	N10204_13	0.66	3.31	0.25	N09696	N09696_4	9.01	2.41	0.3
N08522	N08522_11	0.85	1.54	9.8	N09288	N09288_3	7.38	3.69	0.45	N10204	N10204_14	0.89	3.06	0.28	N09696	N09696_5	6.78	5.28	0.3

N08522	N08522_12	1.36	4.28	0.07	N09288	N09288_4	6.78	1.71	0.33	N10204	N10204_15	1.05	3.36	0.03	N09696	N09696_6	5.33	2.56	0.2
N08522	N08522_13	0.99	5.58	0.42	N09288	N09288_5	7.74	3.09	0.43	N10205	N10205_1	3.81	2.99	0.41	N09696	N09696_7	7.49	1.09	0.1
N08522	N08522_14	1.33	2.57	0.23	N09288	N09288_6	12.1	13.1	0.55	N10205	N10205_2	4.38	1.96	0.19	N09696	N09696_8	4.08	1.44	0.1
N08522	N08522_15	1.37	3.86	0.55	N09288	N09288_7	14.2	3.85	0.31	N10205	N10205_3	4.21	2.45	0.28	N09696	N09696_9	6.35	7.02	0
N08522	N08522_16	4.21	4.34	0.66	N09288	N09288_8	6.66	15	0.12	N10205	N10205_4	4.55	3.25	0.41	N09696	N09696_10	3.03	7.19	0
N08522	N08522_17	1.25	6.09	4.06	N09288	N09288_9	8.19	17.1	0.12	N10205	N10205_5	4.49	11.2	0.28	N09696	N09696_11	1.11	5.12	0
N08522	N08522_18	1.18	5.65	3.78	N09288	N09288_10	1.47	16.4	0.36	N10205	N10205_6	4.37	8.91	0.03	N09696	N09696_12	0.72	4.61	0
N08523	N08523_1	2.01	2.79	1.47	N09288	N09288_11	0.73	4.75	0.11	N10205	N10205_7	3.82	11.1	0.11	N09743	N09743_1	4.46	4.02	0.3
N08523	N08523_2	2.55	0.78	1.32	N09288	N09288_12	0.8	3.95	1.1	N10205	N10205_8	2.43	24.4	0.28	N09743	N09743_2	7.02	4.21	0
N08523	N08523_3	2.85	1.73	1.14	N09288	N09288_13	1.09	5.97	0.41	N10205	N10205_9	1.2	7.27	0.43	N09743	N09743_3	7.62	5.76	0.2
N08523	N08523_4	3.3	1.46	1.32	N09288	N09288_14	0.9	3.8	0.23	N10205	N10205_10	0.85	4.54	0.43	N09743	N09743_4	6.09	8.78	0.3
N08523	N08523_5	3.88	1.35	1	N09288	N09288_15	0.6	8.14	0.07	N10205	N10205_11	0.82	2.66	1.23	N09743	N09743_5	7.42	5.91	0.3
N08523	N08523_6	4.71	1.77	1.22	N09289	N09289_1	5.76	4.37	0.29	N10205	N10205_12	1	2.85	0.33	N09743	N09743_6	6.29	4.74	0.2
N08523	N08523_7	3.55	5.01	0.75	N09289	N09289_2	5.36	5.12	0.27	N10279	N10279_1	7.26	4.6	0.37	N09743	N09743_7	12.4	2.98	0.1
N08523	N08523_8	2.73	1.89	1.75	N09289	N09289_3	5.91	14.6	0.15	N10279	N10279_2	11.1	2.83	0.11	N09743	N09743_8	12.5	6	0
N08523	N08523_9	1.23	2.38	5.89	N09289	N09289_4	5.85	17.3	0.06	N10279	N10279_3	10.2	8.14	0.12	N09743	N09743_9	10.1	77.2	0.3
N08523	N08523_10	2.51	2.33	4.86	N09289	N09289_5	7.16	9.79	0.7	N10279	N10279_4	7.31	11.1	0.4	N09743	N09743_10	2.32	31.4	0
N08523	N08523_11	0.98	1.08	4.32	N09289	N09289_6	6.38	3.15	0.17	N10279	N10279_5	8.85	4.46	0.24	N09743	N09743_11	1.18	10.7	0
N08523	N08523_12	0.34	11.8	14.53	N09289	N09289_7	9.73	4.39	0.07	N10279	N10279_6	14.4	15.1	3.61	N09743	N09743_12	1.23	7.56	0
N08523	N08523_13	1.67	1.89	18.33	N09289	N09289_8	13.9	7.44	0.14	N10279	N10279_7	1.1	20.7	0.78	N09743	N09743_13	0.43	2.71	0
N08523	N08523_14	2.58	1.93	15.71	N09289	N09289_9	4.17	62.4	1.69	N10279	N10279_8	1.39	10.6	0.75	N09743	N09743_14	0.76	2.93	0.1
N08523	N08523_15	2.51	3.51	6.14	N09289	N09289_10	1.25	6.4	0.06	N10279	N10279_9	0.98	8.97	0.11	N09743	N09743_15	0.4	2.07	0.5
N08523	N08523_16	3.62	2.33	0.19	N09289	N09289_11	0.51	9.38	0.15	N10279	N10279_10	0.86	2.59	0.4	N09745	N09745_1	6.31	7.24	0.3
N08523	N08523_17	1.67	7.23	26.74	N09289	N09289_12	1.08	2.47	0.85	N10279	N10279_11	0.49	1.41	0.54	N09745	N09745_2	7.24	5.92	0.2
N08523	N08523_18	7.25	6.82	1.05	N09289	N09289_13	1.57	2.08	0.33	N10279	N10279_12	0.42	1.98	0.49	N09745	N09745_3	6.74	5.13	0.2
N08523	N08523_19	8.04	2.84	0.08	N09289	N09289_14	0.91	4.31	0.07	N10279	N10279_13	0.34	2.42	1.36	N09745	N09745_4	6.41	6.95	0.2
N08523	N08523_20	10.7	0.96	0.5	N09289	N09289_15	0.77	1.99	1.6	N10279	N10279_14	0.88	2.65	0.36	N09745	N09745_5	6.67	27.2	0.3
N08523	N08523_21	5.22	2.54	1.39	N09291	N09291_1	1.36	13.8	0.19	N10279	N10279_15	0.86	3.57	0.01	N09745	N09745_6	4.91	12.9	1.3
N08523	N08523_22	2.79	1.21	0.58	N09291	N09291_2	4.08	6.57	0.29	N10280	N10280_1	2.34	3.14	0.01	N09745	N09745_7	12.8	6.45	0.1
N08523	N08523_23	3.32	0.75	0.34	N09291	N09291_3	3.35	6	0.25	N10280	N10280_2	4.71	0.79	0.05	N09745	N09745_8	12.9	2.7	0
N08523	N08523_24	2.01	2.6	7.65	N09291	N09291_4	7.63	11.9	0.16	N10280	N10280_3	4.27	2.25	0.11	N09745	N09745_9	17.3	7.91	0
N08559	N08559_1	2.13	9.97	0.47	N09291	N09291_5	6.01	11	0.36	N10280	N10280_4	2.82	0.6	0.14	N09745	N09745_10	8.72	37.1	0.4
N08559	N08559_2	2.49	11.7	0.32	N09291	N09291_6	5.44	13.8	0.42	N10280	N10280_5	4.06	1.86	0.21	N09745	N09745_11	1.25	19.3	0.3
N08559	N08559_3	3.11	2.09	0.26	N09291	N09291_7	4.49	6.5	0.43	N10280	N10280_6	9.59	2.32	0.06	N09745	N09745_12	0.78	6.86	0.2

N08559	N08559_4	3.17	4.89	0.5	N09291	N09291_8	3.7	3.75	0.07	N10280	N10280_7	5.99	14.8	0.08	N09745	N09745_13	0.85	5.05	0.4
N08559	N08559_5	3.22	2.95	0.32	N09291	N09291_9	5.13	16.4	0.39	N10280	N10280_8	1.27	27.2	0.07	N09745	N09745_14	0.36	10.5	0.1
N08559	N08559_6	5.31	6.27	0.15	N09291	N09291_10	4.87	21.2	0.06	N10280	N10280_9	2.67	53.8	0.24	N09745	N09745_15	1.13	1.97	0.1
N08559	N08559_7	5.28	2.07	0.23	N09291	N09291_11	0.63	2.63	0.22	N10280	N10280_10	1.26	16.6	0.19	N09744	N09744_1	5.2	4.86	0.3
N08559	N08559_8	1.67	2.42	0.23	N09291	N09291_12	0.58	2.82	0.14	N10280	N10280_11	0.39	1.72	1.33	N09744	N09744_2	4.88	3.9	0.3
N08559	N08559_9	0.86	7.79	0.12	N09291	N09291_13	0.56	2.4	0.56	N10280	N10280_12	0.97	89	0.05	N09744	N09744_3	5.36	7.93	0.3
N08559	N08559_10	0.85	7.01	2.52	N09291	N09291_14	1.22	3.03	3.31	N10280	N10280_13	1.42	6.69	0.01	N09744	N09744_4	6.31	3.5	0.3
N08559	N08559_11	1.05	19.1	0.58	N09291	N09291_15	0.75	2.53	0.8	N10280	N10280_14	1.39	7.48	0.01	N09744	N09744_5	6.82	10.5	0.3
N08559	N08559_12	1.09	9.14	0.41	N09292	N09292_1	4.67	3.31	0.06	N10280	N10280_15	1.56	8.71	0.01	N09744	N09744_6	4.58	9.84	0.3
N08559	N08559_13	4.89	3.93	2.95	N09292	N09292_2	5.34	8.84	0.12	N10284	N10284_1	4.25	2.1	0.46	N09744	N09744_7	4.54	4.56	0.1
N08559	N08559_14	3.33	6.69	1.05	N09292	N09292_3	4.99	11.1	0.26	N10284	N10284_2	8.38	4.69	0.19	N09744	N09744_8	2.59	7.7	0
N08559	N08559_15	6.34	7.61	0.85	N09292	N09292_4	5.32	14	0.13	N10284	N10284_3	8.79	5.9	0.15	N09744	N09744_9	4.51	58.8	0.5
N08559	N08559_16	2.94	5.82	2.87	N09292	N09292_5	6.19	12.8	0.18	N10284	N10284_4	5.47	4.84	0.33	N09744	N09744_10	1.68	33.7	1.4
N08559	N08559_17	0.95	4.85	2.36	N09292	N09292_6	6.24	8.29	0.23	N10284	N10284_5	6.58	10.1	0.4	N09744	N09744_11	1.23	13.2	0.1
N08559	N08559_18	1.33	4.15	0.9	N09292	N09292_7	6.75	3.76	0.68	N10284	N10284_6	16.3	12.1	0.16	N09744	N09744_12	1.01	8.7	0
N08560	N08560_1	2.97	4.96	0.37	N09292	N09292_8	5.05	4.14	0.07	N10284	N10284_7	2.51	58.8	1.18	N09744	N09744_13	0.88	9.73	0.1
N08560	N08560_2	3.28	3.54	0.98	N09292	N09292_9	3.09	7.02	0.08	N10284	N10284_8	2.27	49.4	1.77	N09744	N09744_14	0.57	5.11	0.1
N08560	N08560_3	3.45	3.83	0.94	N09292	N09292_10	1.29	5.48	0.14	N10284	N10284_9	1.18	20.4	3.18	N09744	N09744_15	0.8	4.8	0
N08560	N08560_4	4.28	8.93	0.95	N09292	N09292_11	1.06	3.28	0.04	N10284	N10284_10	0.63	4.37	2.04	N04809	N04809_1	1.32	1.87	0.8
N08560	N08560_5	3.97	3.62	1.39	N09292	N09292_12	0.87	4.32	0.03	N10284	N10284_11	0.48	2.94	1.69	N04809	N04809_2	0.7	3.3	0.7
N08560	N08560_6	5.15	5.99	1.08	N09292	N09292_13	0.68	3.27	0.18	N10284	N10284_12	0.38	2.4	0.2	N04809	N04809_3	3.09	9.19	0.2
N08560	N08560_7	5.7	2.43	1.06	N09292	N09292_14	1.33	5.43	2.11	N10284	N10284_13	1.39	8.98	0.22	N04809	N04809_4	2.77	5.42	0.4
N08560	N08560_8	1.32	2.72	2.25	N09292	N09292_15	0.77	1.96	1.31	N10284	N10284_14	1.44	9.24	0.05	N04809	N04809_5	2.54	3.55	0.9
N08560	N08560_9	1.62	1.12	4.76	N04928	N04928_1	3.47	3.35	0.16	N10284	N10284_15	1.37	9.81	0.04	N04809	N04809_6	2.54	3.21	0.9
N08560	N08560_10	1.39	10.3	0.94	N04928	N04928_2	4.68	3.25	0.13	N09901	N09901_1	7.73	3.13	0.35	N04809	N04809_7	2.33	3	0.7
N08560	N08560_11	1.52	4.56	0.37	N04928	N04928_3	5.38	1.42	0.24	N09901	N09901_2	7.28	3.63	0.21	N04809	N04809_8	2.02	7.03	0.7
N08560	N08560_12	1.09	2.66	1.56	N04928	N04928_4	5.82	3.19	0.18	N09901	N09901_3	6.27	4.42	0.28	N04809	N04809_9	2.39	6.03	0.3
N08560	N08560_13	2.98	4.51	4.77	N04928	N04928_5	6.54	3.54	0.14	N09901	N09901_4	5.24	8.6	0.66	N04809	N04809_10	4.53	38.5	0.5
N08560	N08560_14	1.07	10.5	9.43	N04928	N04928_6	5.49	6.72	0.15	N09901	N09901_5	5.81	11.1	0.38	N04809	N04809_11	1.07	29.5	0.2
N08560	N08560_15	14.6	9.01	0.77	N04928	N04928_7	1.08	9.22	0.09	N09901	N09901_6	14.1	10.3	0.09	N04809	N04809_12	0.96	10.9	0
N08560	N08560_16	14.1	4.61	0.56	N04928	N04928_8	4.91	3.87	0.11	N09901	N09901_7	11	36.9	0.3	N04809	N04809_13	1.37	7.01	0.1
N08560	N08560_17	8.04	4.05	0.03	N04928	N04928_9	4.84	3.61	0.1	N09901	N09901_8	1.26	19.3	0.16	N04809	N04809_14	1.37	9.27	0
N08560	N08560_18	6.97	6.21	0.48	N04928	N04928_10	4.51	63.6	0.14	N09901	N09901_9	0.77	3.46	0.53	N04809	N04809_15	0.7	13.1	0.1
N08560	N08560_19	8.07	3.02	3.25	N04928	N04928_11	1.02	47.4	0.01	N09901	N09901_10	1.11	14.6	0.14	N04809	N04809_16	0.82	3.03	0.7

N08560	N08560_20	10.9	8.28	0.42	N04928	N04928_12	1.22	11.4	0.06	N09901	N09901_11	1.08	6.12	0.04	N04809	N04809_17	1.98	8.42	1.5
N08560	N08560_21	8.13	3	0.83	N04928	N04928_13	1.26	10.2	0.05	N09901	N09901_12	0.98	4.5	0.21	N04809	N04809_18	1.02	13.4	0.3
N08560	N08560_22	3.91	4.95	2.37	N04928	N04928_14	1.32	7.76	0.02	N09901	N09901_13	0.49	2.33	0.31	N04809	N04809_19	1.11	6.28	4.2
N08560	N08560_23	1.66	7.85	1.17	N04928	N04928_15	1.04	8.52	0.22	N09901	N09901_14	0.62	3.36	0.44	N04809	N04809_20	1.85	16.1	0.1
N08560	N08560_24	1.25	32.2	2.51	N04928	N04928_16	1.08	4.98	0.83	N09901	N09901_15	1.02	4.16	0.01	N04809	N04809_21	2.49	3.33	0.4
N08561	N08561_1	2.86	6.92	1.82	N04928	N04928_17	1.21	5.9	0.19	N04876	N04876_1	4.94	17.5	0.13	N04809	N04809_22	2.55	3.23	0
N08561	N08561_2	8.36	0.8	2.11	N04928	N04928_18	1.03	5.86	0.01	N04876	N04876_2	4.23	53.4	0.22	N04809	N04809_23	2.11	36.9	0.1
N08561	N08561_3	3.19	1.2	2.02	N04928	N04928_19	3.12	3.36	0.31	N04876	N04876_3	5.75	10.4	0.05	N04809	N04809_24	1.01	25.2	0
N08561	N08561_4	4.05	1.82	1.68	N04928	N04928_20	2.15	8.34	0.04	N04876	N04876_4	5.27	11.3	0.03	N04803	N04803_2	5.42	5.24	0.1
N08561	N08561_5	3.99	1.64	2.07	N04928	N04928_21	0.92	23.7	0.01	N04876	N04876_5	5.27	11.3	0.03	N04803	N04803_3	6.29	7.47	0.1
N08561	N08561_6	5.53	1.58	1.8	N04928	N04928_22	0.82	18.3	0.01	N04876	N04876_6	5.09	20.2	0.13	N04803	N04803_4	6.28	6.79	0.1
N08561	N08561_7	4.57	12.6	1.21	N04928	N04928_23	0.69	9.88	0.01	N04876	N04876_7	5.74	20.4	0.15	N04803	N04803_5	7.64	5.77	0.1
N08561	N08561_8	1.36	4.88	11.47	N04928	N04928_24	0.9	11	0.01	N04876	N04876_8	5.33	19.9	0.12	N04803	N04803_6	7.87	11.2	0.1
N08561	N08561_9	0.79	1.76	3.36	N04928	N04928_25	0.88	8.22	0.01	N04876	N04876_9	2.34	17.2	0.06	N04803	N04803_7	7.77	4.15	0.1
N08561	N08561_10	1.21	1.8	4.76	N04928	N04928_26	0.95	27.1	0.01	N04876	N04876_10	2.36	75.9	1.36	N04803	N04803_8	4.38	4.46	0.1
N08561	N08561_11	0.34	1.15	3.5	N04928	N04928_27	4.82	10.8	0.01	N04876	N04876_11	1.05	44.4	0.15	N04803	N04803_9	6.84	8.75	0.1
N08561	N08561_12	1.35	3.58	0.15	N04930	N04930_1	2.28	13.6	0.17	N04876	N04876_12	0.76	40	0.04	N04803	N04803_10	1.68	58.6	0.6
N08561	N08561_13	1.34	1.9	0.67	N04930	N04930_2	3.44	2.26	0.12	N04876	N04876_13	0.42	70.3	0.12	N04803	N04803_11	1.12	16.5	0
N08561	N08561_14	1.71	1.79	0.14	N04930	N04930_3	3.46	2.01	0.2	N04876	N04876_14	1.01	29.3	0.08	N04803	N04803_12	1.22	8.35	0
N08561	N08561_15	2.78	3	0.13	N04930	N04930_4	3.56	10.6	0.31	N04876	N04876_15	1.05	28.9	0.02	N04803	N04803_13	1.29	4.83	0
N08561	N08561_16	1.85	6.02	0.49	N04930	N04930_5	5.13	2.05	0.31	N04876	N04876_16	0.47	14.1	0.96	N04803	N04803_14	1.29	4.51	0.8
N08561	N08561_17	5.04	0.85	4.98	N04930	N04930_6	3.35	4.16	0.18	N04876	N04876_17	0.61	18.9	0.95	N04803	N04803_15	1.86	2.7	1.9
N08561	N08561_18	2.31	2.51	1.89	N04930	N04930_7	1.65	3.83	0.22	N04876	N04876_18	0.7	33.5	16.8	N04803	N04803_16	1.36	4.92	2.2
N08562	N08562_1	2.56	1.13	1.48	N04930	N04930_8	0	2.31	0.3	N04876	N04876_19	1.01	37.7	2.08	N04803	N04803_17	1.32	2.5	0.1
N08562	N08562_2	2.6	2.1	0.04	N04930	N04930_9	3.58	19.6	0.23	N04876	N04876_20	1.25	38.6	0.42	N04803	N04803_18	0.69	3.59	2.9
N08562	N08562_3	3.44	1.56	1.21	N04930	N04930_10	1.71	33.3	0.28	N04876	N04876_21	0.98	35.3	0.07	N04803	N04803_19	2.32	3.07	0.2
N08562	N08562_4	3.82	3.17	1.77	N04930	N04930_11	1.35	29.2	0.07	N04876	N04876_22	0.71	41.1	0.58	N04803	N04803_20	0.89	4.62	0.7
N08562	N08562_5	4.15	3.1	2.56	N04930	N04930_12	1.4	7.77	0.01	N04876	N04876_23	0.69	46.9	0.05	N04803	N04803_21	1.11	2.85	0.1
N08562	N08562_6	4.68	9.78	0.71	N04930	N04930_13	1.07	3.05	0.09	N04876	N04876_24	0.6	57.2	0	N04803	N04803_22	2.16	3.03	0
N08562	N08562_7	5.53	6.84	2.39	N04930	N04930_14	1.15	3.18	0.09	N04876	N04876_25	0.84	45.4	0	N04803	N04803_23	2.57	4.62	0
N08562	N08562_8	1.55	8.07	1.62	N04930	N04930_15	0.85	2.76	0.67	N04876	N04876_26	0.88	38.4	0.01	N04803	N04803_24	2.31	6.69	0
N08562	N08562_9	1.05	1.22	7.34	N04930	N04930_16	0.48	3.09	0.61	N04876	N04876_27	0.81	46.8	0.01	N04803	N04803_25	2.7	10.6	0.2
N08562	N08562_10	0.92	8.45	1.42	N04930	N04930_17	1.37	2.39	0.54	N04876	N04876_28	0.5	62.6	0.08	N04803	N04803_26	0.04	9.77	0.1
N08562	N08562_11	0.5	1.89	7.67	N04930	N04930_18	2.54	6.92	3.64	N04876	N04876_29	0.71	61.9	0	N04805	N04805_1	3.24	7.95	0.2

N08562	N08562_12	0.6	3.59	10.38	N04930	N04930_19	1.23	6.34	0.36	N04876	N04876_30	1.17	44	1.23	N04805	N04805_2	3.99	1.74	0.3
N08562	N08562_13	9.04	1.63	13.29	N04930	N04930_20	1.27	6.63	0.02	N04878	N04878_1	2.36	3.38	0.44	N04805	N04805_3	4.27	4.55	0.2
N08562	N08562_14	1.97	4.25	1.54	N04930	N04930_21	1.44	4.86	0.01	N04878	N04878_2	2.32	1.62	0.24	N04805	N04805_4	4.23	6.98	0.2
N08562	N08562_15	2.35	7.05	0.55	N04930	N04930_22	0.91	5.13	0.01	N04878	N04878_3	3.66	5.38	0.3	N04805	N04805_5	4.79	10.3	0.4
N08562	N08562_16	1.26	10.4	0.33	N04930	N04930_23	0.96	6.88	0.01	N04878	N04878_4	5.38	2.95	0.17	N04805	N04805_6	5.54	3.77	0.3
N08562	N08562_17	1.51	5.57	0.45	N04930	N04930_24	1.16	5.36	0.01	N04878	N04878_5	6.64	1.87	0.16	N04805	N04805_7	3.99	4.55	0.3
N08562	N08562_18	1.78	13.4	0.85	N04930	N04930_25	0.79	4.46	0.01	N04878	N04878_6	4.97	4.79	0.37	N04805	N04805_8	2.94	5.77	0.6
N08601	N08601_1	4.43	2.39	0.45	N04930	N04930_26	1.09	4.41	0.01	N04878	N04878_7	14.3	5.06	0.31	N04805	N04805_9	1.84	22.1	1.6
N08601	N08601_2	4.99	2.73	0.24	N04930	N04930_27	1.2	5.08	0.01	N04878	N04878_8	5.64	8.58	0.2	N04805	N04805_10	1.4	42	2.4
N08601	N08601_3	4.68	6.96	0.25	N04932	N04932_1	2.97	2.78	0.09	N04878	N04878_9	2.48	31.4	0.17	N04805	N04805_11	0.95	8.54	0.1
N08601	N08601_4	5.62	1.94	0.43	N04932	N04932_2	4.28	2.55	0.02	N04878	N04878_10	8.12	30.7	0.05	N04805	N04805_12	1.08	11.5	0
N08601	N08601_5	5.85	0.57	0.25	N04932	N04932_3	5.19	1.36	0.1	N04878	N04878_11	4.63	19	0.03	N04805	N04805_13	1.03	5.77	0.1
N08601	N08601_6	5.97	1.69	0.38	N04932	N04932_4	5.31	1.5	0.24	N04878	N04878_12	1.14	7.34	0.01	N04805	N04805_14	0.83	3.96	11
N08601	N08601_7	5.33	18.7	0.25	N04932	N04932_5	5.76	2.29	0.18	N04878	N04878_13	0.73	6.17	0.03	N04805	N04805_15	1.04	4.55	3.4
N08601	N08601_8	5.45	9.34	0.28	N04932	N04932_6	4.19	7.54	0.12	N04878	N04878_14	0.71	12.7	0.05	N04805	N04805_16	0.92	5.35	1
N08601	N08601_9	2.96	6.72	0.25	N04932	N04932_7	5.48	4.74	0.15	N04878	N04878_15	0	99	0.01	N04805	N04805_17	1.09	3.9	0.6
N08601	N08601_10	2.87	12.3	0.4	N04932	N04932_8	5.68	5.58	0.08	N04878	N04878_16	1.73	8.32	0.02	N04805	N04805_18	1.2	4.73	0.1
N08601	N08601_11	1.14	6.73	0.52	N04932	N04932_9	6.03	8.91	0.22	N04878	N04878_17	1.61	3.68	1.09	N04805	N04805_19	0.8	3.02	2.2
N08601	N08601_12	0.77	5.58	0.36	N04932	N04932_10	4.09	36.2	0.09	N04878	N04878_18	1.71	5.63	0.54	N04805	N04805_20	1.42	8.2	0.6
N08601	N08601_13	0.94	4.58	0.5	N04932	N04932_11	0.86	36.1	0.08	N04878	N04878_19	1.01	7.55	0.16	N04805	N04805_21	2.57	9.35	0.1
N08601	N08601_14	0.83	6.85	0.68	N04932	N04932_12	0.98	13.1	0	N04878	N04878_20	1.14	7.43	0.04	N04805	N04805_22	4.26	5.81	0.4
N08601	N08601_15	2.52	6.88	0.9	N04932	N04932_13	1.32	3.91	0	N04878	N04878_21	1.34	9.85	0.17	N04805	N04805_23	3.94	5.95	0.2
N08601	N08601_16	3.4	16	1.17	N04932	N04932_14	0.99	6.26	0.1	N04878	N04878_22	0.97	7.57	0.01	N04805	N04805_24	2.46	13.6	0.1
N08601	N08601_17	4.81	14.8	0.56	N04932	N04932_15	1.28	12.8	0.02	N04878	N04878_23	1.5	7.2	0.02	N09616	N09616_1	7.41	5.52	0.1
N08601	N08601_18	3.13	12.5	0.96	N04932	N04932_16	0.99	11.4	0.41	N04878	N04878_24	1.15	10.1	0.01	N09616	N09616_2	7.72	2.65	0
N08601	N08601_19	1.61	3.17	0.47	N04932	N04932_17	1.35	14.6	3.85	N04878	N04878_25	1.02	12.4	0.01	N09616	N09616_3	7.45	11.1	0.3
N08601	N08601_20	5.43	5.57	4.49	N04932	N04932_18	2.69	7.01	6.47	N04878	N04878_26	0.89	6.66	0.01	N09616	N09616_4	6.68	2.94	0.2
N08601	N08601_21	1.43	14.2	0.5	N04932	N04932_19	1.75	9.97	0.23	N04878	N04878_27	0.89	6.66	0.01	N09616	N09616_5	8.47	4.97	0
N08602	N08602_1	0.53	1.58	13.84	N04932	N04932_20	1.44	5.32	0.1	N04880	N04880_1	2.49	6.97	0.18	N09616	N09616_6	7.45	18.5	0.3
N08602	N08602_2	2.91	3.11	0.92	N04932	N04932_21	1.46	3.06	0.03	N04880	N04880_2	3.28	5.75	0.13	N09616	N09616_7	23.5	3.41	0.1
N08602	N08602_3	4.63	4.25	0.35	N04932	N04932_22	1.32	4.3	0	N04880	N04880_3	3.84	3.9	0.33	N09616	N09616_8	20.2	2.75	0.4
N08602	N08602_4	5.79	2.21	0.3	N04932	N04932_23	1.6	3.8	0	N04880	N04880_4	4.34	12.5	0.22	N09616	N09616_9	11.8	30.9	0
N08602	N08602_5	5.51	1.69	0.21	N04932	N04932_24	0.81	13.7	0	N04880	N04880_5	5.13	8.25	0.39	N09616	N09616_10	11.1	14.7	0
N08602	N08602_6	5.67	3.36	0.01	N04932	N04932_25	1.02	4.54	0	N04880	N04880_6	5.91	9.67	0.27	N09616	N09616_11	1.86	21.3	0

N08602	N08602_7	7.01	4.31	0.3	N04932	N04932_26	1.33	9.04	0	N04880	N04880_7	3.71	9.81	0.16	N09616	N09616_12	0	4.42	0.1
N08602	N08602_8	4.02	1.82	0.15	N04932	N04932_27	0.86	7.03	0.02	N04880	N04880_8	2.57	7	0.09	N09618	N09618_1	4.73	4.77	1.5
N08602	N08602_9	2.37	4.42	0.26	N04934	N04934_1	4.13	18.2	0.1	N04880	N04880_9	2.81	11.7	0.09	N09618	N09618_2	6.5	2.09	0.2
N08602	N08602_10	2.29	8.38	0.42	N04934	N04934_2	5.32	67.2	0.15	N04880	N04880_10	1.31	22	0.84	N09618	N09618_3	6.5	2.09	0.2
N08602	N08602_11	0.63	2.66	1.68	N04934	N04934_3	4.62	22.9	0.17	N04880	N04880_11	0.94	14.9	0.02	N09618	N09618_4	6.93	2.09	0.2
N08602	N08602_12	0.88	9.51	0.32	N04934	N04934_4	3.75	1.98	0.45	N04880	N04880_12	0.95	15.2	0.01	N09618	N09618_5	7.74	3.57	0.2
N08602	N08602_13	1.29	10.4	0.2	N04934	N04934_5	4.08	21.5	1.03	N04880	N04880_13	0.92	13.9	0.19	N09618	N09618_6	12.7	1.63	0.1
N08602	N08602_14	0.08	6.87	0.15	N04934	N04934_6	4.76	4.73	0.23	N04880	N04880_14	1.06	19.6	0.01	N09618	N09618_7	12.7	1.92	0.1
N08602	N08602_15	3.23	8.05	1.1	N04934	N04934_7	0.82	16.5	0.06	N04880	N04880_15	0.92	16.2	0.58	N09618	N09618_8	16.6	1.76	0
N08602	N08602_16	2.98	5.57	0.37	N04934	N04934_8	12.6	9.9	0.05	N04880	N04880_16	1.22	6.92	0.07	N09618	N09618_9	6.21	44	1.7
N08602	N08602_17	7.15	7.16	10.14	N04934	N04934_9	5.7	3.91	0.68	N04880	N04880_17	1.49	5.35	0.24	N09618	N09618_10	2.42	28.8	0.9
N08602	N08602_18	3.49	2.32	2.52	N04934	N04934_10	2.86	53.8	0.24	N04880	N04880_18	1.77	4.53	0.89	N09618	N09618_11	2.66	23.4	0.8
N08602	N08602_19	1.35	3.53	2.82	N04934	N04934_11	1.07	21	0.43	N04880	N04880_19	1	24.2	0.03	N09618	N09618_12	1.44	11.2	0.1
N08602	N08602_20	0.49	29.8	2.74	N04934	N04934_12	1.46	20.1	0.02	N04880	N04880_20	1.1	17.9	0.06	N09665	N09665_1	3.13	2.96	0.4
N08602	N08602_21	0.66	6.05	23.89	N04934	N04934_13	0.53	12.1	0	N04880	N04880_21	1.22	11.4	0.05	N09665	N09665_2	6.15	4.86	0.1
N08603	N08603_1	3.54	2.95	0.36	N04934	N04934_14	1.47	23.5	0.02	N04880	N04880_22	0.75	36.1	0.02	N09665	N09665_3	5.99	3.8	0.1
N08603	N08603_2	4.99	2.73	0.24	N04934	N04934_15	0.81	8.51	0.04	N04880	N04880_23	0.67	37	0.02	N09665	N09665_4	5.41	3.59	0.3
N08603	N08603_3	4.68	6.96	0.25	N04934	N04934_16	0.99	7	0.12	N04880	N04880_24	0.66	43.6	0.01	N09665	N09665_5	6.88	3.36	0.4
N08603	N08603_4	5.62	1.94	0.43	N04934	N04934_17	1.96	9.29	3.02	N04880	N04880_25	0.41	72.1	0.02	N09665	N09665_6	5.8	5.08	0.3
N08603	N08603_5	5.85	0.57	0.25	N04934	N04934_18	4.35	12.5	0.1	N04880	N04880_26	0.71	37.2	0.17	N09665	N09665_7	4.43	1.58	0.2
N08603	N08603_6	5.97	1.69	0.38	N04934	N04934_19	0.98	9.92	0.05	N04880	N04880_27	0.57	61.9	0.09	N09665	N09665_8	11.9	1.77	0
N08603	N08603_7	5.33	18.7	0.25	N04934	N04934_20	1.09	72.3	0.01	N04880	N04880_28	0.61	63.3	0.07	N09665	N09665_9	9.77	42.3	0.1
N08603	N08603_8	5.45	9.34	0.28	N04934	N04934_21	1.47	13.1	0.04	N04880	N04880_29	0.71	48.8	0.1	N09665	N09665_10	1.71	37.6	0
N08603	N08603_9	2.96	6.72	0.25	N04934	N04934_22	1.35	9.45	0.05	N04880	N04880_30	1.01	57	0.6	N09665	N09665_11	2.36	25.5	0.1
N08603	N08603_10	2.87	12.3	0.4	N04934	N04934_23	1.67	5.16	0.25	N09850	N09850_1	3.37	1.78	0.32	N09665	N09665_12	0.87	5.84	0.1
N08603	N08603_11	0.99	6.59	0.38	N04934	N04934_24	1.12	9.11	0.02	N09850	N09850_2	4.15	2.09	0.14	N09665	N09665_13	1.29	7.5	0
N08603	N08603_12	11.9	8.33	0.2	N04934	N04934_25	1.45	6.91	0.01	N09850	N09850_3	5.09	5.65	0.24	N09665	N09665_14	1.25	6.47	0.1
N08603	N08603_13	0.84	6.02	13.11	N04934	N04934_26	1.2	7.56	0.03	N09850	N09850_4	5.54	2.31	0.72	N09665	N09665_15	0.57	4.85	0.2
N08603	N08603_14	0.83	6.85	0.68	N04934	N04934_27	1.54	12.3	0.01	N09850	N09850_5	5.83	2.33	0.07	N09666	N09666_1	5.38	2.83	0.1
N08603	N08603_15	2.52	6.88	0.9	N04936	N04936_1	4.35	1.82	0.24	N09850	N09850_6	10.4	3.31	0.04	N09666	N09666_2	5.94	3.59	0.2
N08603	N08603_16	3.4	16	1.17	N04936	N04936_2	4.97	2.02	0.3	N09850	N09850_7	6.72	6.69	0.04	N09666	N09666_3	6.06	2.93	0.2
N08603	N08603_17	4.81	14.8	0.56	N04936	N04936_3	5.33	1.61	0.36	N09850	N09850_8	1.55	29.3	0.04	N09666	N09666_4	6.18	3.26	0.2
N08603	N08603_18	3.13	12.5	0.96	N04936	N04936_4	5.59	1.49	0.23	N09850	N09850_9	1.41	7.22	0.05	N09666	N09666_5	7.61	3.05	0.2
N08603	N08603_19	1.61	7.06	0.47	N04936	N04936_5	5.7	1.49	0.39	N09850	N09850_10	1.21	8.56	0.07	N09666	N09666_6	6.25	3.83	0.2

N08603	N08603_20	5.43	5.57	4.49	N04936	N04936_6	6.18	1.29	0.7	N09850	N09850_11	1.22	4.45	0.01	N09666	N09666_7	5.96	1.61	0.3
N08603	N08603_21	1.43	14.2	0.5	N04936	N04936_7	10.6	2.21	0.19	N09850	N09850_12	1.13	5.04	0.07	N09666	N09666_8	10.1	2.42	0
N08604	N08604_1	4.68	1.64	1.38	N04936	N04936_8	20	1.58	0.09	N09852	N09852_1	4.97	1.42	0.31	N09666	N09666_9	6.31	0.96	0
N08604	N08604_2	4.08	3.4	2.35	N04936	N04936_9	11.8	10.6	0.19	N09852	N09852_2	6.25	1.43	0.28	N09666	N09666_10	6.52	2.63	0
N08604	N08604_3	5.16	1.54	2.14	N04936	N04936_10	9.44	34.1	0.15	N09852	N09852_3	6.23	3.01	0.06	N09666	N09666_11	1.82	23	0
N08604	N08604_4	4.17	1.35	2.76	N04936	N04936_11	1.61	10.2	0.13	N09852	N09852_4	6.62	1.74	0.45	N09666	N09666_12	0.9	4.36	0.2
N08604	N08604_5	5.29	2.06	2.69	N04936	N04936_12	1.22	5.22	0.23	N09852	N09852_5	8.78	2.58	0.42	N09666	N09666_13	1.13	3.41	0.2
N08604	N08604_6	7.31	2.43	2.88	N04936	N04936_13	1.52	20.5	0.03	N09852	N09852_6	6.84	32.6	0.14	N09666	N09666_14	0.9	3.79	0
N08604	N08604_7	10.1	1.59	6.47	N04936	N04936_14	1.29	8.48	0.03	N09852	N09852_7	7.86	36	0.39	N09666	N09666_15	1.06	4.14	0.1
N08604	N08604_8	1.29	1.85	20.1	N04936	N04936_15	0.84	9.62	0.1	N09852	N09852_8	1.31	23.7	0.46	N09667	N09667_1	4.65	6.52	0.3
N08604	N08604_9	1.95	2.15	8.88	N04936	N04936_16	0.71	6.17	0.59	N09852	N09852_9	1.5	18	0.54	N09667	N09667_2	4.78	8.13	0.2
N08604	N08604_10	0.81	1.98	1.57	N04936	N04936_17	0.42	4.24	3.28	N09852	N09852_10	1.25	6.1	0.05	N09667	N09667_3	4.74	11.7	0.2
N08604	N08604_11	1.02	2.29	0.24	N04936	N04936_18	1.19	3.75	2.97	N09852	N09852_11	1.46	3.42	0.05	N09667	N09667_4	4.9	10.9	0.2
N08604	N08604_12	1.22	0.52	0.08	N04936	N04936_19	2.07	25.7	0.05	N09852	N09852_12	1.08	2.77	0.06	N09667	N09667_5	4.96	10.6	0.4
N08604	N08604_13	0.4	3.74	0.28	N04936	N04936_20	2	19.2	0.1	N09899	N09899_1	5.49	2.76	0.13	N09667	N09667_6	5.27	8.14	0.7
N08604	N08604_14	6.38	12.3	10.87	N04936	N04936_21	1.83	5.53	0.11	N09899	N09899_2	7.68	2.73	0.18	N09667	N09667_7	5.32	5.59	0.2
N08604	N08604_15	0.63	6.66	0.17	N04936	N04936_22	1.84	4.39	0.12	N09899	N09899_3	6.54	2.29	0.39	N09667	N09667_8	12.1	2.65	0
N08605	N08605_1	1.41	15.5	1.55	N04936	N04936_23	1.63	9.68	0.11	N09899	N09899_4	10	5.21	0.18	N09667	N09667_9	7.32	18.3	0.3
N08605	N08605_2	2.06	1.9	1.61	N04936	N04936_24	1.27	9.58	0.03	N09899	N09899_5	21.6	12.6	0.07	N09667	N09667_10	1.62	34.2	0
N08605	N08605_3	2.33	1.32	1.47	N04936	N04936_25	1.14	5.7	0.1	N09899	N09899_6	8.89	12.7	0.02	N09667	N09667_11	1.18	5.83	0.2
N08605	N08605_4	3.16	2.3	1.18	N04936	N04936_26	1.28	9.99	0.05	N09899	N09899_7	2.01	21.6	0.01	N09667	N09667_12	0.6	2.48	0.1
N08605	N08605_5	3.09	2.19	0.95	N04936	N04936_27	1.16	15.5	0.11	N09899	N09899_8	7.35	63.7	0.26	N09667	N09667_13	0.6	4.71	0
N08605	N08605_6	3.3	11.4	0.78	N09305	N09305_1	3.03	1.87	0.7	N09899	N09899_9	1.15	36.9	0.36	N09667	N09667_14	0.69	4.71	0
N08605	N08605_7	2.79	1.87	1.54	N09305	N09305_2	3.21	2.8	0.35	N09899	N09899_10	0.8	9.39	0.01	N09667	N09667_15	0.78	11.3	0
N08605	N08605_8	1.55	2.56	1.22	N09305	N09305_3	4.08	4.69	0.14	N09899	N09899_11	1.83	5.01	0.01	N04815	N04815_1	4.62	11.6	0.1
N08605	N08605_9	0.85	2.36	3.46	N09305	N09305_4	4.05	5.19	0.28	N09899	N09899_12	0.98	7.8	0.01	N04815	N04815_2	7.3	4.84	0.2
N08605	N08605_10	0.54	1.54	4.56	N09305	N09305_5	4.5	3.3	0.33	N09899	N09899_13	0.99	3.77	2.41	N04815	N04815_3	8.25	3.18	0.2
N08605	N08605_11	1.14	1.8	4.97	N09305	N09305_6	3.44	5.82	0.2	N09899	N09899_14	0.42	3.47	1.19	N04815	N04815_4	5.73	16.4	0.1
N08605	N08605_12	1.33	3.44	0.09	N09305	N09305_7	4.74	3.35	0.15	N09899	N09899_15	0.47	3.57	0.79	N04815	N04815_5	7.02	14	0.2
N08605	N08605_13	1.07	2.97	1.15	N09305	N09305_8	5.85	14.5	0.37	N09900	N09900_1	3.84	4.12	0.23	N04815	N04815_6	7.41	6.29	0.4
N08605	N08605_14	0.96	6.44	0.05	N09305	N09305_9	7.3	71.9	1.86	N09900	N09900_2	4.56	3.3	0.07	N04815	N04815_7	6.95	6.88	0.1
N08605	N08605_15	2.87	3.22	0.11	N09305	N09305_10	3.3	64.6	4.65	N09900	N09900_3	4.09	3.08	0.27	N04815	N04815_8	6.93	12.5	0.1
N08605	N08605_16	2.09	2.05	0.08	N09305	N09305_11	1.86	17.3	0.13	N09900	N09900_4	3.71	4.23	0.25	N04815	N04815_9	22.8	42.4	0.9
N08605	N08605_17	3.37	11.6	1.12	N09305	N09305_12	0.43	6.7	0.27	N09900	N09900_5	5.16	6.95	0.19	N04815	N04815_10	15.8	76.2	0.4

N08605	N08605_18	3.42	6.36	1.82	N09305	N09305_13	0.54	5.06	0.28	N09900	N09900_6	12.3	9.1	0.03	N04815	N04815_11	2.4	16.9	0.9
N08605	N08605_19	2.25	3.42	2.31	N09305	N09305_14	0.54	5.06	0.28	N09900	N09900_7	18.2	8.44	0.01	N04815	N04815_12	1.52	9.3	0.2
N08605	N08605_20	2.12	3.77	0.05	N09305	N09305_15	0.58	8.7	0.18	N09900	N09900_8	6.79	30.6	0.01	N04815	N04815_13	0.82	6.28	0.1
N08605	N08605_21	5.83	1.33	3.97	N09305	N09305_16	0.72	4.42	4.09	N09900	N09900_9	0.77	7.86	0.3	N04815	N04815_14	0.78	9.55	0.1
N08605	N08605_22	3.28	2.41	5.21	N09305	N09305_17	0.6	4.27	0.12	N09900	N09900_10	0.9	8.64	0.04	N04815	N04815_15	0.83	8.32	0.1
N08605	N08605_23	5.85	0.96	1.43	N09305	N09305_18	0.83	17.2	3.85	N09900	N09900_11	0.69	8.97	0.08	N04815	N04815_16	1.29	11.6	0.1
N08605	N08605_24	1.29	2.15	4.74	N09305	N09305_19	0.83	8.15	1.54	N09900	N09900_12	0.96	9.34	0.04	N04815	N04815_17	1.3	6.88	0.5
N08605	N08605_25	1.14	1.88	9.04	N09305	N09305_20	1.45	8.15	0.29	N09900	N09900_13	0.91	3.76	0.07	N04815	N04815_18	0.83	8.57	0.1
N08605	N08605_26	1.08	2.97	10.41	N09305	N09305_21	0.61	4	0.13	N09900	N09900_14	1.07	5.04	0.13	N04815	N04815_19	1.07	8.14	0.5
N08605	N08605_27	1.28	3.87	11.52	N09305	N09305_22	1.27	3.25	0.09	N09900	N09900_15	0.72	12	0.05	N04815	N04815_20	1.28	5.58	0.3
N08606	N08606_1	2.53	4.29	1.85	N09305	N09305_23	1.37	5.12	0.08	N09901	N09901_1	7.73	3.13	0.35	N04815	N04815_21	1.79	12.3	0.1
N08606	N08606_2	2.45	2.43	1.79	N09305	N09305_24	1.4	4.47	0.04	N09901	N09901_2	7.28	3.63	0.21	N04815	N04815_22	1.29	15.5	0.4
N08606	N08606_3	2.61	8.83	1.74	N09306	N09306_1	4.82	9.57	0.12	N09901	N09901_3	6.27	4.42	0.28	N04815	N04815_23	0.91	16.2	0.7
N08606	N08606_4	3.9	2.22	1.29	N09306	N09306_2	5.57	4.8	0.13	N09901	N09901_4	5.24	8.6	0.66	N04815	N04815_24	1.35	20.6	0.1
N08606	N08606_5	3.9	8.67	1.5	N09306	N09306_3	5.35	9.43	0.11	N09901	N09901_5	5.81	11.1	0.38	N04817	N04817_1	4.07	4.28	0.2
N08606	N08606_6	5.32	6.07	0.76	N09306	N09306_4	5.64	2.7	0.23	N09901	N09901_6	14.1	10.3	0.09	N04817	N04817_2	5.88	5.38	0.2
N08606	N08606_7	6.05	7.59	1	N09306	N09306_5	5.7	6.63	0.35	N09901	N09901_7	11	36.9	0.3	N04817	N04817_3	5.83	4.65	0.1
N08606	N08606_8	6.29	4.22	1.75	N09306	N09306_6	6.06	7.85	0.21	N09901	N09901_8	1.26	19.3	0.16	N04817	N04817_4	5.04	3.13	0.2
N08606	N08606_9	1.23	5.74	3.11	N09306	N09306_7	7.71	4.34	0.1	N09901	N09901_9	0.77	3.46	0.53	N04817	N04817_5	5.6	3.03	0.1
N08606	N08606_10	1.41	4.34	2.38	N09306	N09306_8	6.1	7.51	0.14	N09901	N09901_10	1.11	14.6	0.14	N04817	N04817_6	6.47	7.26	0.2
N08606	N08606_11	0.65	3.66	9.03	N09306	N09306_9	5.91	23.3	0.16	N09901	N09901_11	1.08	6.12	0.04	N04817	N04817_7	16	2.74	0.2
N08606	N08606_12	0.75	12.5	8.72	N09306	N09306_10	2.99	46.1	0.1	N09901	N09901_12	0.98	4.5	0.21	N04817	N04817_8	14	5.21	0.3
N08606	N08606_13	1.04	6.89	0.35	N09306	N09306_11	0.99	33	1.07	N09901	N09901_13	0.49	2.33	0.31	N04817	N04817_9	12.3	34	0.1
N08606	N08606_14	1.33	5.15	0.32	N09306	N09306_12	0.73	12.1	0.16	N09901	N09901_14	0.62	3.36	0.44	N04817	N04817_10	1.62	21	0.8
N08606	N08606_15	1.76	3.22	1.52	N09306	N09306_13	1.68	3.94	0.6	N09901	N09901_15	1.02	4.16	0.01	N04817	N04817_11	0.74	4.39	0.1
N08606	N08606_16	0.57	4.21	14.24	N09306	N09306_14	0.93	5.11	0	N09926	N09926_1	2.28	9.15	0.31	N04817	N04817_12	0.67	10.8	0
N08606	N08606_17	0.39	0.66	4.19	N09306	N09306_15	0.68	3.39	0.32	N09926	N09926_2	2.57	2.75	0.39	N04817	N04817_13	0.81	4.67	0
N08606	N08606_18	0.1	2.3	15.88	N09306	N09306_16	1.05	4.41	0.06	N09926	N09926_3	3.29	3.87	0.34	N04817	N04817_14	0.94	4.91	0.1
N08649	N08649_1	5.27	3.31	0.28	N09306	N09306_17	1.13	9.22	0.13	N09926	N09926_4	3.48	2.86	0.24	N04817	N04817_15	0.93	13.6	0
N08649	N08649_2	5.75	4.62	0.27	N09306	N09306_18	1.18	10.9	0.41	N09926	N09926_5	3.63	4.25	0.28	N04817	N04817_16	1.23	4.71	0.2
N08649	N08649_3	6	4.08	0.21	N09306	N09306_19	0.7	6.55	0.01	N09926	N09926_6	2.54	26.1	0.13	N04817	N04817_17	1.17	5.07	1.3
N08649	N08649_4	5.47	12.6	0.35	N09306	N09306_20	1.64	11.4	0	N09926	N09926_7	3.1	72.8	0.16	N04817	N04817_18	1.35	2.87	1.3
N08649	N08649_5	6.48	12.1	0.23	N09306	N09306_21	0.02	0	1.06	N09926	N09926_8	2.53	41.2	0.42	N04817	N04817_19	1.68	2.76	5.9
N08649	N08649_6	6.34	13.9	0.34	N09306	N09306_22	1.13	9.62	0	N09926	N09926_9	1.85	16.9	0.15	N04817	N04817_20	2.58	5.8	0.5

N08649	N08649_7	6.32	4.13	0.14	N09306	N09306_23	0.99	12.2	0	N09926	N09926_10	1.13	5.06	0.02	N04817	N04817_21	1.07	19.4	0
N08649	N08649_8	8.28	16.4	0.05	N09306	N09306_24	0.86	14.2	0	N09926	N09926_11	1.3	5.54	0.11	N04817	N04817_22	1.17	5.4	0
N08649	N08649_9	1.51	16	0.9	N09306	N09306_25	0.99	16.4	0	N09926	N09926_12	0.97	8.86	0.04	N04817	N04817_23	1.05	5.6	0.2
N08649	N08649_10	0.75	2.36	3.2	N09306	N09306_26	0.88	11.6	0	N09928	N09928_1	2.74	2.09	0.1	N04817	N04817_24	0.93	28.4	0.1
N08649	N08649_11	0.55	2.88	0.65	N09306	N09306_27	0.99	10.2	0	N09928	N09928_2	2.72	1.36	0.08	N04811	N04811_1	2.83	4.07	0.3
N08649	N08649_12	0.48	3.15	0.47	N09306	N09306_28	0.85	10	0	N09928	N09928_3	4	1.17	0.15	N04811	N04811_2	3.62	4.87	0.2
N08649	N08649_13	0.57	2.25	0.03	N09306	N09306_29	1.04	13.6	0	N09928	N09928_4	4.9	1.64	0.27	N04811	N04811_3	4.58	4.62	0.2
N08649	N08649_14	1.78	4.61	0.18	N09306	N09306_30	0.91	21.2	0.03	N09928	N09928_5	4.17	4.62	0.07	N04811	N04811_4	4.54	5.84	0.1
N08649	N08649_15	6.1	9.45	0.34	N09308	N09308_1	2.8	4.87	0.32	N09928	N09928_6	3.57	3.32	0.08	N04811	N04811_5	4.59	3.55	0.4
N08650	N08650_1	5.38	3.58	0.15	N09308	N09308_2	3.81	15.1	0.4	N09928	N09928_7	1.24	24.8	0.14	N04811	N04811_6	4.5	3.61	0.2
N08650	N08650_2	5.08	4.89	0.28	N09308	N09308_3	3.9	11	0.16	N09928	N09928_8	2.06	21.1	0.21	N04811	N04811_7	6.04	4.13	0.2
N08650	N08650_3	5.64	4.87	0.36	N09308	N09308_4	5.56	11.4	0.35	N09928	N09928_9	1.42	13.3	0.02	N04811	N04811_8	1.04	4.14	0.3
N08650	N08650_4	6.35	1.44	0.39	N09308	N09308_5	4.15	8.94	0.19	N09928	N09928_10	1.33	3.87	0.05	N04811	N04811_9	1.32	6.82	0.1
N08650	N08650_5	6.99	10.8	0.34	N09308	N09308_6	4.04	17.9	0.36	N09928	N09928_11	5.91	13.3	0.1	N04811	N04811_10	1.65	15	0.4
N08650	N08650_6	6.53	8.71	0.27	N09308	N09308_7	4.74	12.4	0.28	N09928	N09928_12	1.16	2.8	0.08	N04811	N04811_11	1.8	4.24	0.1
N08650	N08650_7	8.27	4.15	0.24	N09308	N09308_8	5.55	4.88	0.06	N09930	N09930_1	8.86	4.41	0.61	N04811	N04811_12	0.58	7.04	0.1
N08650	N08650_8	11.6	3.71	0.49	N09308	N09308_9	3.82	15.1	0.15	N09930	N09930_2	11.9	1.95	0.09	N04811	N04811_13	0.69	6.01	0
N08650	N08650_9	6.66	2.52	0.25	N09308	N09308_10	1.45	44.2	0.11	N09930	N09930_3	11.8	2.84	0.27	N04811	N04811_14	0.86	3.08	9.1
N08650	N08650_10	0.63	2.84	1.26	N09308	N09308_11	0.72	17.5	0.1	N09930	N09930_4	10.5	5.22	0.39	N04811	N04811_15	1.05	2.98	6.6
N08650	N08650_11	0.82	22.6	1.89	N09308	N09308_12	0.6	18.2	0.24	N09930	N09930_5	12.2	6.8	0.18	N04811	N04811_16	2.73	11.4	3.1
N08650	N08650_12	2.01	5.47	1.01	N09308	N09308_13	0.48	14.3	2.09	N09930	N09930_6	21.3	7.09	0.05	N04811	N04811_17	0.55	3.14	3.5
N08650	N08650_13	0.77	3.44	0.71	N09308	N09308_14	0.76	13.7	0.21	N09930	N09930_7	19	13.7	0.1	N04811	N04811_18	0.99	3.31	0.5
N08650	N08650_14	1.34	3.24	0.6	N09308	N09308_15	0.74	14.3	0.16	N09930	N09930_8	1.95	26.3	0.05	N04811	N04811_19	1.73	1.72	2.3
N08650	N08650_15	3.33	2.53	10.63	N09308	N09308_16	0.9	12.4	0.16	N09930	N09930_9	0.9	25.1	0.06	N04811	N04811_20	3.35	2.93	0.1
N08651	N08651_1	4.94	2.56	0.48	N09308	N09308_17	1	19.4	0.71	N09930	N09930_10	0.73	6.78	0.07	N04811	N04811_21	3.39	2.89	0
N08651	N08651_2	5.46	1.68	0.6	N09308	N09308_18	1.01	14.2	0.1	N09930	N09930_11	0.84	7.85	0.14	N04811	N04811_22	2.73	4.07	0
N08651	N08651_3	6.18	2.19	0.55	N09308	N09308_19	1.06	22.6	0.08	N09930	N09930_12	1.46	8.07	0.2	N04811	N04811_23	3.15	3.85	0
N08651	N08651_4	7.5	2.63	0.38	N09308	N09308_20	0.72	37.3	0.01	N09975	N09975_1	9.77	2.08	0.11	N04811	N04811_24	1.87	3.67	0.4
N08651	N08651_5	7.4	4.36	0.68	N09308	N09308_21	0.64	46.6	0.03	N09975	N09975_2	9.72	3.52	0.1	N09169	N09169_1	4.76	2.9	0.2
N08651	N08651_6	7.06	9.79	0.69	N09308	N09308_22	0.65	37.3	0.02	N09975	N09975_3	9.69	3.48	0.18	N09169	N09169_2	5.12	3.22	0.2
N08651	N08651_7	7.89	3.39	0.78	N09308	N09308_23	0.89	38.8	0.04	N09975	N09975_4	10.1	9.7	0.1	N09169	N09169_3	5.08	2.94	0.2
N08651	N08651_8	8.29	2.08	0.52	N09308	N09308_24	0.8	29.5	0.09	N09975	N09975_5	8.01	11.2	0.16	N09169	N09169_4	5.63	1.82	0.4
N08651	N08651_9	4.3	2.1	0.46	N09310	N09310_1	5.17	9.12	0.05	N09975	N09975_6	11.3	10.9	0.32	N09169	N09169_5	6.36	3.35	0.2
N08651	N08651_10	2.54	6.87	1.38	N09310	N09310_2	5.86	6.7	0.23	N09975	N09975_9	1.24	22	0.06	N09169	N09169_6	8.25	11	0.2

N08651	N08651_11	0.59	3	1.47	N09310	N09310_3	5.64	13.5	0.05	N09975	N09975_10	1.25	3.56	0.15	N09169	N09169_7	8.22	4.27	0
N08651	N08651_12	1.33	5.9	0.3	N09310	N09310_4	5.38	8.09	0.18	N09975	N09975_11	0.8	3.56	0.08	N09169	N09169_8	7.22	2.63	0.1
N08651	N08651_14	1.9	7.83	1.12	N09310	N09310_5	5.56	14.8	0.18	N09975	N09975_12	0.88	2.05	0.15	N09169	N09169_9	4.25	16.7	0
N08651	N08651_15	0.16	7.1	2.83	N09310	N09310_6	7.23	14.5	0.11	N09975	N09975_13	0.91	3.58	0.03	N09169	N09169_10	2.83	13.7	0
N08652	N08652_1	4.29	0.48	0.33	N09310	N09310_7	12.6	3.94	0.4	N09975	N09975_14	0.38	1.78	0.21	N09169	N09169_11	1.44	25.9	0
N08652	N08652_2	5.6	0.03	0.36	N09310	N09310_8	5.8	6.72	0.21	N09975	N09975_15	0.45	1.9	0.32	N09169	N09169_12	0.97	5.19	0.4
N08652	N08652_3	5.14	3.11	0.92	N09310	N09310_9	5.1	10.6	0.24	N09976	N09976_1	4.82	1.76	0.07	N09169	N09169_13	0.71	24.4	0.4
N08652	N08652_4	5.41	0.76	0.66	N09310	N09310_10	3.86	42.6	1.18	N09976	N09976_2	5.97	2.58	0.2	N09169	N09169_14	0.85	12.7	0
N08652	N08652_5	6.5	1.73	0.6	N09310	N09310_11	0.98	38.1	0.08	N09976	N09976_3	5.51	1.43	0.22	N09169	N09169_15	1.01	6.42	0
N08652	N08652_6	6.92	6.25	0.42	N09310	N09310_12	0.93	37.3	0.08	N09976	N09976_4	4.63	1.79	0.27	N09170	N09170_1	5.72	2.9	0.5
N08652	N08652_7	8.43	2.1	0.35	N09310	N09310_13	0.91	13.2	1.48	N09976	N09976_5	7.06	8.31	0.25	N09170	N09170_2	8.04	3.42	0.2
N08652	N08652_8	8.74	2.18	0.16	N09310	N09310_14	0.6	16.9	1.67	N09976	N09976_6	8.35	16.4	0.05	N09170	N09170_3	7.82	4.24	0.2
N08652	N08652_9	5.73	1.54	0.19	N09310	N09310_15	0.6	20.1	0.62	N09976	N09976_7	9.22	13.7	0.03	N09170	N09170_4	4.54	10.5	0.3
N08652	N08652_10	0.68	15.4	6.22	N09310	N09310_16	0.59	18	0.34	N09976	N09976_8	1.43	34.1	0.22	N09170	N09170_5	6.3	6.51	0.5
N08652	N08652_11	0.47	4.03	1.11	N09310	N09310_17	0.71	25.7	0.04	N09976	N09976_9	1.22	28.6	0.86	N09170	N09170_6	4.68	4.64	0.3
N08652	N08652_12	1.61	4.13	0.13	N09310	N09310_18	0.98	12.7	0.2	N09976	N09976_10	1.02	16.8	0.18	N09170	N09170_7	12.6	7.63	0.1
N08652	N08652_13	0.84	2.17	0.48	N09310	N09310_19	0.83	36.9	0.37	N09976	N09976_11	1.03	7.31	0.01	N09170	N09170_8	12.2	3.66	0.1
N08652	N08652_14	0.74	7.34	7.47	N09310	N09310_20	0.99	29.4	0.08	N09976	N09976_12	0.96	6.01	0.42	N09170	N09170_9	5.85	15.4	0.3
N08652	N08652_15	4.13	4.19	1.23	N09310	N09310_21	0.62	41.1	0.06	N09976	N09976_13	0.18	6.15	3.76	N09170	N09170_10	9.38	56.8	0
N08652	N08652_16	7.03	4.68	4.73	N04982	N04982_1	5.52	2.08	0.01	N09976	N09976_14	0.28	3.48	3.37	N09170	N09170_11	1.29	30.9	0.2
N08652	N08652_17	7.31	8.96	2.89	N04982	N04982_2	5.83	1.18	0.09	N09976	N09976_15	0.33	5.32	2.5	N09170	N09170_12	0.76	39.3	0.3
N08652	N08652_18	7.22	1.39	5.11	N04982	N04982_3	6.43	1.75	0.1	N09977	N09977_1	4.47	4.07	0.47	N09170	N09170_13	0.71	9.51	1.2
N08652	N08652_21	2.08	2.15	5.72	N04982	N04982_4	8.2	0.75	0.14	N09977	N09977_2	3.14	3.23	0.01	N09170	N09170_14	0.47	22.7	0.3
N08653	N08653_1	2.89	0.84	1.43	N04982	N04982_5	7.37	0.56	0.12	N09977	N09977_3	3.46	4.2	0.24	N09170	N09170_15	0.36	5.16	7.1
N08653	N08653_2	3.42	1.5	1.62	N04982	N04982_6	7.4	3.5	0.11	N09977	N09977_4	3.77	6.98	0.52	N09171	N09171_1	10.1	3.53	0.2
N08653	N08653_3	3.85	1.3	1.72	N04982	N04982_7	7.54	2.36	0.01	N09977	N09977_5	5.45	13.1	0.11	N09171	N09171_2	11.7	3.1	0.1
N08653	N08653_4	3.94	0.87	1.58	N04982	N04982_8	5.78	1.38	0.02	N09977	N09977_6	4.07	6.08	0.51	N09171	N09171_3	9.49	3.28	0.1
N08653	N08653_5	5.47	1.86	1.14	N04982	N04982_9	7.47	10.4	0.02	N09977	N09977_7	3.36	37.8	0.01	N09171	N09171_4	9.69	6.33	0.2
N08653	N08653_6	5.21	6.61	0.62	N04982	N04982_10	4.44	34.3	0.21	N09977	N09977_8	4.09	17.5	0.5	N09171	N09171_5	10.6	9.57	0.3
N08653	N08653_7	4.9	3.05	3.9	N04982	N04982_11	2.06	7.74	0.01	N09977	N09977_9	1.72	19.3	0.51	N09171	N09171_6	11.9	13.9	0.1
N08653	N08653_8	2.92	1.55	16.5	N04982	N04982_12	1.5	7.38	0.01	N09977	N09977_10	0.56	3.47	0.82	N09171	N09171_7	16.1	4.97	0
N08653	N08653_9	1.74	4.5	1.63	N04982	N04982_13	1.47	11.3	0.01	N09977	N09977_11	0.9	6.24	0.08	N09171	N09171_8	24	4.37	0.1
N08653	N08653_10	0.82	2.42	2.15	N04982	N04982_14	0.94	9.66	0.63	N09977	N09977_12	0.77	8.06	0.01	N09171	N09171_9	15.9	10.4	0.1

APPENDIX 14: Table 2, XRF magnetic fraction results of mine paths 2014 and 2015 at wet concentrate plant B.

MA_ID	TiO2	Fe2O3	Al2O3	Cr2O3	SiO2	V2O5	CaO	MgO	MnO	Nb2O5	ZrO2	HfO2	P2O5	K2O	CeO2	SnO2	PbO	Th	U
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	[ppm]	[ppm]	[ppm]
RBS02	50.15	37.68	4.33	0.22	3.13	0.12	0.107	0.3	1.54	0.04	0.088	0	0.073	0	0.154	0.006	144	442	21
RBS01	51.83	38.66	3.1	0.217	2.33	0.12	0.073	0.25	1.55	0.04	0.077	0	0.118	0	0.207	0.006	45	624	21
RBS03	50.53	38.72	3.74	0.204	2.8	0.13	0.096	0.25	1.55	0.05	0.13	0	0.078	0	0.156	0.008	119	414	16
RBS05	50.34	37.64	4.81	0.216	3.58	0.11	0.131	0.31	1.52	0.05	0.057	0	0.066	0	0.126	0.009	176	339	20
RBS08	50.89	38.3	3.67	0.238	2.74	0.11	0.107	0.62	1.44	0.04	0.061	0	0.232	0	0.183	0	90	506	28
RBS13	51.12	37.76	3.8	0.228	2.85	0.11	0.097	0.6	1.43	0.04	0.071	0	0.195	0	0.166	0.004	151	447	24
RBS12	50.34	39.2	3.27	0.22	2.43	0.12	0.108	0.53	1.47	0.04	0.045	0	0.212	0	0.162	0.002	101	462	24
RBS14	50.34	38.32	3.55	0.234	2.76	0.12	0.126	0.62	1.44	0.04	0.104	0	0.202	0.002	0.161	0.007	137	445	21
RBS15	49.63	38.72	4.02	0.229	3.23	0.1	0.122	0.61	1.44	0.04	0.077	0	0.218	0	0.191	0.004	138	480	23
RBS16	52.07	37.88	3.22	0.283	2.54	0.12	0.222	0.53	1.47	0.04	0.062	0	0.295	0.006	0.244	0.008	74	634	21
RBS17	50.02	38.31	3.82	0.237	2.82	0.12	0.156	0.65	1.49	0.04	0.053	0	0.211	0	0.181	0.005	115	475	25
RBS11	51.23	40.33	2.83	0.211	2.21	0.1	0.096	0.5	1.54	0.12	0.128	0	0.207	0.011	0.174	0.008	33	516	25
RBS10	50.25	42.56	2.24	0.219	1.9	0.11	0.008	0.46	0.36	0.11	0.53	0	0.263	0	0.194	0.001	0	594	25
RBS09	52.15	39.28	2.67	0.24	2.31	0.12	0.104	0.57	1.62	0.12	0.192	0	0.202	0.012	0.153	0.005	136	501	48
RBS07	52.1	39.61	2.92	0.217	2.38	0.13	0.089	0.57	1.67	0.13	0.414	0	0.2	0	0.149	0.009	93	526	31
RBS06	52.5	38.9	3.33	0.247	2.69	0.13	0.109	0.65	1.62	0.13	0.115	0	0.177	0	0.132	0.006	190	410	37
RBS04	51.45	39.11	3.02	0.216	2.5	0.12	0.095	0.59	1.54	0.12	0.248	0	0.182	0.023	0.157	0.006	21	485	50

APPENDIX 15: Table 3, XRF Non-magnetic fraction results of mine paths 2014 and 2015 at wet concentrate plant B.

MA ID	TiO2	Fe2O3	Al2O3	Cr2O3	SiO2	V2O5	CaO	MgO	MnO	Nb2O5	ZrO2	HfO2	P2O5	K2O	CeO2	SnO2	PbO	Th	U
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	[ppm]	[ppm]	[ppm]
RBS02	15.99	1.38	16.81	0	31.9	0	0.03	0.23	0.03	0	32.97	0.65	0.09	0	0	0.01	0	242	259
RBS01	16.26	0.63	16.79	0	29.57	0	0.05	0.25	0.03	0	34.86	0.67	0.16	0	0.01	0.02	0	381	274
RBS03	15.68	1.51	20.71	0	29.26	0	0.05	0.31	0.03	0	31.15	0.58	0.1	0	0	0.01	0	253	236
RBS05	15.71	1.51	20.82	0	29.11	0	0.04	0.33	0.03	0	31.17	0.63	0.1	0	0	0.01	0	259	243
RBS08	15.43	1.39	14.91	0	30.33	0	0.03	0.2	0.03	0	35.54	0.69	0.12	0	0	0.02	0	325	262
RBS13	16.39	1.04	18.15	0	29.28	0	0.04	0.22	0.04	0	33.54	0.66	0.09	0	0.01	0.02	0	192	236
RBS12	19.66	0.89	18.01	0	28.67	0	0.05	0.25	0.03	0	30.96	0.59	0.14	0	0	0.01	0	299	243
RBS14	15.75	0.45	16.67	0	30.55	0	0.04	0.2	0.03	0	34.7	0.69	0.08	0	0	0.01	0	180	250
RBS15	15.08	0.48	17.25	0	32.1	0	0.04	0.2	0.03	0	32.99	0.63	0.09	0	0	0.01	0	212	245
RBS16	15.64	0.4	15	0	28.18	0	0.05	0.15	0.03	0	37.61	0.75	0.1	0	0	0.02	0	166	284
RBS17	13.39	10.69	15.99	0	27.3	0	0.05	0.16	0.1	0	29.22	0.57	0.1	0	0.02	0.01	0	99	228
RBS11	13.88	0.55	19.13	0	29.25	0	0.04	0.5	0.01	0	33	0.64	0.13	0	0.22	0.01	0	84	249
RBS10	15.37	0.44	13.51	0	29.86	0	0.01	0.39	0.02	0	36.47	0.75	0.08	0	1.49	0.05	0	122	267
RBS09	16.08	0.53	14.77	0	32.18	0	0.02	0.5	0.02	0	32.12	0.72	0.09	0	1.57	0.06	0	187	248
RBS07	17.24	0.55	12.03	0	29.65	0	0.02	0.38	0.02	0	35.04	0.81	0.1	0	1.72	0.07	0	317	309
RBS06	17.18	0.66	14.03	0	30.27	0	0.02	0.53	0.02	0	33.08	0.74	0.1	0	1.7	0.06	0	304	294
RBS04	15.32	0.49	13.46	0	30.7	0	0.01	0.43	0.02	0	35.73	0.74	0.08	0	1.49	0.06	0	177	273