A SUMMARY OF THE SOLID MINERAL OCCURRENCES AND MINERAL POTENTIAL OF TANZANIA

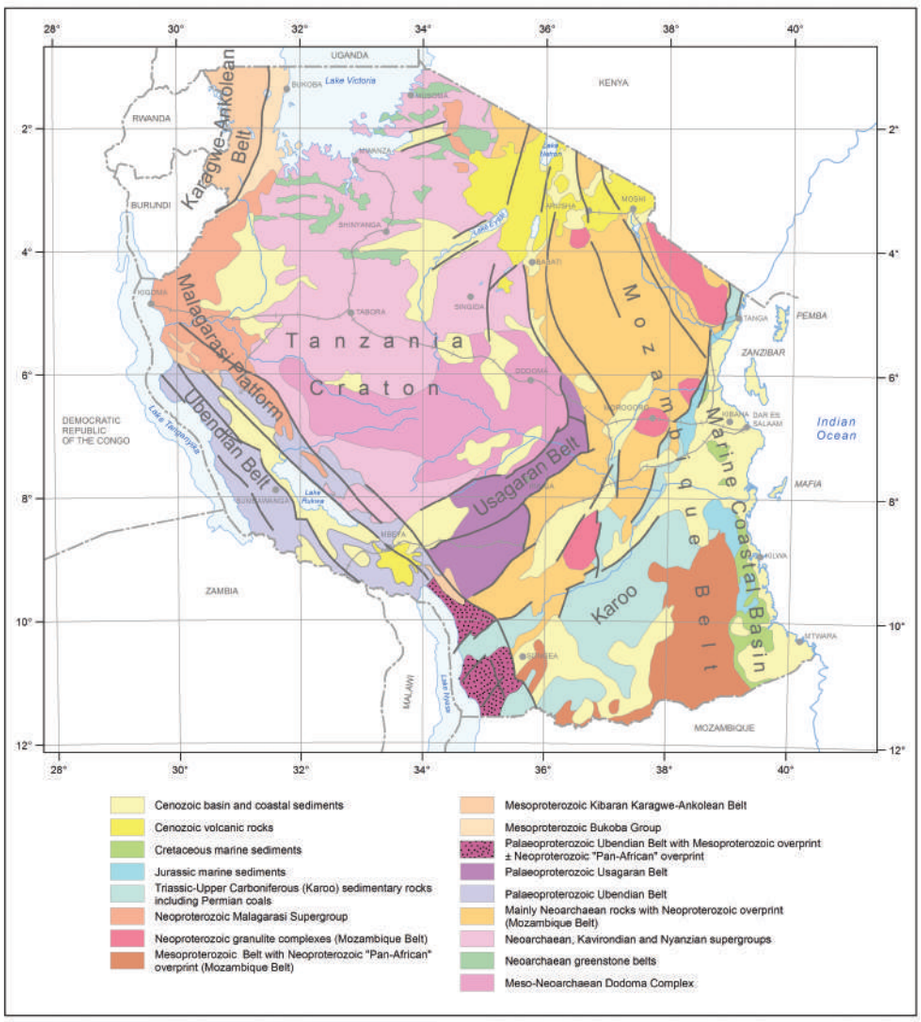


Figure 1. Geotectonic Map of Tanzania

Tanzania, a country that offers a stable political environment with sound legal and fiscal policies, is well endowed with mineral resources. It is located south of the Equator within the tropics of Eastern Africa bordering the Indian Ocean and covers a total area of 947,300km^2 including the islands of Mafia, Pemba, and Zanzibar. Tanzania's varied geography comprises a large central plateau with mountain ranges in the north of the country including the volcanic peaks of Mount Meru and Mount Kilimanjaro, the latter at 5895 m.a.s.l. is the highest peak in Africa. There are highlands in the south and extensive plains along the coast. Two branches of the Great Rift Valley run through the country. The Eastern Rift in the north-central part of the country, and the Western Rift which defines much of the country's western border and includes Lake Tanganyika which is the second deepest lake in the world. Additionally, the southern half of Lake Victoria, the largest lake in Africa, lies in Tanzania between the two branches of the rift system.

Geological Setting

Tanzania's geology is dominated by an Archaean Craton primarily exposed in western Tanzania. Crystalline rocks of Proterozoic age rim this granitic nucleus to the northwest, southwest and the east, with sediments and volcanics of Paleozoic to Recent age present in the rifted grabens, coastal plains and inland basins; major Karoo sequences occupy structural basins in the southeast of the country.

The Tanzania Craton predominantly comprises lithologies that formed between 2.8-2.6 Ga that now occupy a series of NNW-SSE trending structural belts in the north-central and west of the country. Traditionally, the Craton is subdivided into the Nyanzian granitoid-greenstone terrane of northern Tanzania, the Kavirondian metasedimentary rocks of the Lake Victoria area and the Dodoman

migmatitic orthogneisses of central Tanzania (Figure 1). The present consensus is that the Dodoman and Nyanzian terranes are coeval, with the former possibly representing deeper crustal levels subjected to higher grade metamorphism and migmatization; the metasediments of the Kavirondian Supergroup unconformably overlie the greenstone units of the Nyanzian Supergroup and represent probable erosion products of it. There are two recognised suites of granitoids an Older and Younger one, and the Younger Granitoids (~2.5 Ga), at least in part, intrude the Kavirondian metasedimentary sequences. The composite granitoid-greenstone terranes of the Craton host world-class gold deposits similar to other Archean cratonic areas in Africa, and additionally it is intruded by a number of diamondiferous kimberlite pipes, the largest and most productive being the Mwadui pipe.

The Archaean cratonic nucleus is surrounded to the southwest and southeast by composite Paleoproterozoic mobile belts of the Ubendian and Usagaran domains respectively, with ages ranging from 2.05 -1.75 Ga, typically comprising high-grade crystalline metamorphics and numerous post-orogenic gabbroic and granitic intrusives. The NW trending Ubendian mobile belt includes a wide variety of metamorphic rocks but the dominant lithology is amphibole-bearing orthogneiss with minor mafic-ultramafic phases, the metamorphic grade is typically almandine-amphibolite facies; metasediments although rare comprise aluminous mica-schist and gneiss, marbles and ferruginous quartzites. It is considered to contain a large component of reworked Archaean rocks. Units of the Ubendian mobile belt are intruded by granites that yield dates of 1725 ±45 Ma. The Usagaran mobile belt sequences also comprise high-grade metamorphics dominated by granulites and paragneiss of pelitic origin; eclogites and felsic metavolcanics of the Ndembera Group, along with quartzites are important lithologies. The Usagaran belt similarly contains reworked Archaean material; it is intruded by a series of post-tectonic granites that yield Rb/Sr dates of 1845 ±110 Ma and an indicative SHRIMP zircon age of 1877 ±7 Ma. Lithologies of the Usagaran mobile belts host base metal ± gold deposits plus various types of gemstones and industrial minerals. The Ubendian mobile belt is structurally limited, to the west and southwest, by the Congo Craton and lithologies of this belt host orogenic gold as well as minor Sn-W mineralisation related to post-orogenic granites; other mineral resources include pegmatite hosted semi-precious gemstones.

Mesoproterozoic rocks in Tanzania are mainly represented by the Kibaran equivalent sequences exposed in the N to NE trending Karagwe-Ankolean Mobile Belt, on the western margin of the Craton. The mobile belt corresponds to three main tectonic units, a Western domain of orthogneisses, volcano-sedimentary rocks and abundant anatectic granites, an Eastern domain of carbonaceous schists and clastic sedimentary rocks and an intervening Tectonic Zone domain of siliciclastic sedimentary rocks with thrust belts marked by layered mafic-ultramafic intrusions and including syn-tectonic A-type granitoids. The belt contains numerous, partially reworked remnants of both Archaean and Paleoproterozoic units. The 1.4Ga Kibaran age rocks are host to major Ni-Co-Cu and PGE-Cu-Ni deposits associated with mafic/ultramafic intrusions, at Kibanga and Kapalagulu respectively, as well as post-orogenic granite related Sn-W, Nb-Ta mineralisation

East of the main Tanzania Craton is a complex and highly deformed domain comprising a bimodal assemblage of amphibolite to granulite grade metamorphic rocks, referred to as the Western Granulite Belt. The belt includes major units of reworked Archaean crust that carry a major Neoproterozoic overprint and is separated from the Craton by a Tectonic Front Zone interpreted to be a Neoproterozoic structure, dated between 640-550Ma. To the east is a mixed sequence of low-high grade units, the Eastern Granulite Belt, comprising granulites, granitic gneiss, schist, pelitic-silicic metasediments and marbles of Neoproterozoic age. This area commonly referred to as the Mozambique Belt, hosts base and precious metal deposits as well as Ni-PGM prospects, gemstones and industrial minerals.

Phanerozoic units include Late Carboniferous to Jurassic Karoo sequences comprising volcano-sedimentary depositional sequences that host good quality coal and some uranium mineralisation. Mesozoic-Cenozoic clastic sequences occur in the main Rift Basins along with basaltic volcanics with thick marine to lacustrine deposits along the coast. Mineral occurrences include residual weathering products such as nickeliferous laterites, bauxites and uraniferous calcretes as well as heavy mineral beach sands, extensive kaolin-rich clays, gypsum, diatomite and rock phosphate.

Mineral Deposits and Occurrences

At a regional scale, there are several major mineral deposit types that are recognised in Tanzania and potentially of economic importance, for example:

- Gold deposits primarily hosted in the Archaean greenstones and BIF units
- Diamond bearing kimberlites in the Craton
- Base metal mineralisation associated with crystalline basement rocks
- Ni-Cr and PGM mineralisation associated with mafic-ultramafic units
- Ta-Nb and REE deposits associated with alkaline magmatism
- Gemstones within the Proterozoic mobile belts

In addition there is also high potential for hydrocarbon deposits with oil and gas in the Mesozoic basins and high-quality coal in the lower units of the Karoo sequences plus the potential for uranium in the Karoo sandstones. There is also a wide range of industrial minerals and dimension stones recorded throughout Tanzania.

The majority of Tanzania's **gold deposits** are found in greenstone units of the Neoarchaean Nyanzian Supergroup exposed in the northern part of the craton to the south of Lake Victoria. This comprises sequences of dominantly mafic volcanics and immature sediments including chert and banded iron formation. The majority of gold mineralisation is orogenic in nature associated with penetrative, NW striking, steeply dipping quartz veined shear zones that sub-parallel the strike of the main lithological contacts; but it is also present as disseminated gold-pyrite occurrences in the banded iron formation units. Typical ore assemblages are quartz, native gold, pyrite, galena and sphalerite. Notable examples are recorded from Sekenke, Kirondatal, Londoni in the Singida gold field and the Saza-Geita goldfields; the broad age window for the gold mineralisation is 2700-2660Ma. Economically less important gold mineralisation is found in the Paleoproterozoic units of the Ubendian and Usagaran mobile belts, for example, in the Lupa area within the Ubendian domain, where gold is present in shear zones cutting greenschist-amphibolite grade lithologies. The lower metamorphic grade compared with the main Ubendian lithologies however may indicate the mineralisation in fact relates to a tectonic sliver of Archaean (Nyanzian) greenstones. Similar lithologies associated with shear zone hosted gold mineralisation are also found in Paleoproterozoic units in the Mpanda polymetallic mineral field area. Additionally the Mesoproterozoic Karagwe-Ankolean mobile belt along the border area with Rwanda-Burundi, contains a number of slivers of Archaean lithologies that host gold mineralisation, for example, the Mwiruzi, Nyakahura and Kalenge occurrences.

Numerous gold occurrences are found in rocks of the Western Granulite Terrane, specifically the Kilindi-Handeni Superterrane, which coincides with the western part of the Mozambique Belt and corresponds to predominantly Archaean crust reworked by Pan-African tectono-thermal events. The most significant occurrences are the Mkurumu, Negero, Ngezi and Magambazi gold deposit hosted by amphibolite-facies greenstones and orthogneisses of the E-W trending Mkurumu-Magamba Terrane and typically associated with prominent E-W to ENE-WSW regional shear zones. The Magambazi prospect is highly prospective and estimated to contain an endowment of over 40t Au, sulphides include arsenopyrite, pyrrhotite

and chalcopyrite and exploration has defined at least 11 km of prospective ground referred to as the Handeni Gold Trend, stretching from Magambazi Hill to Semwaliko.

The Tanzanian Craton is also host to a number of kimberlite intrusions some of which carry **diamonds**. To date more than 350 kimberlite pipes and clusters have been recorded in Tanzania of which 6 are or have been mined, although some 20% are recorded as being diamondiferous. The majority of occurrences are found in northern Tanzania in and around the Shinyanga area, for example the Williamson diamond mine that has been operating for some 75 years. There are two distinct ages of kimberlite volcanism recorded from the Tanzania Craton one around 1100Ma (Mesoproterozoic) and a significantly younger one of late Mesozoic-Cenozoic age. The latter includes the Mwadui kimberlite which is the only pipe currently being economically mined for diamonds and is the World's largest measuring some 1.46 km^2 at surface. A NNW-trending, 200 km wide zone extending southward from Mwanza through the Craton for some 600km to the Singida area is the most favourable tract for diamondiferous kimberlites. The tract is characterised by a number of regionally extensive NNW-SSE trending Jurassic-age dolerite dykes that are evident on the airborne magnetics and it is possible that these Gondwana break-up fracture systems were reactivated and exploited as pathways for kimberlite emplacement during the latest Cretaceous-Tertiary. As most kimberlites known in Tanzania are pre-Miocene in age they must have experienced an extensive erosional history, thus there is a large potential for alluvial diamonds, both in modern day and paleo-placer deposits.

Base-metals are recorded from various sequences in Tanzania. Minor (Cu-Fe) base-metal mineralisation is associated with the gold-bearing volcanogenic massive sulphide deposits within the Archaean, notably the Bulyanhulu and Samena deposits. Base-metal mineralisation is also present in Palaeoproterozoic rocks including the Mukwamba Pb-Cu-Au-Ag deposit as well as the Lufusi and Pare copper prospects. There are numerous copper occurrences of malachite +azurite ±chalcocite ±bornite within rocks of the Usagaran mobile belt which are possible indicators of larger mineralised systems. The main host rocks are metasediments, ultramafics and pegmatites with mineralisation present as hydrothermal veins/lodes and irregular impregnations. The main, locally mined, examples are Lufusi, Tambi and Godegode all of which are vein/lode occurrences hosted by different lithologies. The Lufusi occurrence, for example, is hosted in ultramafic rocks and comprises composite Ni-Cu (-PGE) mineralisation. At Kinusi where active artisanal mining is taking place, the mineralisation is present as high-grade malachite-bornite veins with Cu grades of 3-27%.

The Busi iron occurrence west of Mpunjo lies within the western part of the Mozambique Belt and comprises a concordant muscovite-magnetite schist in which magnetite content can reach up to 50%; the band can be traced for several kilometres on the basis of its magnetic signature.

Additionally the sedimentary sequences of the Neoproterozoic Bukoban Group host several stratiform Cu-Ag occurrences that are possibly of the Kupferscheifer-type. The main outcrop of the Bukoban Group occurs in western Tanzania where it unconformably overlies both the Archaean Craton and the Palaeoproterozoic Ubendian rocks. Continental red bed sequences of the Bukoban are prime exploration targets for stratiform copper, cobalt and silver deposits based on similarities to syngenetic copper mineralisation found in the Central African Copper Belt. A prime example is the Kigugwe deposit, which lies to the east of Mbeya in which copper values in shales are usually of the order of 1-3%.

A major **nickel(-cobalt)** deposit is found in layered ultramafic rocks associated with the tectonic domain of the Karagwe-Ankolean Mobile Belt in NW Tanzania close to the border with Burundi, some 130 kms southwest of Lake Victoria. The deposit lies within the 1.4 Ga Kabanga-Musonggati-Kapalagulu belt of mafic-ultramafic intrusions hosted by low-medium grade mica-graphite schists. Massive high-grade nickel sulphides occur in numerous layers and lenses that can reach several metres in thickness; over 58Mt of nickel-copper sulphide ores grading 2.63% Ni, combined measured and inferred resource, are reported from the deposits of the Kabanga area. Cobalt, copper and platinum mineralisation is also reported. The Haneti-Itiso ultramafic complex located some 95 km north of Dodoma is considered to be highly prospective for **nickel and PGM's**. The complex strikes NW-SE and sporadically crops out over a strike length of 80 kms with the most extensive outcrops of serpentinised ultrabasics occurring some 15 kms east of Haneti village. Exploration results indicate a 30km strike of nickel-platinum prospectivity and in particular at Mwaka Hill and Mihanza Hill, the former also showing the best gold values. Gem quality, apple-green chrysoprase, a Ni-bearing chalcedonic quartz occurs as near surface thin discontinuous veins that are locally mined along with green opal through the Tanzanian Gemstone Industry Ltd.

The Mesoproterozoic Karagwe-Ankolean Mobile Belt is intruded by several Neoproterozoic peraluminous leucogranites with associated economically exploited **tin-tungsten** mineralisation found in veins and greisens over a wide area. The numerous post late Cretaceous carbonatites exposed in Tanzania are associated with the main rift systems and host a range of mineral deposits namely phosphate at Mbalizi and Minjingu, Arusha; **tantalum-niobium** at Panda Hill Mbeya and **REE** at Wigu Hill. The recently discovered REE-Nb-Ta-phosphate deposit at Ngualla located some 150km NW of Mbeya is the most economically significant carbonatite-related deposit in the country. It is reported to be one of the largest and richest prospects in the World, typically displaying 3 - 8% REE oxide in weathered surface rock and 1.5 - 2.5% REE oxide in fresh material.

Quality **gemstones** are found in various geological settings in Tanzania and includes amethyst, aquamarine, emerald, garnet, ruby and sapphire among others. The Neoproterozoic units of the Mozambique Belt host the economically important and unique Merelani tanzanite gem deposit. Tanzanite is a variety of gem zoisite and found only in the Arusha area of northeastern Tanzania. Furthermore the granulite grade gneisses of the Ubendian and Usagaran domains host deposits of rubies, sapphires and emeralds such as the Winza mining area located to the SW of Yalumba Hill which itself comprises a garnet rich eclogite. Gemstones are also commonly associated with pegmatites in units of the Neoproterozoic Eastern Granulites. Gem quality zircons, sapphires, ruby, garnet and tourmaline are all present along with quartz-microcline-perthite and muscovite at several localities.

Several parts of the Karoo Supergroup in Tanzania contain low-sulphur coal bearing beds, namely the Songwe, Metangula and Ruhuhu Basins and estimated resources are as high as 1,500Mt coal. Additionally redox-style **uranium** mineralisation is reported from Karoo sandstone sequences in the Mkuju, Songea Luwegu and Madaba-Lukuliro areas. Uranium mineralisation covers an area of some 120 km^2 at Mkuju and over 325 km^2 at Madaba-Lukiliro. Recognition of economic concentrations of roll-front uranium within Karoo basins regionally, for example northern Malawi, has encouraged increased exploration activity specifically targeting this style of mineralisation in Tanzania, for example, the Mkuju-Nyota deposit. Additionally, recently acquired airborne radiometric data shows that the Usagaran granites and gneisses are potential source rocks for redox-style uranium deposits which implies that the western margins of the Karoo basins are prospective for uranium. In addition there is potential for calcrete-related secondary uranium mineralisation associated with the mbuga deposits over large areas of Archaean granitoids within the Craton as evidenced by the airborne geophysical surveys.

Graphite is present in abundant but highly variable amounts in many of the metasedimentary units of the Eastern Granulites and Mozambique Belt of southeast Tanzania. Potentially significant

deposits of flake graphite are being explored at Nachingwea, where Chiliogali Hill has an inferred resource of over 325,000 tonnes of contained flake graphite, and Epanko where a potential resource of 1.28Mt of graphite has been identified through drilling.

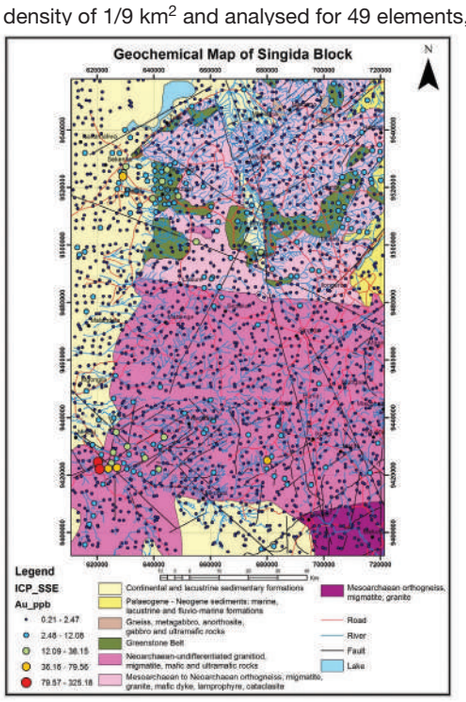
Availability of Geoscientific Data

The Geological Survey of Tanzania (GST) is a Government Institution under the Ministry of Minerals responsible for acquiring, processing, interpreting, archiving and disseminating national geo-scientific data to various stakeholders for the purpose of promoting and attracting investment in different sector especially mining. Being the oldest best geo-scientific organization in East and Central Africa, GST has been providing geo-scientific services since 1925.

As the custodian of the national geo-scientific data and information collected over the past 90 years, the institution has all it takes to solve geo-scientific problems. The data and information at our disposal include geo-scientific maps and reports, countrywide low resolution airborne geophysical data and high resolution for some parts of the country; and geochemical data for some selected areas. GST hosts a core library with drill cores collected across the country and a national geological Museum with various minerals, fossils and rock samples.

Mineral exploration firms, miners, construction and water drilling companies and other related earth resource stakeholders need not to survey the country's vast land but they are encouraged to consult (at a one stop geo-scientific centre) the Geological Survey of Tanzania for guidance. The GST's offices are centered in the capital town of Tanzania – Dodoma.

Geochemical Data: regional geochemical data is routinely collected by the **GST** as part of a systematic national geochemical baseline programme. As part of the SMMRP programme, geochemical sampling was undertaken over nine QDS's, 6 were sampled from the Singida block, 2 from the Handeni area and 1 from Dodoma. A total of over 3000 stream sediment samples were collected at an average density of 1/9 km^2 and analysed for 49 elements, including all major exploration and pathfinder elements, using a combination of ICPM and XRF techniques at international laboratories. The analytical data was interpreted and plotted using standard internationally accepted statistical methods to produce anomaly maps for targeted follow-up. The example left shows trace element data for the Singida block.



Geological data: historical and recently mapped geological maps are available for consultation at the **GST**. Under the SMMRP 18 Quarter Degree Sheets (QDS), covering some 53,000 km^2 have been mapped at a scale of 1:50,000 and published at 1:100,000; they correspond to five blocks Singida(4), Handeni(5), Dodoma(3) and Lupa-Mbeya(2) as well as three individual QDS in the south and one in the coastal area. In addition a mineral potential map at a scale of 1:500,000 has been completed for an area of approximately 170,000 km^2 across eastern Tanzania incorporating the Singida-Dodoma-Handeni prospective tract (Block A). There is also an upgraded national geological, tectonic and mineral occurrence map available at a scale of 1:2 000,000.

Geophysical Data: extensive geophysical coverage exists from the low resolution surveys undertaken in the period from 1976-80 and a new high resolution multi-disciplinary airborne survey was undertaken over much of central and northeastern Tanzania under the SMMRP in 2012-13. An area of some 137,500 km^2 was flown for magnetics and radiometrics at a line spacing of 250m, amounting to 554,500 line-kms, as well as gravity at a line spacing of 3000m. The survey covered three major adjacent blocks in northern Tanzania (Blocks 2A, B, C) and a smaller area (Block 1) over the Lupa goldfields.

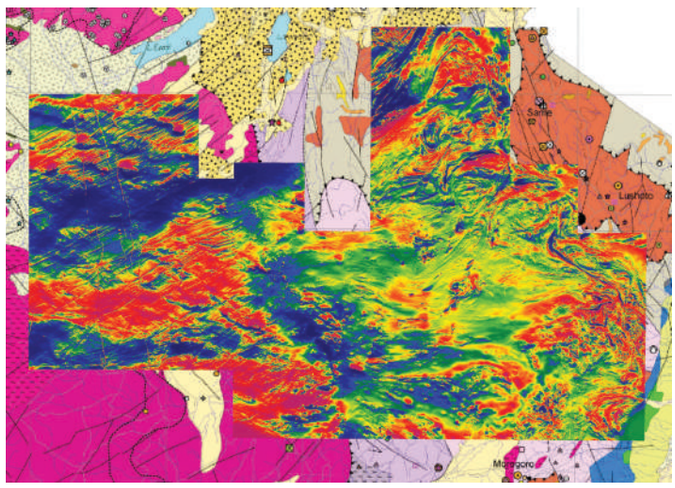


Image of the total magnetic intensity for Block 2

In addition high-resolution VTEM surveys were carried out over selected target areas identified by **GST** in Block 2. The interpretation of the final processed data was undertaken over 12 selected QDS's by the **GST** geophysicists in association with international consultants and a 1:500,000 scale geophysical map of Block A incorporating the Singida-Handeni corridor was also produced.

Mineral Occurrence Data: – the availability of data on the location and size of existing and historic mineral occurrences is essential for identifying and validating potential anomalous mineral resource blocks. The digital mineral occurrence database at the **GST** holds records of some 2208 mineral occurrences that have been compiled and updated under the SMMRP and are available for consultation and purchase.

All data enquiries should be addressed to:
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