From Colonial Tin to Global Lithium and Tantalum: Extractive Histories and Contemporary Exploration of Strategic Mineral Resources in Manono-Kitotolo (DRC)

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Abstract (English)

The Manono-Kitotolo pegmatites in the Democratic Republic of the Congo (DRC) constitute the world's largest mineralized granitic pegmatite system, hosting substantial resources of lithium, tin, and tantalum. This study reviews historical and contemporary mining and exploration activities in the region, from colonial-era tin extraction to modern industrial lithium exploration and widespread artisanal mining of tin and tantalum.

We present new insights into the geology and mineralogy of the deposits and propose a model for the formation of giant composite pegmatites through repeated injections of Li-saturated granitic melts along NE-SW trending structural corridors.

Finally, we summarize recent developments and exploration activities and situate these within the broader geopolitical context of rising global demand for critical minerals and the DRC's complex resource governance challenges.

Keywords: history, mining, exploration, geology, lithium, tin, tantalum, DRC

Abstract (Nederlands)

De Manono-Kitotolo pegmatieten in de Democratische Republiek Congo (DRC) vormen het grootste granitische pegmatietsysteem ter wereld, en bevatten aanzienlijke voorraden lithium, tin en tantaal. Deze studie onderzoekt de historische en hedendaagse mijnbouw- en exploratieactiviteiten in de regio, variërend van tinwinning in de koloniale tijd tot moderne industriële lithiumexploratie en artisanale winning van tin en tantaal.

We presenteren nieuwe inzichten in de geologie en mineralogie van de afzettingen en stellen een model voor waarin de vorming van deze uitzonderlijk grote pegmatieten wordt verklaard door herhaalde injecties van lithiumverzadigde granitische smelten langs NO-ZW-georiënteerde breuksystemen.

Daarnaast vatten we recente ontwikkelingen en exploratieactiviteiten in de regio samen, en plaatsen deze in de bredere geopolitieke context van de toenemende wereldwijde vraag naar kritieke mineralen, evenals de complexe uitdagingen rond grondstoffenbeheer in de DRC.

Trefwoorden: mijnbouw, exploratie, geologie, tin, tantaal, DRC

1 Introduction

The eastern provinces of the Democratic Republic of the Congo, notably North Kivu, South Kivu, Maniema and Tanganyika, host world-class deposits of tin (cassiterite), tantalum (columbite-group minerals, also referred to as CGM or coltan) and tungsten (wolframite/ferberite), collectively known as the 3Ts. These three, together with gold (3TG), are also known as the *conflict minerals* (OECD 2016; Schütte and Näher 2020). They are mostly extracted from alluvial and eluvial deposits by many thousands of artisanal miners (Matthysen et al. 2019; IPIS 2021). This informal mode of mining, coupled with opaque trading networks and weak governance, has become deeply intertwined with conflict and armed rebel groups seeking to control these valuable resources (Vogel et al. 2018; Gobbers and Matthysen 2022). As a result, the minerals serve to finance and exacerbate ongoing conflicts, and aggravate geopolitical and ethnic tensions in the area (Gobbers and Matthysen 2022). Notably, political tensions between the DRC and neighbouring countries, particularly Rwanda and Uganda, escalated in early 2025 following the advance of M23, a rebel group which Rwanda is accused of supporting (Africa Center for Strategic Studies 2022; UN News 2025; IPIS 2025a).

A new geopolitical dimension to the 'resource curse' of the DRC (Trefon 2016) is the growing strategic importance of lithium, an essential component for lithium-ion rechargeable batteries, crucial to powering the modern world within a context of global climate sustainability goals (Hund et al. 2023). To date, lithium has not been mined at any significant scale from eastern DRC, but is known to occur in large quantities, specifically at Manono-Kitotolo in the Tanganyika province (formerly the Katanga Province). Whilst this paper does not seek to engage in a political analysis of mineral resources and conflict in the DRC, we deem it essential to offer a broader historic and geopolitical perspective in order to contextualize local developments and understand the dynamics shaping resource exploitation and exploration in the region.

The mineralization of tin, tantalum and tungsten, as well as other strategic metals such as lithium and beryllium, in eastern DRC, southern Uganda, Rwanda and northern Burundi is associated with granitic magmatism in Mesoproterozoic geological terrains known as the Karagwe-Ankole and Kibara belts (Pohl 1994; Fernandez-Alonso et al. 2012; Hulsbosch 2019). The mineralization is hosted in magmatic rocks known as pegmatites, hydrothermal quartz veins, and their chemical and mechanical weathering products (Dewaele et al. 2016; Hulsbosch 2019). While the weathered (eluvial) and reworked (alluvial) surface deposits are amenable for extraction through simple artisanal and small-scale mining (ASM) methods - essentially requiring only a shovel and water - associated lithium deposits occur in the unweathered hard rocks at deeper levels and require more advanced industrial exploitation methods. Given the growing global demand for lithium, the known occurrence of lithium within some (unweathered) pegmatites at depth has sparked new interest for industrial exploitation in the region (Melcher et al. 2015; Dewaele et al. 2016; Kalikone et al. 2023; Acke et al. 2025b; Rodriguez Ardila et al. 2025; Goodenough et al. 2025; Delvaux et al. 2026) . Current activities include exploration projects by Congolese, Australian, Canadian, Indian, USA and Chinese companies.

The present work focuses on the history of mining and ongoing exploration activities at the Manono-Kitotolo tin-tantalum-lithium deposits, which represent the largest of all pegmatite systems in eastern DRC. With a known extent of 13.5 km long and a thickness up to 300 m (Fig 2), and new pegmatite extensions being discovered, the Manono-Kitotolo (MK) pegmatites are not only the largest in eastern DRC, they also stand as the largest known hard-rock pegmatite deposits in the world (Benson et al. 2025; Rodriguez Ardila et al. 2025). The MK system consists of multiple sub-parallel south-east dipping pegmatite bodies (Fig 1, 2), and includes separate bodies referred to as the Roche Dure, Kyoni, M'Pete and Tempete pegmatites in the southwestern Kitotolo sector, and the Carriere De L'Est, Malata and Kahungwe pegmatites in the northeastern Manono sector (Fig 2).

Cassiterite was industrially mined from Manono-Kitotolo by Géomines since 1919, until declining tin prices and production numbers halted operations in the early 80's (O'Malley 2014). In the last two decades, artisanal mining of cassiterite and columbite-group minerals in the area has increased drastically. Over six thousand miners in the area dig up eluvium and alluvium deposits on a daily basis, using the Lukushi river and flooded quarries to concentrate cassiterite and columbite-group minerals (IPIS 2021) . Given Manono's major strategic and geopolitical importance, we provide an overview of the geological setting and the mineralogy of the Manono-Kitotolo pegmatites, as well as the history of mining and current exploration for tin, tantalum and lithium in the wider region.

2 Mining History of Manono-Kitotolo

Historic operations at Manono-Kitotolo date back to early Belgian colonial times, when cassiterite was found in the Manono area in 1910 during a general survey of eluvial deposits in the Katanga province by Société Géologique et Minière du Congo (Géomines) (Bassot and Morio 1989; Hillman 1997) . The discovery of cassiterite within the lateritized eluvium prompted further prospecting of the area and Géomines started exploitation in 1919 (Bassot and Morio 1989; Buckingham 1996). In the initial years, roughly 150 tonnes were produced per year (Hillman 1997). Exploitation of the lateritic deposits, ranging up to 70 m in depth, led to the discovery of the weathered pegmatite deposits in 1925, sparking a new prospection campaign through shafts and boreholes which was completed in 1935 (Bassot and Morio, 1989). In the following years, infrastructure was established such as the hydroelectric power plant at Mpiana-Mwanga and a tin smelter, which processed a significant portion of the Belgian Congo's cassiterite production (Bassot and Morio, 1989). By World War II, Congo had become the largest producer of tin in Africa (Hillman 1997). Géomines was essentially enjoying a monopoly position due to exclusive concession rights, which allowed them to switch between prospecting and production, and to leave lower grade sections for times of high tin prices and higher grade sections for times o low prices (Hillman 1997). The hard-rock pegmatites were further explored and exploited after 1949, leading to 40 to 45 boreholes being drilled in the western end of the Kitotolo sector (i.e. Roche Dure). The first reports on the structure and mineralogy of the pegmatite include the work of (Landa et al. 1950; Thoreau 1950, 1953, 1961; Bernard 1954; Thoreau et al. 1956). Operations at the Roche Dure quarry lasted from 1951 until 1956. Geochemical results of 39 of the original boreholes were reported by Bassot and Morio (1989), along with the historic accounts we summarized here.

Despite initial successes encountered by drilling the hard rock pegmatite, tin production began to decline, exacerbated by political changes and economic challenges. After independence in 1960, Géomines changed to Congo-Etain, and following Mobutu's post-independence nationalization campaign in 1968, Congo-Etain was acquired by Zairetain (Buckingham 1996; O'Malley 2014). However, production continued to decline due to deterioration of the equipment, staffing shortages, and depletion of the easily mineable alluvial/eluvial deposits. Later, some efforts to revitalize operations at the Roche Dure project were initiated but ultimately failed, leading to the closure of the mine in 1982. Over 100 million cubic meters of ore had been extracted during Manono's operational lifespan (Bassot and Morio, 1989), producing an estimated total of 140.000 to 185.000 tons of cassiterite and 10.000 tons of columbite-group minerals (Dewaele et al. 2016).

3 Geological Setting

The Manono-Kitotolo pegmatites are located approximately 500 km north of the country's major mining capital, Lubumbashi, and ca 250 km southeast of Kalemie. Manono lies on the western bank of the Lukushi river, a tributary of the Luvua river, which in turn joins the Lualaba section of the Congo river flowing northwards. The town of Manono is serviced by a small airport and is further connected to Lubumbashi and Kalemie through a network of largely unpaved roads (more in section 7).

The deposits and pegmatites are part of the Mesoproterozoic Kibara Belt (KIB), which along with its cogenetic Karagwe-Ankole Belt (KAB) in the north, represent an orogenic mobile belt situated between the Archaean-Palaeoproterozoic Congo Craton to the west and north, the Bangweulu Block to the south, and the Archaean Tanzania Craton to the east (Fig 1, Fernandez-Alonso et al. (2012)). The KIB and the KAB have very similar geological histories and metallogenic contexts, but are geologically separated by the northwest-trending Paleoproterozoic Rusizi belt, which extends south-east into the Ubende belt (Fernandez-Alonso et al. 2012; Debruyne et al. 2015). The KIB and KAB combined have collectively been referred to as the Kibara Metallogenic Province, which hosts primary rare metal mineralization in magmatic Nb-Ta-Sn pegmatites, containing cassiterite, columbite-group minerals (CGM), amblygonite (a Li-phosphate), spodumene, beryl, as well as magmatic-hydrothermal Sn or W quartz veins, both associated with leucogranites of early Neoproterozoic age (Cahen et al. 1984; Pohl 1994; Hulsbosch 2019; De Clercq et al. 2021; Villeneuve et al. 2022)

The Kibara Belt consists of Paleo- and Mesoproterozoic supracrustal units, mostly comprising metasedimentary rocks, intruded by large Mesoproterozoic granitic massifs and subordinate mafic bodies around 1400-1375 Ma (Ngulube 1994; Kokonyangi et al. 2001, 2004, 2006). The latest intrusive units are the leucogranites, or 'tin granites', and associated mineralized pegmatites and quartz veins. The stratigraphy of the KIB is relatively poorly constrained, with only the southern part of the KIB (Mitwaba area) having been studied in detail, and the northern part mostly inferred from remote sensing (Kokonyangi et al. 2006; Debruyne et al. 2015). The formal lithostratigraphy for the Kibara Supergroup was compiled by Laghmouch et al. (2012), and comprises from bottom to top: the Kiaora group (K1), the Lufira or Nzilo Group (K2), the Hakansson Group (K3), and the Lubudi Group (K4), each separated by an unconformity and/or a basal conglomerate (Kokonyangi et al. 2006; Laghmouch et al. 2012).

Historically, the numerous granitic intrusions in the KIB were categorized into five distinct groups (A to E) based on Rb-Sr dating and the degree of deformation (Cahen et al. 1984). However, more recent SHRIMP U–Pb zircon age determinations of Mitwaba granitoids, indicate that the main granite generations A to D, which comprise most of the granitic bodies in the KIB, were emplaced during a relatively narrow time period at 1.38 Ga Click or tap here to enter text., coinciding with ages around 1375 Ma for the equivalent granites in the KAB (Tack et al. 2010). The last group, the E-granites, equivalent to the 'G4 tin granites' in the Rwandan KAB, and their associated aplites, pegmatites and quartz veins, give zircon ages between 1020-950 Ma (Kokonyangi et al. 2004; Tack et al. 2010; Villeneuve et al. 2019; De Clercq et al. 2021). Columbite-group minerals and cassiterite U-Pb ages from the KIB as well as the KAB also largely coincide with the younger side of this age range (Melcher et al. 2015; Nambaje et al. 2021) Some hydrothermal remobilization of Sn and Ta during later Pan-African orogenic events has been recorded in cassiterite and CGM ages between 530 and 615 Ma in the Karagwe-Ankole Belt (Dewaele et al. 2011, 2015; Nambaje et al. 2021). To date, there is no particular evidence for Neoproterozoic (Pan-African) deformation or overprinting of the Manono-Kitotolo pegmatites following emplacement, although evidence for younger brittle or brittle-ductile deformation events have been recorded elsewhere (Acke et al. 2025a; Delvaux et al. 2026).

4 Methods and Materials

Fieldwork at Manono-Kitotolo was conducted by the first author in August 2022, together with exploration company Dathcom Mining AS who were carrying out diamond drilling as part of their resource estimation at Roche Dure (Kitotolo sector) and Carriere de L'Est (Manono sector). Field observations were made of the geology, the historic mining activities and ongoing artisanal mining activities. The deposit was studied in both outcrop and drill core samples. Samples were taken from outcrop and drill cores provided by Dathcom/AVZ (Fig 3). Thin sections and mineral mounts were prepared at KU Leuven and studied by optical microscopy, cathodoluminescence imaging, scanning electron microscopy (SEM-EDS) and electron probe micro-analyses (EPMA) at KU Leuven.

Results presented below offer a summary of findings from the field, laboratory analyses, available literature, new releases, and satellite imagery (Landsat/Copernicus, Airbus, Maxar Technologies, Google Earth). The IPIS Open Data Dashboard and IPIS Webmap of the DRC (Muller 2020; IPIS 2021) are used to assess the extent of artisanal mining activities in the area.

Mineral concentrates were acquired from artisanal miners at various sites (Fig 4) to evaluate mineral assemblages and compositional variability in the produced mineral concentrates. For three mounts, SEM-EDS element maps were acquired for the entire mount. The EDS maps were subsequently classified using the semi-automatic classification plug-in QGIS to estimate relative modal abundances (Meeus 2025) . Within this classification we qualitatively differentiate between columbite and tantalite based on the relative prevalence of Nb_2O_5 or Ta_2O_5, respectively. The resulting estimates only provide a rough approximation, given that the samples are by definition not representative due to 1) the manual sorting methods applied, 2) inevitable density separation during mounting and 3) the accuracy of the quantification plug-in method, which depends on the amount of training, with complications arising from solid solutions (Meeus 2025) . Nevertheless, the results provide an insight into the overall compositional variability of the artisanally produced ores.

5 Geology of the deposit

5.1 The host rock

The Manono-Kitotolo pegmatites are emplaced into Kibaran metasediments of the Kiaora Group with NE-trending sheets of metadolerite/metagabbro, both of which record amphibolite-facies metamorphism (Kokonyangi et al. 2001, 2006; Laghmouch et al. 2012; Dewaele et al. 2016). The metasediments of the Kiaora Group record two foliations (S1 and S2), the first one relating to a ENE-trending asymmetric fold and thrust phase (D1) and the second one relating to NW-verging isoclinal folding and reverse faulting (D2). D1 is only recorded in the Kiaora group, and thus predates the deposition of the Nzilo, Hakansson and Lubudi Groups, while D2 is recorded in all groups (Kokonyangi et al. 2006). The Kiaora group mainly consists of metapelite with minor carbonate/calc-silicates units, deposited within shallow marine environments (Kokonyangi et al. 2006) . At Manono, the Kiaora metapelites dominantly consist of quartz, muscovite, tourmaline and biotite/siderophyllite, occasional garnet, zircon, apatite and large porphyroblasts of chloritoid, which overprint the foliation textures (Fig 3G). Tourmaline is abundant in the more micaceous layers, and is related to metasomatic fluid influx from the regional granites, pegmatites and quartz veins.

The metadolerite forms the main host rock at the footwall-pegmatite contacts in the Manono sector (Carriere De L'Est, Malata and Kahungwe). They consist of amphibole (actinolite-hornblende), sericitized plagioclase, quartz, Fe-Ti oxides (ilmenite, magnetite), apatite and accessory minerals such as zircon, monazite and xenotime. Holmquistite, a dark purple lithian amphibole, was reported by Thoreau (1961) in a metadolerite xenolith entrained in pegmatite. A sample of this is housed in the RMCA collections, but it was not observed in any of the samples studied here. The metadolerite at Manono has not been dated directly, but similar mafic bodies in the Mitwaba area yielded zircon U/Pb ages of 1417 ± 1.7 Ma and an upper intercept age of 1376 ± 13 Ma for the Kidilo orthoamphibolites and Lwabwe metagabbro/metadolerite, respectively (Kokonyangi et al. 2006).

5.2 The pegmatite system

The Manono-Kitotolo pegmatites present a complex system of albite-spodumene Lithium-Cesium-Tantalum (LCT) type pegmatites (cf Černý and Ercit, 2005), characterized by repetitive modal and textural layering and pronounced unidirectional growth textures of spodumene and K-feldspar perpendicular to the dip of the pegmatites (Fig 3).

Spodumene is the dominant Li phase throughout the MK pegmatites . It forms white tabular or prismatic crystals reaching up to 40 cm in length, and typically showing unidirectional growth textures perpendicular to the pegmatite contacts (Fig 3C,E). Prismatic spodumene exhibits thin rims or crosscutting intervals of symplectite spodumene-quartz intergrowths (SQI). Spodumene also occurs as fine-grained needle-shaped masses between the interstices of albite and K-feldspar in thin section. The SQI rims are interpreted as in-situ disequilibrium growth features, while interstitial spodumene needles likely formed at the late magmatic-hydrothermal stage (Acke et al. 2025a) . Accessory phases include CGM, cassiterite, wodginite, uranmicrolite, beryl, apatite, lithiophilite-triphylite (Fig 3F) and tourmaline. Notably, all Li-phosphates are Fe-Mn phosphates (Fig 3F) and no montebrasite or amblygonite have been observed. Albitisation (Na-metasomatism) is pervasive, causing the replacement of primary mineral phases by cleavelanditic albite. Interstitial muscovitisation (K-metasomatism) is also common. Greisen with greenish muscovite are common at the contacts between pegmatites and the host rocks (Rodriguez Ardila et al. 2025).

Fluid-mediated alteration of spodumene includes kaolinization and sometimes lepidotisation, leading to a purple shine in the altered spodumene masses. The alteration can also give the spodumene a dark green, red or brown colour, visible both in outcrop and in drill cores along fractures (Fig 3D). These altered varieties have lost most or all of their lithium content. Samples containing lepidolite are relatively abundant in the collections of rock collections of Manono-Kitotolo at the Royal Museum for Central Africa (RMCA). However, no lepidolite was observed in any of the drill cores studied by the first author (drill cores from Roche Dure and Carriere De L'Est). Fine grained purple lepidolite masses with quartz and blue fluorapatite were only found as float samples near the Malata quarry (Fig 3G) in the north-east. Given their absence in the few studied drill cores, we suggest lepidolite is relatively uncommon in the overall system, and that its relative abundance in historic mineral collections represents a sampling bias. A general observation from exploration is that lepidolite masses appear to be more common in the northeast (M. Cronwright, Pers Comm), which is consistent with our observations.

Meter-scale layering (or zoning) is visible from a distance in outcrop (Fig 3A), while drill cores reveal repeated zoning patterns with alternating intervals of greisen, aplite and quartz-, albite- and spodumene-rich zones (Fig 3B). A well-defined internal zonation pattern is lacking on the large scale, although textural zoning - or banding - instead seems to be repeated at a meter to decimeter scale (Fig 3B). This is an adaptation to earlier reports by Dewaele et al (2016), in which classic zonation was inferred from samples representing typical facies or textures of pegmatite zones. It is important to note that the observations by Dewaele et al. (2016) were based on samples obtained from the RMCA collections, without spatial information on their relative position within the pegmatite bodies. These descriptions include textures interpreted to represent border, wall and intermediate zones, as well as aplite, greisen and albitite zones.

Our observations demonstrate that all typical 'zones' or facies are represented as layers or bands in outcrop and drill core, but that they do not occur in a classical concentric manner, from the outside inwards. Rather, the zones alternate each other in a seemingly random manner. Spodumene-rich units with typical unidirectional spodumene crystals in a quartz-feldspar-muscovite matrix is the most abundant facies, referred to in Dewaele et al. (2016) as 'intermediate zone'. This facies is repeatedly alternated with K-feldspar rich zones or layers, quartz-rich zones, or occasionally with aplite and sugary albitite zones. Greisenisation (muscovitisation) and albitisation zones are visible throughout the pegmatite bodies. Geochemical assays of the drill core reveal multiple 'high grade' zones, in which Li_2O contents exceed 2% (AVZ ASX 2022). These high-grade zones appear to dip parallel to the overall pegmatite (Fig 2C), and may represent spodumene-rich intermediate zones of individual pegmatite sheets (Borst et al. 2024; Rodriguez-Ardila et al. 2025).

In light of the drill core and field observations, as well as the cross sections presented by the exploration companies, we propose that the giant Manono-Kitotolo pegmatite system formed through incremental emplacement of numerous Li-saturated granitic melts to form a large stacked pegmatite system (Borst et al. 2024; Rodriguez-Ardila et al. 2025). We envisage that batches of pegmatite-forming melt were separated from their source in pulses, and were consecutively emplaced along structurally controlled conduits. This implies that pegmatite emplacement was not necessarily limited to the main Manono-Kitotolo system, but that pegmatite-forming melts were very likely emplaced more widely in the region. The latter is consistent with recent discoveries of more pegmatite bodies along strike (i.e. "Pegmatite Corridor") as well as directly to the north and south of the main Manono-Kitotolo pegmatite system (Fig 2A, Fig 7).

A multi-emplacement model, whereby melts are repeatedly injected and solidifying in separate batches, would lead to intense internal and external metasomatic overprinting and can explain some of the textural complexities observed (Borst et al. 2024; Rodriguez-Ardila et al. 2025). However, due to the lack of clear internal cross-cutting relationships, consecutive batches must have been emplaced relatively rapidly, such that overall temperatures remained relatively high and clear crosscutting contacts were not developed. Given the observed decimeter-scale of the repetitive layering and zoning, each pegmatite body would have developed its own complex internal textural zoning, relating to alternating stages of flux and volatile enrichment in the melt, boundary layer formation and fluid-melt exsolution, each controlling (promoting or limiting) nucleation rates, growth rates and saturation, and collectively contributing to the complex zoning and aplite-pegmatite layering (cf (Webber et al. 1997; London 2008, 2014). A multi-emplacement model also has implications for factors such as the degree of undercooling, which is considered a crucial driver for the development of textural layering and compositional zoning in lithium pegmatites (Sirbescu et al. 2017; McCaffrey and Jowitt 2023). These aspects remain topics of further quantitative studies.

5.3 Composition of the artisanal mineral concentrates

Phase maps of the analysed concentrates are shown in Fig 8. A concentrate washed in the Lukushi river (AB22MK03) consists dominantly of cassiterite (~ 60%) with only minor CGM (~2% columbite and ~4.4% tantalite, respectively), as well as minor accessory zircon (~0.2%) and xenotime (~0.1%). The columbite-group minerals show a compositional range of #Mn (Mn/(Fe+Mn)) of 0.37 to 0.72 and #Ta (Ta/(Ta+Nb)) of 0.16 to 0.7 (Fig 9). Silicates include quartz, k-feldspar, albite and spodumene, which make up most of the remaining part of the assemblage (~12, 3, 12 and 3%, respectively).

A concentrate produced at the Malata quarry (MK22AB22) has a similar proportion of cassiterite to CGM, with 41% cassiterite and ~2% CGM (of which 1.1% columbite vs 0.8% tantalite). The CGM grains in this mount mostly comprises the Mn-endmembers, with #Mn ranging 0.6 to 1.0 and #Ta ranging from 0.19 to 1.0 (Fig 9). Minor wodginite (Mn-Ta-Sn oxide, <0.1%) and one grain of microlite (Na-Ca-Ta oxide) are also identified. Accessory phases include zircon (<0.2%), rutile (<0.1%), ilmenite (0.15%), Fe-oxides (8%) and abundant silicates (quartz and albite, ca 40%).

In contrast, a concentrate obtained from the Kahungwe quarry (MK22AB23) consists dominantly of CGM (with ~32% columbite and ~44% tantalite, respectively), with only minor cassiterite (8%). Similar to the Malata sample, the CGM are dominantly columbite-(Mn) and tantalite-(Mn) with #Mn ranging from 0.54 to 1.0 and #Ta from 0.31 to 0.8 (Fig 9). Wodginite (<2%) and a single grain of (uran)microlite (Na-Ca-U-Sn-oxide) are also identified, as well as traces of ilmenite (<0.1%) and Fe-oxides (0.5%). Silicates include quartz (9%), albite (3%), K-feldspar (2%) and garnet (<0.2%).

Compositions that are dominantly cassiterite are more likely obtained from eluvial and alluvial cover, which has experienced more density sorting towards (less dense) cassiterite dominant distributions, whereas the CGM dominant concentrate from the Kahungwe quarry is likely directly sourced from in-situ weathered spodumene pegmatite. CGM are typically less resistant to mechanical break down away from source compared to cassiterite, and thus likely becomes too fine grained to recover when transported over some distance (CGM hardness: 6-6.5, cassiterite hardness: 7). The abundance of CGM, along with their pure Mn-endmembers and high Ta contents in CGM from the northern side of the Kahungwe quarry may also support suggestions from exploration that the MK system is more strongly fractionated towards the northeast (Cronwright, Pers Comm).

However, given that the pegmatites typically contain both cassiterite and CGM, we cannot exclude some degree of density-based separation to increase the relative abundance of CGM over cassiterite in the Kahungwe concentrate, whether it be through sedimentary processes or manual concentration methods. When the miners sell the ores at unofficial or semi-official (i.e. via cooperatives) markets, buyers typically use hand-held XRF machines to assess the concentrations of Nb, Ta and Sn of the ore, in order to assess the relative value. As such, the miners are somewhat aware of the grade and proportions of cassiterite and CGM (or the Ta/Nb proportions) in the ores they are selling. What is unclear, however, is how accurate these XRF measurements are (i.e. as this requires proper calibration) and whether or not they receive 'fair' prices that genuinely reflect the compositional variability of the concentrates.

6 Recent developments

6.1 Current exploration of the Manono-Kitotolo pegmatites

Global lithium exploration saw a major upturn around 2016, driven by a projected nine-fold future demand by 2040, the recognition of lithium as a critical raw material for the energy transition by several leading economies and increased price projections (IEA 2024b, a). It was during this lithium exploration boom that activities at Manono-Kitotolo also saw a revival, following earlier exploration activities mainly focused on tin and tantalum. In 2017, Joint Venture Dathcom Mining AS was created between DRC state-owned Cominière (a continuation of former Géomines/Zairetain), Chinese-owned Dathomir and Australian AVZ Minerals Ltd, with 30, 10 and 60% of the shares, respectively. With a 60% stake in Dathcom, AVZ was responsible for most of the expenditure and started their exploration activities of the hard-rock pegmatite. In 2017, Dathcom commenced drilling in the southern Kitotolo sector (Fig 2, Fig 6), which was later expanded to Carriere De L'Est (Fig 5). To facilitate drilling in the Roche Dure quarry, Dathcom started draining the quarry in 2019 (Fig 6D). The latest JORC compliant resource estimate released a total resource (measured, indicated and inferred) of 842 Mt at 1.61 wt.% Li_2O, 709 ppm Sn, and 37 ppm Ta, with high-grade zones exceeding 2 wt.% Li_2O (AVZ ASX Announcement 2024).

A total contained resource of 3.79 Mt Li (only considering measured and indicated, 6.34 Mt Li when including inferred resources as well) (AVZ ASX Announcement 2024) establishes Manono-Kitotolo as the largest pegmatite-hosted lithium deposit in the world (Benson et al., 2025). It is worth emphasizing that this estimate only covers a large part of Roche Dure and a smaller part of the Carrière De L'Est pegmatite, and it does not include other known parts of the system (Malata, Kahungwe, M'Pete, Tempete etc).

In 2022, Dathcom's project was halted following various legal disputes between AVZ Minerals and its joint venture (JV) partners Cominière and Dathomir, as well as Chinese owned Jin Cheng (Jinxiang) Lithium, a subsidiary of Zijin Mining. The latter were offered a 15% stake in Dathcom from JV partner Cominière (Zijin 2022). The transfer of these shares to Jin Cheng was deemed legally void by AVZ, citing it was in breach of AVZ's right of first refusal (AVZ Minerals Ltd 2022). Various international arbitration cases followed, which can be read up on online (Copperbelt Katanga Mining 2022; Hoffmann and Mpiana 2023; AVZ 2024, 2025a; Birney 2024; Reuters 2025a).

In 2023, a ministerial decree revoked Dathcom's exploration license in 2023, citing insufficient project development progress. Subsequently, the DRC authorities granted an exploration rights for the northern part of the pegmatite (the Manono sector) to Cominière and Jin Cheng Lithium, subsidiary of Zijin, under a new joint venture Manono Lithium SAS (PR15775) (Zijin 2023a) . Exploration activities at the "Manono North East Lithium Exploration Project" commenced later that year. The exploration permit (PR) was later converted into an exploitation license (PE15775, Table 1). AVZ subsequently reported favorable outcomes in arbitration proceedings against Jin Cheng (AVZ, 2024b) and in an ICC Tribunal case against Cominière, in which the tribunal ordered Cominière to pay damages and interest for non-compliance with JV obligations (AVZ 2025b; Reuters 2025a).

Despite ongoing legal proceedings, development activities in the PE15775 license area have continued. Satellite imagery and local reporting indicate substantial on-site development, including road construction, drainage of Lake Lukushi, the construction of an air strip within the drained, the appearance of a new waste pile along Lukushi river, and the establishment of two large industrial sites to the east and north of the Manono sector (Fig 5). The Zijin website reports a Resource of 6.47 Mt, at a grade of 3.72 wt.% Li_2O at the Manono North East Lithium project. No further details can be found on the resource estimation process. Zijin and Cominière announced that lithium production will start in the summer of 2026 (Clowes 2025; Adombila 2026a). At the time of writing, a license covering the Kitotolo sector (PR13359) remains open to exploration to AVZ and Cominière under La Congolaise D'Exploitation Miniere SA (Table 1).

6.2 Exploration of the historic tailings (terrils)

During the many years of industrial exploitation, eleven coarse tailings dumps (terrils, labelled A to J) and fine tailings terraces were created along the south-western sides of the Manono-Kitotolo quarries (Fig 2 and 6). The terrils form prominent flat-topped, terraced hills, rising up to 70 m high above the otherwise largely flat landscape. Given the inefficiency of the early industrial processing facilities, the coarse and fine tailings still contain significant amounts of cassiterite and CGM , as well as spodumene - which was part of the gangue assemblage and was not extracted at the time.

For the tailings, a separate exploration license was granted to a JV between Cominière, Minor SARL and Canada-based Tantalex Resources ('Manono Tailings project', PR13698) (Tantalex 2017), under the JV name Minocom Mining SA (Table 1). Tantalex completed 13 km of aircore drilling through the historic tailings and released a maiden Li-Sn-Ta resource estimate of 5.46 Mt (measured and indicated) with 0.72 wt.% Li2O, 286 ppm Sn and 24 ppm Ta (Tantalex 2022a, 2023). The Total Inferred Resource is 6.63 Mt at 0.49 Li2O (Tantalex 2022a) . A preliminary economic assessment report was published in October 2023, which includes volume calculations, resource estimation, geometallurgical testing and details on planned processing facilities. Each dump consists of a mixture of lateritic alluvial/eluvial material and weathered pegmatite material, except for terril K which consists exclusively of pegmatite material. The pegmatite tailings are more enriched in Li2O (up to 1.72 wt.%), and thus form the main target of exploration (Sedgman Novopro 2023). Satellite imagery shows that terril G, I and K, and the surrounding tailings terraces are also dug up by artisanal miners (Fig 7). Grid sampling and drilling activities by Tantalex can also be seen in the 2022 satellite photos (Fig 7E).

6.3 Exploration activities in the wider region

Various ongoing exploration projects for Sn, Ta and Li in the wider area have demonstrated the presence of additional pegmatite bodies near the Manono-Kitotolo pegmatites, both along strike of the main MK system, or along other parallel NE-SW oriented structural corridors. Some of these have gone largely unnoticed by the academic community, and these findings have not been mentioned in the open literature. As such, we provide a summary of some key projects, where information is available through company websites, ASX reports, and/or personal communication with other researchers or exploration geologists working in the area. An overview of permits, as registered on the DRC Mining Cadaster Portal, is provided in Table 1 and shown in Fig 7.

An aeromagnetic survey led to the definition of a 25 km long by 5 km wide corridor that extends towards the northeast and southwest from the main Manono-Kitotolo pegmatite bodies (Fig 2). This area is referred to as 'Pegmatite Corridor' by Tantalex, whom - in addition to the Manono tailings project under PR13698 have one exploration license in the southwest of this corridor (PR12448), and one tin-tantalum exploitation license directly south of it (PE12447). Both of these are in joint ventures with Cominière SA (United Cominiere SAS, Table 1), and are situated directly southwest of Manono-Kitotolo (Fig 7). On the southern mining licence (PE12477), Tantalex built a Tin and Tantalum processing plant called TITAN. The project is known as the Lubule Tin & Tantalum alluvial project, or TITAN South (Table 1). The TITAN plant separates cassiterite and coltan from alluvial gravel from the 9 km long Lubule river catchment area (Tantalex 2022b). The plant has a designed capacity of 130 tonnes per hour operating for sixteen hours per day (2,080 tonnes of alluvial material per day). The first 15 tons of tin concentrates were exported from TITAN in April 2024 (Tantalex 2024) , when it operated at 50 tonnes per hour for eight hours per day (ITA, 2024). In PR12448, Tantalex drilled 6 holes in 2018 confirming the presence of pegmatites in the northeast corner of the license, where diamond holes intercepted multiple, parallel spodumene-bearing pegmatite bodies with 99.5 meters in apparent thickness (Tantalex 2021).

Roughly 25 km south of Manono-Kitotolo, elluvial cover and weathered pegmatites in an area called Kanuka are being mined for tin and tantalum by Chinese-owned Benefone Mining SAS, in collaboration with DRC-based Mining Mineral Resources (MMR). MMR operates focusses on Sn and Ta production, with various operations in Mitwaba, Malemba-Mwanza, Mitwaba and Kisengo (MMR 2025). The Kanuka project comprises one exploitation licence (PE13082, operated by 'Benefone Mining SAS') and one exploration license (PER4100, 'Kanuka Mining Company', Table 1). Under their agreement with MMR, Benefone Mining SAS sells the tin and tantalum they produce directly to MMR (Pers Comm, MMR, Feb 2025). Benefone's interest is primarily in lithium exploration in the underlying pegmatites, with established lithium potential shown in ASX reports from Australian Force Commodities, who held both licenses until 2019 in a joint venture with Cominière, named COMFORCE (Force

Commodities Ltd 2019). The project comprised 194 km² across the two contiguous licenses (Table 1, Fig 7). A drilling campaign by Force Commodities in 2018 resulted in 45 holes that intersected several Li-bearing pegmatite sheets with a NE-SW trend, and extending over 5 km in length and 200 m in width (Force Commodities Ltd 2019). MMR reports that the mineralisation type is dominated by lepidolite, rather than spodumene.

Force Commodities also held two licenses directly east of PR12447 (Fig 7), at the Kitotolo-Katamba Lithium Project (PE12453 and PE13247), where initial assay results confirmed high-grade lithium mineralization up to 2.15 wt.% Li_2O. Further assays confirmed high-grade lithium mineralization in several shallow pegmatite bodies. In 2019, Force Commodities also joined forces with Walni Mineral Company (WAMICO) on the Kitotolo West Lithium Project (PR4295), an area of 400 km² contiguous to the Kitotolo-Katamba lithium project, which was considered highly prospective for lithium mineralization with known areas of artisanal mining activities and exposed lithium bearing pegmatites (Force Commodities Ltd 2019). Force Commodities changed its name to Critical Resources Ltd in 2021 and withdrew from its projects in the DRC. The Kitotolo West Project (PR4295) is still listed under WAMICO in the Mining Cadastre, but no recent information can be found online. The exploration licenses for Kitotolo-Katamba were taken over by Zijin, under Joint Venture Katamba Mining, and were transferred to exploitation licenses (PE12453 and PE13247) in 2019 and 2018, respectively (Table 1). Both are listed under 'La Congolaise D'Exploitation Miniere SA' in the DRC Mining Cadaster Portal.

Along the north-east extension of Manono-Kitotolo, Canadian-based AJN Resources (recently changed name to DRC Gold Corp) reports exploration results for the 'Manono Northeast project' in two joint ventures with Palm Constellation SARL and Future Mining Company Sarl (PER14537). The AJN website reports they performed a 6,000 m percussion drilling program to test the potential continuation of the Manono-Kitotolo pegmatites over 7 km of the PR15282 and PR14537 concessions. They report having intersected a flat-dipping pegmatite of 80 by 100 m wide, containing spodumene and minor lepidolite within the PR15282 permit (AJN resources 2024). The pegmatite bodies strike in the same orientation (NE-SW) as the Manono-Kitotolo pegmatites.

AJN (DRC Gold Corp) also has a stake in the Kabunda South project, together with MEK under the name Mining Enterprise Katanga SARLU, which comprises two exploration permits (PR15383 & PR15623, Table 1, Fig 7). The website reports that spodumene pegmatites and associated tin alluvial workings were identified over a total length of 11 km (AJN Resources 2024). Initial sampling and mapping programs identified two priority areas, which cover a strike length of 1.2 km and 1.5 km, respectively, with swarms of pegmatites reaching 300 meter in thickness. Follow up drilling activities were announced on the website. Large spodumene pegmatite occurrences are also reported just south of Kiambi, along the river Luvua, at the Kabombo-Pweto Pegmatite project. These were formerly explored by Force Commodities (, later exploited for Sn-Ta by CHEMAF and now licenced to Pheapon Mining SARL (PE12745, Table 1).

Finally, in 2025 US-based KoBold acquired eight exploration permits in areas surrounding the Manono-Kitotolo pegmatites (Table 1, Fig 7), within the Tanganyika and Haut-Lomami provinces (Reuters 2025b) and announced a large scale exploration campaign including geological mapping and stream sediment sampling. Another five licenses were acquired in early 2026, making a total of thirteen exploration permits, covering an approximate 3000 km^2 (Adombila, 2026; Copperbelt Katanga Mining, 2026). KoBold's entry into the DRC minerals sector occurs within the broader geopolitical context of engagements between the United States and the DRC concerning regional peace, security, and critical mineral supply chains (Reuters 2025c; United States Department of State 2025; BBC 2025; Bloomberg News 2026). KoBold also expressed interest in acquiring AVZ's license of the Roche Dure deposit at Manono (PR13359), but no agreement has been reached to date (EcoFin Agency 2026; Bloomberg News 2026).

6.4 Accessibility and development of infrastructure

After industrial mining ceased in the 80's, the town of Manono fell into economic decline. Manono took a heavy hit during the Second Congo war (1998-2003), and around 2014/2015 was affected by the Katanga insurgency. Many buildings were destroyed, including a brewery, the hospital, a lot of housing and the Belgian-built central cathedral. Power cables were removed and the 54 MW hydro-electric powerplant at Mpiana Mwanga, some 85 km southeast of Manono along the Luvua river, was also damaged, leaving much of the region without stable power supply. After that, electricity was mostly generated using diesel generators, leading to common power outages, until a solar power system at Manono was commissioned by Belgian-based Enerdeal in 2018 (Enerdeal 2018) . The solar installation contains 3,200 solar panels connected to a 3MWh capacity battery system, and provides 1 MWp of power to Manono. This new installation has provided more consistent power supply to Manono's airport, its under-resourced hospital, a school, homes and businesses, although power outages are still common. Enerdeal reports Manono's solar installation represents one of the largest stand-alone (off-grid) installations in Central Africa (Enerdeal 2018).

Since the new interest for industrial lithium mining in and around Manono, plans were also initiated to rehabilitate the powerplant in order to support mining activities. First, Dathomir, who held a 10% stake in Dathcom, agreed with the DRC authorities to rehabilitate and refurbish the road between the plant and Manono in 2017. This was not achieved, and in 2020, an MOU was signed between AVZ and the Congolese authorities to explore the refurbishment of the powerplant (Renewable Energy World 2020; AVZ 2020) . Amid the various legal proceedings mentioned earlier, AVZs plans were stalled and instead, Katamba Mining, a joint venture between Zijin Mining (70%) and Cominière (30%), carried out the refurbishment and in March 2024, the 97-year old facility first restarted its turbines after being out of service for thirty years (Zijin, 2023a, Mukoko Pierre and Luabeya, 2025; Water Power Magazine, 2025) . The renovation required over 80 million USD of investment (Mining Weekly 2025). Online reports state the plant has a capacity of 40 MW with an annual power output of 186 million kWh, which exceeds the original output with 30% (Water Power Magazine 2025; Mining Weekly 2025) . However, reports from a March 2025 MP visit suggest only the first unit was operational, delivering only 4 MW (Mukoko Pierre and Luabeya 2025).

Logistically, the town remains very isolated. The main entry to Manono is by road from Lubumbashi in the south (ca 600 km), or from Kalemie to the east (ca 250 km). Starting from Lubumbashi, it takes one to two days to reach Manono during ideal conditions in the dry season. At the time of the author's visit in 2022, much of the road network between Lubumbashi and Manono was in poor condition, in particular within the Tanganyika province, with some very sandy intervals. Many of the sandy sections become very muddy and difficult to pass during wet season, meaning trucks can take as long as two or three weeks to reach Manono. Overturned and overloaded trucks were commonly observed, and checkpoint roadblocks for revenue - a common issue in eastern DRC (Verwijen et al. 2024) - were encountered at various points, in particular at province borders. Both can seriously delay travel times.

However, in light of the many ongoing exploration activities and planned operations by the many companies discussed above, a significant improvement of the road network between Lubumbashi and Manono is expected. As of yet, Manono is not accessible by rail. The airport of Manono is operational and has seen some minor upgrades recently. A new airstrip is under construction by Zijin in Lake Lukushi to support the influx of workers and materials, but no news of this new airstrip has yet been communicated via the Zijin website. Overall, it is clear that Manono will become less isolated and more easily accessible as a result of these new developments.

7. Artisanal mining

Since the mine closure in the 1980's, artisanal miners continued to work the softer sediments and tailing piles to concentrate cassiterite and coltan. They use the abandoned and flooded quarries and Lukushi river to wash the minerals, or pump water to the sites where digging takes place. Figure 4 shows photos of four digging/washing sites where concentrates were obtained from the miners. The intensity of artisanal and small-scale mining (ASM) activity in the area has gone up and down with the seasons and years depending on tin and tantalum prices, and various other socio-economic factors, such as the implementation of the US Dodd-Frank Act in 2010, which required companies to disclose the origin of their raw materials which significantly affected the ASM sector in eastern DRC (Stoop et al. 2018; Schütte and Näher 2020). Also, an influx of migrants from the Kasai region was noted during our visit in 2022, following alleged political instability and a struggling diamond sector (IPIS 2025b). A UN refugee tent camp was erected north of Manono at Kahungwe to accommodate migrants in 2021, many of whom were working in the artisanal mining sector as the sole opportunity of generating income.

The IPIS Open Data Dashboard reports 24 active 'mining sites' immediately surrounding the old Manono-Kitotolo mines, at which a total of 6112 workers were reported during various IPIS visits in 2017. Six of these are registered as managed by SAEMAPE (Division des Mines) and part of the ITSCI traceability scheme, with Lubumbashi listed as the destination of the ore (IPIS 2021). No armed actors were reported in any mines near Manono.

A time series of satellite images clearly documents the appearance and expansion of artisanal dig sites through time south-west of Manono (Fig 6), creating bare soil exposure scattered with small round or square pools (pits and washing ponds), and producing a lunar-like cratered landscape. The areas are stripped off the first few meters of soil. Abandoned sites show partial regrowth of vegetation within one to three years, but the cratered features remain visible in the landscape (Fig 6). In May 2024, a major expansion and southwest-ward migration can be seen in the dig sites, potentially suggesting a new influx of workers. Without any form of rehabilitation or environmental restoration, these vast plots of land will remain unsuitable for urban expansion or agricultural use. The Lukushi river near the outlet of Lake Lukushi was largely filled with sediment from artisanal mining at the time of our visit. Lake Lukushi, now drained, was an important source of fish to the local community. As such, the overall impact on the environment of both artisanal and industrial activities can not be underestimated and require further study and observation.

In the wider region of the Tanganyika, Haut Lomami and Haut-Katanga Provinces, over 38.000 artisanal mine workers were counted during site visits according to the IPIS Open Data Dashboard (IPIS 2021) An estimated 27.000 workers were involved specifically in cassiterite and coltan mining sites. In the Tanganyika province, IPIS (2021) reported a strong presence of armed groups at 18 out of the 81 mining sites visited, with most groups appearing at least once per week. Additionally, child labor was observed at 10 of these sites. In contrast, no armed groups were reported at the 21 mining sites visited in Haut-Katanga, although child labor was observed on at least 2 sites. In the 73 mining sites visited in Haut Lomami, there were no reports of armed groups, but child labor was reported at 5 sites.

Unfortunately, formal information on the number of artisanal miners remains limited, with the primary data source being the IPIS database, which compiles site visit data from between 2009 and 2023. However, most of IPIS' visits to Manono area in Tanganyika and the nearby provinces occurred between 2015 and 2017, meaning the information has not been updated to reflect the current geopolitical context, the observed spatial increase in tin and tantalum artisanal mining and the discovery and exploration of additional lithium-tin-tantalum deposits. Consequently, it is difficult to assess whether the numbers reflect actual operations and, more importantly, the conditions under which artisanal miners currently operate in the area.

8 Conclusions

The Manono-Kitotolo pegmatite system represents a globally significant metallogenic province for lithium, tin, and tantalum. It has a long-standing history of both industrial and artisanal mining, and has recently attracted renewed interest, particularly for lithium exploration. Recent exploration campaigns have led to the discovery of additional pegmatites along the southwestern and northeastern extensions of the main Manono-Kitotolo system, as well as along parallel structural corridors. These support the existence of several large NE-SW trending crustal structures that served as favourable conduits for pegmatite emplacement.

These new findings highlight the vast scale of this mineralised lithium pegmatite district within the Kibara Belt, and confirm its status as the largest known lithium pegmatite system in the world. The resurgence of industrial interest is expected to stimulate significant investment in local infrastructure, improving accessibility to the region.

However, alongside these economic opportunities, the region and its population are likely to face substantial environmental and social challenges associated with mining activities, similar to those observed in the Copperbelt. These challenges may include the regulation of widespread artisanal mining, potential tensions between industrial and artisanal operators, land-use disputes, and broader geopolitical, environmental and social issues tied to resource exploitation.

While the growing global demand for critical minerals underscores the strategic importance of the Manono-Kitotolo metallogenic province, achieving sustainable development will require careful management and governance of these complex socio-economic, environmental and political dynamics. This study provides a foundation for understanding the deposit's geological potential while emphasizing the necessity of responsible and sustainable resource management in the Democratic Republic of the Congo.

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10 Conflict of Interest

The authors declare they have no competing financial interests.

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Tables

Type	License*	Validity**	Name on CAMI permit	Project Name	Abb (Fig1)	Nearest Villages/Geographic points	Companies	Minerals
Exploitation licenses	PE15775	2024-2049	Manono Lithium SAS	Manono North East Lithium Exploration Project	MK	Manono	JIN CHENG(Zijin)/Cominiere SA	Spodumene, Cassiterite, CGM
	PE12447	2022-2047	United Cominiere SAS	TITAN South, Lubule alluvial project	TT	Lubule river	Tantalex/United Cominiere SA	Cassiterite, CGM
	PE13082	2013-2043	Benefone Mining SAS	Kanuka Tin Project	KN	Kanuka, Kania river, Malala river	MMR/Cominiere SA (Force Comodities***)	Lepidolite, Cassiterite, CGM
	PE12745	2017-2047	Pheapon Mining SARL	Kiambi Kabombo-Pweto Pegmatite Project	KP	Kiambi, Kabombo, Pweto, Luvua river	CHEMAF/Benefone Mining	Spodumene, Cassiterite, CGM
	PE13065	2013-2043	Societe D'Exploitation des Gisements de Malemba Nkulu	Katondo-Mwanza Project	KD	Mwanza, Malemba-Nkulu	MMR	Cassiterite, CGM
	PE12442	2023-2048	Tantalum and Niobium from Tanganyika	Kabunda Project	KB	Kapongola, Kipaila, Luvua River	Unknown	Cassiterite, CGM
	PE12453-NP	2019-2044	La Congolaise D'Exploitation Miniere SA	Kitotolo-Katamba Lithium Project	-	Katamba, Mulenda	Zijin/Cominiere SA (Force Comodities***)	Cassiterite, CGM
	PE13247-NP	2018-2048	La Congolaise D'Exploitation Miniere SA	Kitotolo-Katamba Lithium Project	-	Katamba, Mulenda	Zijin/Cominiere SA (Force Comodities***)	Cassiterite, CGM
	PE4295	2023-2038	Walni Mineral Company SARL	Kitotolo West Lithum Project		Mulongo	WAMICO/Cominiere SA	Cassiterite, CGM
	PE12562	2013-2043	Kisengo Mining	Kisengo Project	KS	Kisengo, Nyunza	Kisengo Mining/MMR	Cassiterite, CGM
	PR13081	2013-2043	Crown Mining SARL	Kamola Lithium Project JV (north)	-	Bukena, Lac Bowe	HIPO/Crown Mining SARL	Lepidolite, Cassiterite, CGM
	PE14813	2023-2048	Crown Mining SARL	Kamola Lithium Project JV (south)	KM	Mukwende, Kamola	HIPO/Crown Mining SARL	Cassiterite, CGM
Exploration licenses	PR13359	2021-2027	La Congolaise D'Exploitation Miniere SA	Manono Lithium Tin Project	MK	Manono	AVZ/Cominiere SA	Spodumene, Cassiterite, CGM
	PR15282	2023-2028	Palm Constellation SARL (100%)	Manono Northeast Project	-	Manono	AJN Resources/Palm Constellation SARL	Spodumene, Cassiterite, CGM
	PR15383, PR15623	2023-2028	Mining Enterprise Katanga SARLU (100%)	Kabunda South Project	KB	Kapongola, Dela, Luvua River	AJN Resources//MEK	Spodumene, Cassiterite, CGM
	PR15648	2023-2028	Guilgal SARL	-	-	Kapongola, Dela, Luvua River	Guilgal SARL	tbc
	PR15324	2023-2028	Charlize Ressources SAS	Kanuka north Project	KN	Kanuka	Charlize Ressources SAS	Lepidolite, Cassiterite, CGM
	PR15325	2023-2028	OVK Mining SARL	Kanuka north Project	-	Kanuka	OVK Mining SARL	Lepidolite, Cassiterite, CGM
	PR16318 to PR16324, PR16513	2025-2030	Kobold Exploration DRC SA	Various areas	-	Musofoi, Kitombetombe, Lusonde	KoBold Metals	tbc
Expired exploration/exploitaiton license, awaiting status change	PER13698	2017-2022	Minocom Mining SAS (100%)	Manono Lithium Tin Tailings Project	MK	Manono	Tantalex/Minor SARL/Cominiere SA	Spodumene, Cassiterite, CGM
	PER12447, PER12448	2016-2019	United Cominiere SAS (100%)	TITAN north, Pegmatite Corridor (Buckell Lithium Project)	TT		Tantalex/Cominiere SA	Spodumene, Cassiterite, CGM
	PER14537	2019-2024	Future Mining SARL	Manono Northeast Project	-		AJN Resources/Future Mining SARL	tbc
	PER4076, PER15278, PER4072	2010-2021	Crown Mining SARL (100%)	Kamola Lithium Project JV	KM	Mukwende, Kamola	HIPO/Crown Mining SARL	Lepidolite, Cassiterite, CGM
	PER4100	2010-2015	Kanuka Mining Company (100%)	Kanuka Lithium Tin Project	KN	Kanuka, Kania river, Malala river	MMR/Cominiere SA/Force Comodities***	Lepidolite, Cassiterite, CGM

* PE = Permis d'Exploitation, PR = Permis de Recherche, PER = Permis Actif en Transformation de PR en PE, expired or status unclear. As reported on DRC Mining Cadastre Portal (last consulted on 11/02/2026)

** Validity as reported on DRC Mining Cadaster Portal

** Force Commodities changed name to Critical Resources in 2021. The company is no longer involved in DRC projects

Table 1. Selection of active exploration and exploitation permits in the Manono-Kitotolo region as discussed in the text. This list is not exhaustive. License information is based on records available through the DRC Mining Cadastre Portal (CAMI), last consulted on 12 Feb 2026. The legal status of certain permits remains subject to ongoing disputes and/or arbitration proceedings; inclusion in this table reflects their listing in official cadastral records at the time of consultation and does not imply endorsement of, or judgment regarding, their legal validity. Companies participating in joint ventures are identified to the best of the authors' knowledge based on publicly available company disclosures and reports, and may not represent complete ownership structure.

Figures

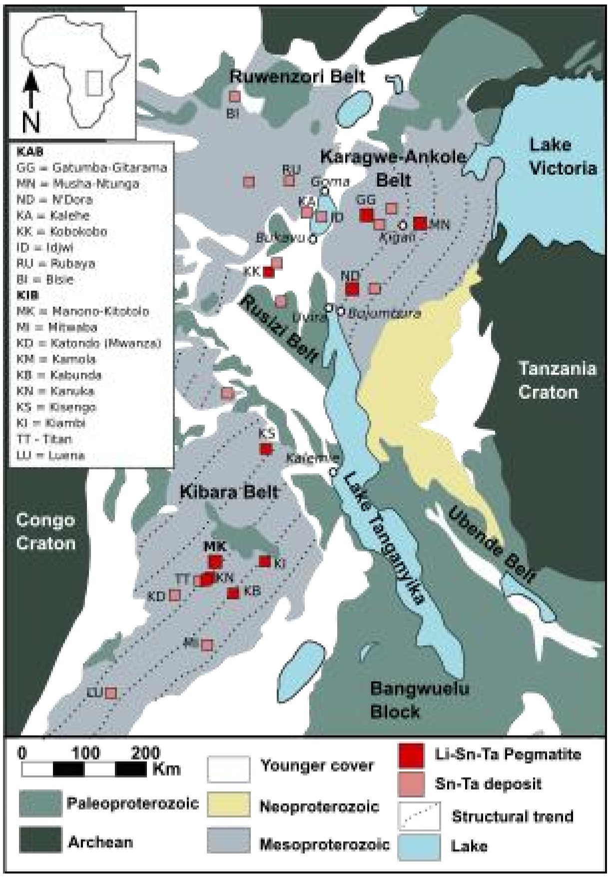

Fig 1. Geological overview of the Mesoproterozoic Kibara and Karagwe-Ankole Belts and location of known Li-Sn-Ta pegmatites and Sn-Ta extraction sites. Manono-Kitotolo (MK) pegmatites indicated in bold. Simplified base map modified after Koegelenberg and Kisters (2014).

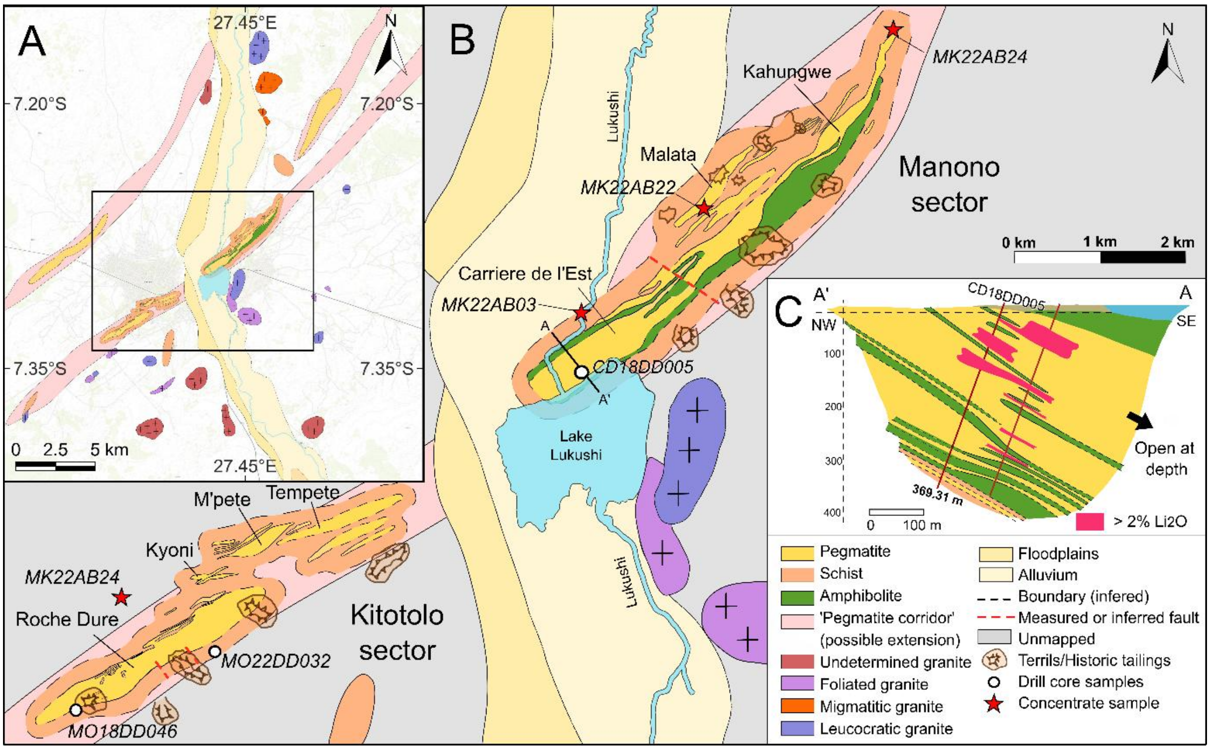

Fig 2. Overview (A) and detailed (B) geological map of the Manono-Kitotolo area, showing the Roche Dure, Kyoni, M'pete and Tempete (Carriere 5) pegmatites in the Kitotolo sector and Carriere De L'Est, Malata (Carriere 6) and Kahungwe in the Manono sector. Drill cores (white circles) and artisanal concentrate sample locations (red stars) are indicated. C) A cross-section A-A' at Carriere De L'Est showing the dip and thickness of the pegmatite system based on drill core data, modified after AVZ ASX (2024).

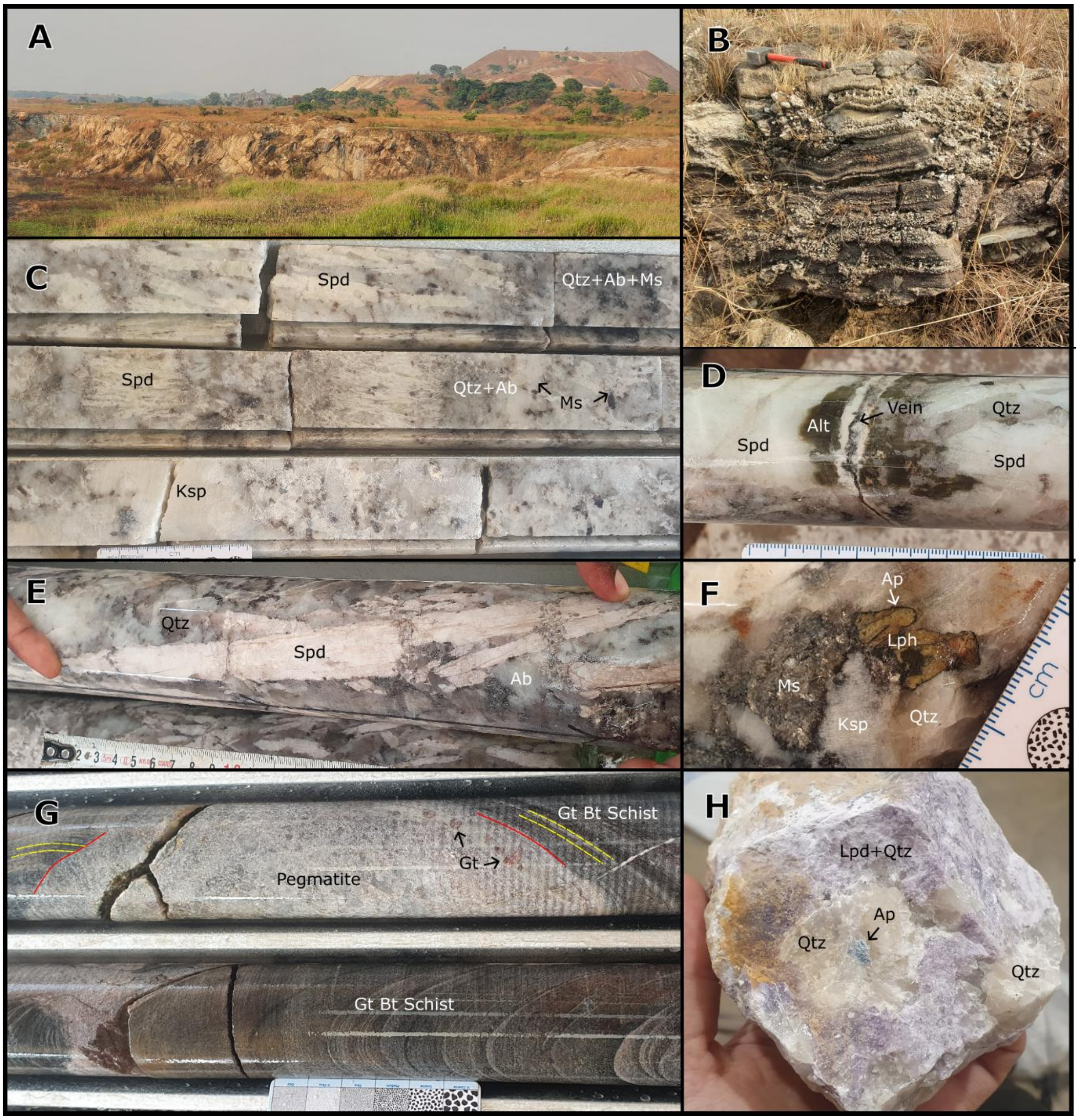

Fig 3. A) *View over Roche dure quarry showing southeast dipping layering from a distance. Waste pile (terril) G is visible in the background. B) Aplite layering visible in outcrop at Carriere De L'Est. C-F) Photos of drill cores from Roche dure and Carriere De L'Est pegmatites, with typical unidirectional growth of spodumene. Decimeter scale textural and compositional zoning is visible in C, with alternating spodumene- zones and albite- or quartz-rich zones. Variable degrees of albitisation and greisenisation are observed throughout the drill core. D) Alteration of spodumene is expressed by green discoloration along fractures or in outcrop. White alteration is kaolinite. E) Fresh spodumene crystals are white and can exceed 40 cm in length. F) Phosphates are lithiophilite-triphylite, often replaced by apatite, and associated with muscovite patches G) Host rock garnet biotite schist crosscut by granitic pegmatite pocket, with garnet along the contacts. H) Lepidolite sample with patches of quartz and blue mangano-fluorapatite.*

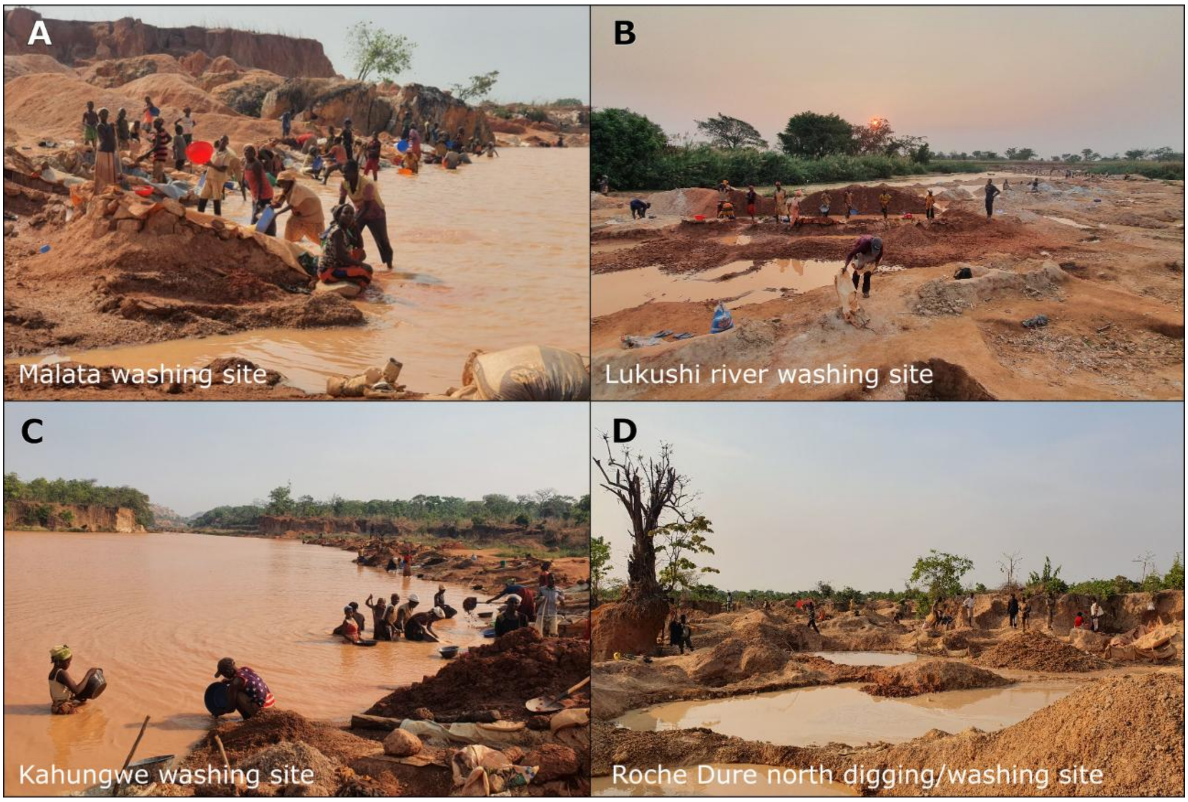

Fig 4. *Artisanal mining activities of cassiterite and columbite-tantalite from alluvial and eluvial deposits surrounding the Manono-Kitotolo sites.* ***A)*** *Miners concentrating heavy minerals in the flooded quarry of the Malata pegmatite (near IPIS site: Ngobo/La mort) .* ***B)*** *Washing site in the Lukushi river (IPIS site: Kalunda Byenge).* ***C)*** *Washing site in the flooded quarry of the Kahungwe pegmatite (IPIS site: Bondo).* ***D)*** *Digging and washing site near the Roche Dure quarry (near IPIS site: Sanka 1&2). Photos @ Anouk Borst, August 2022.*

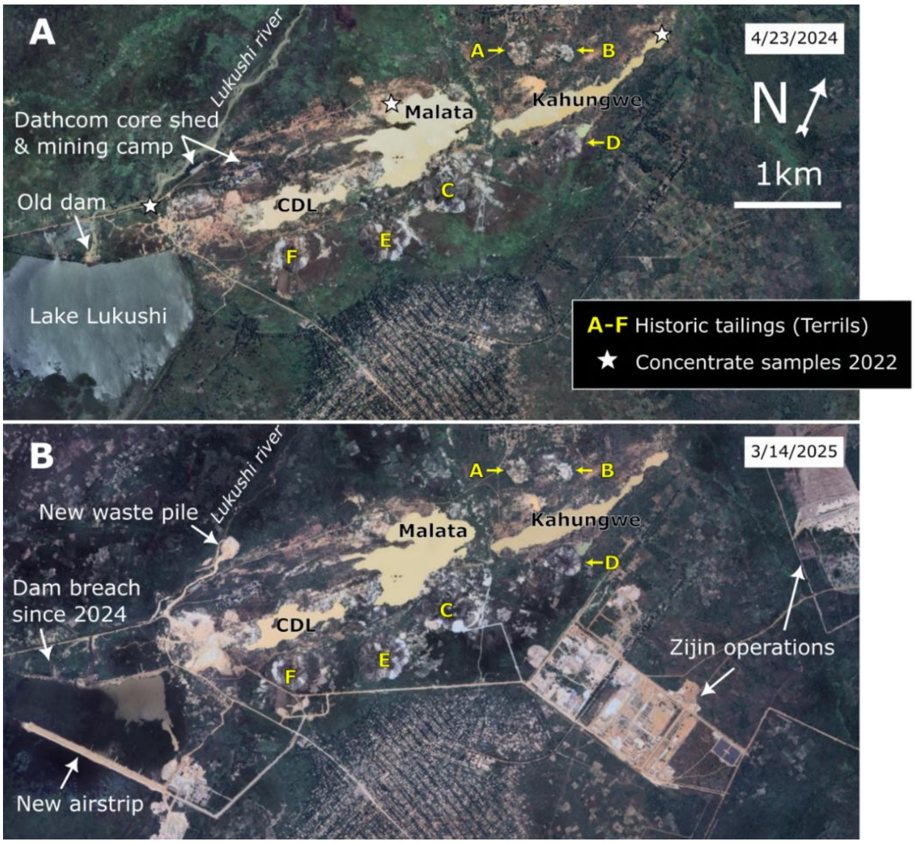

Fig 5. *Recent activity at the Manono sector (Manono Lithium project, PR15775) including the construction of an airstrip in the nearly drained Lake Lukushi, and two industrial sites east of the quarries. CDL = Carriere De L'Est. Sampling sites of artisanal mineral concentrates are shown in A.*

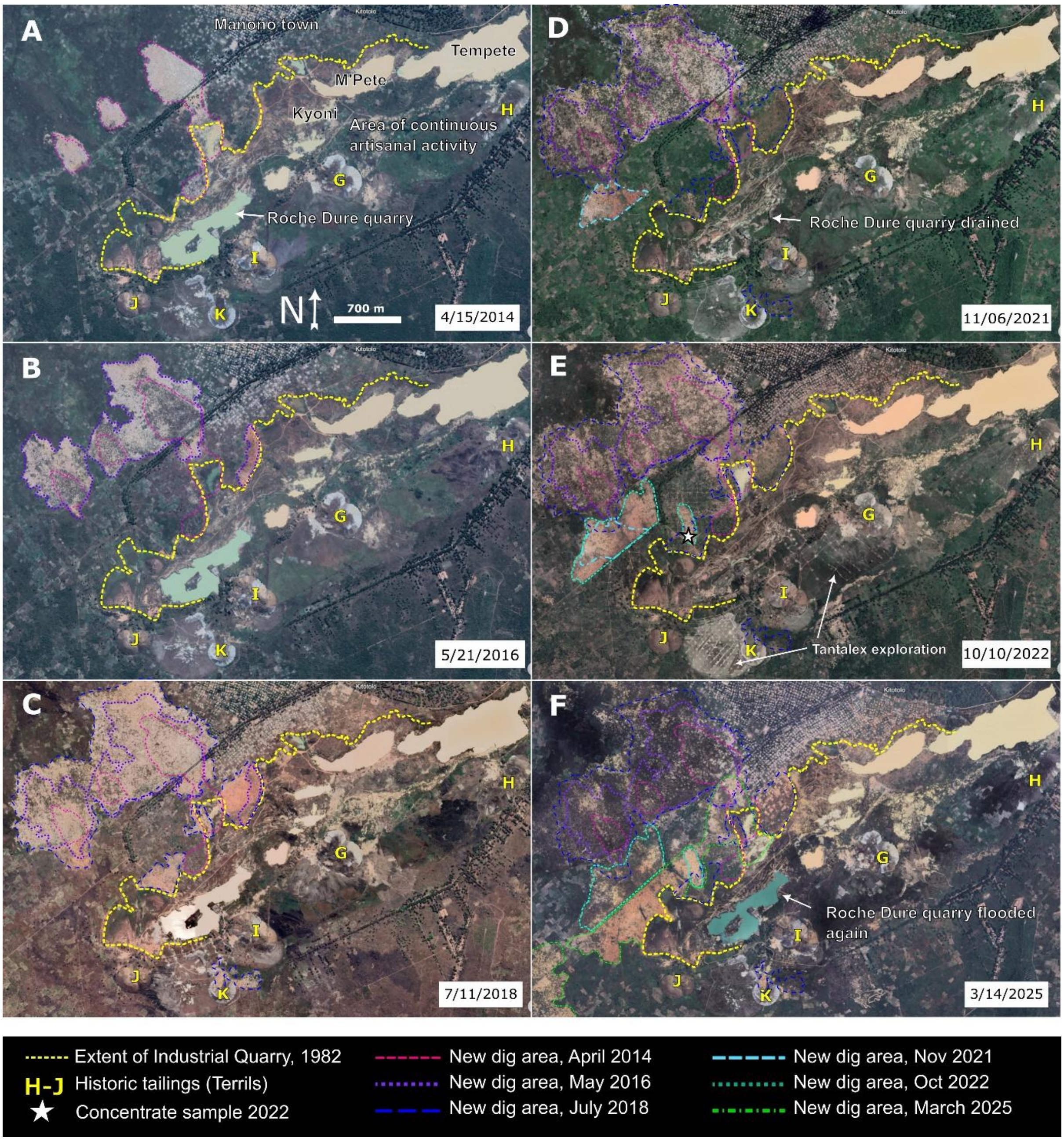

Fig 6A-F. *Expansion of artisanal dig sites in and around the Kitotolo sector as seen from a Google Earth time series between 2014 and 2025. Prior to 2014, most artisanal mining activity took place within the perimeter of the old quarries (yellow stippled lines). Smaller areas outside are starting to be dug up north of Roche Dure quarry. These areas have expanded rapidly between 2014 and 2025, as highlighted by the coloured outlines (total area encompassing over 6 km^2). The Roche Dure quarry was drained for drilling by Dathcom in 2019, and was flooded again by 2024. Sampling and drilling activities on the tailings terraces at terrils G and K by Tantalex are visible in 2022 (E). Photos sourced from Google Earth (Landsat/Copernicus, Airbus, Maxar Technologies).*

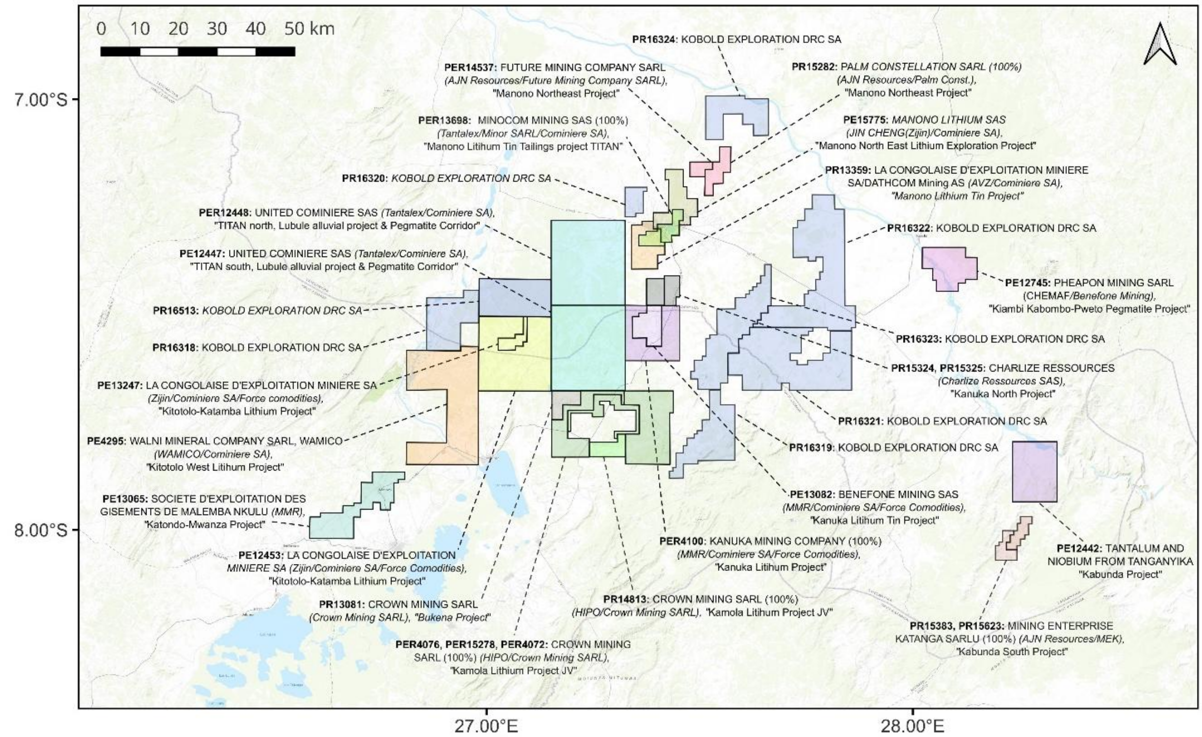

Fig 7. Selection of exploration and exploitation licenses in the wider Manono region, extending across the Tanganyika, Haut-Lomami and Haut-Katanga Provinces, as registered in the DRC Mining Cadastre Portal (last accessed: 11/02/2026). Boundaries are shown for illustrative purposes only. The legal status of certain licenses remains subject to ongoing arbitration proceedings; depiction in this figure reflects their listing in DRC cadastral records at the time of consultation and does not imply endorsement or confirmation of legal validity. Further details are provided in Table 1.

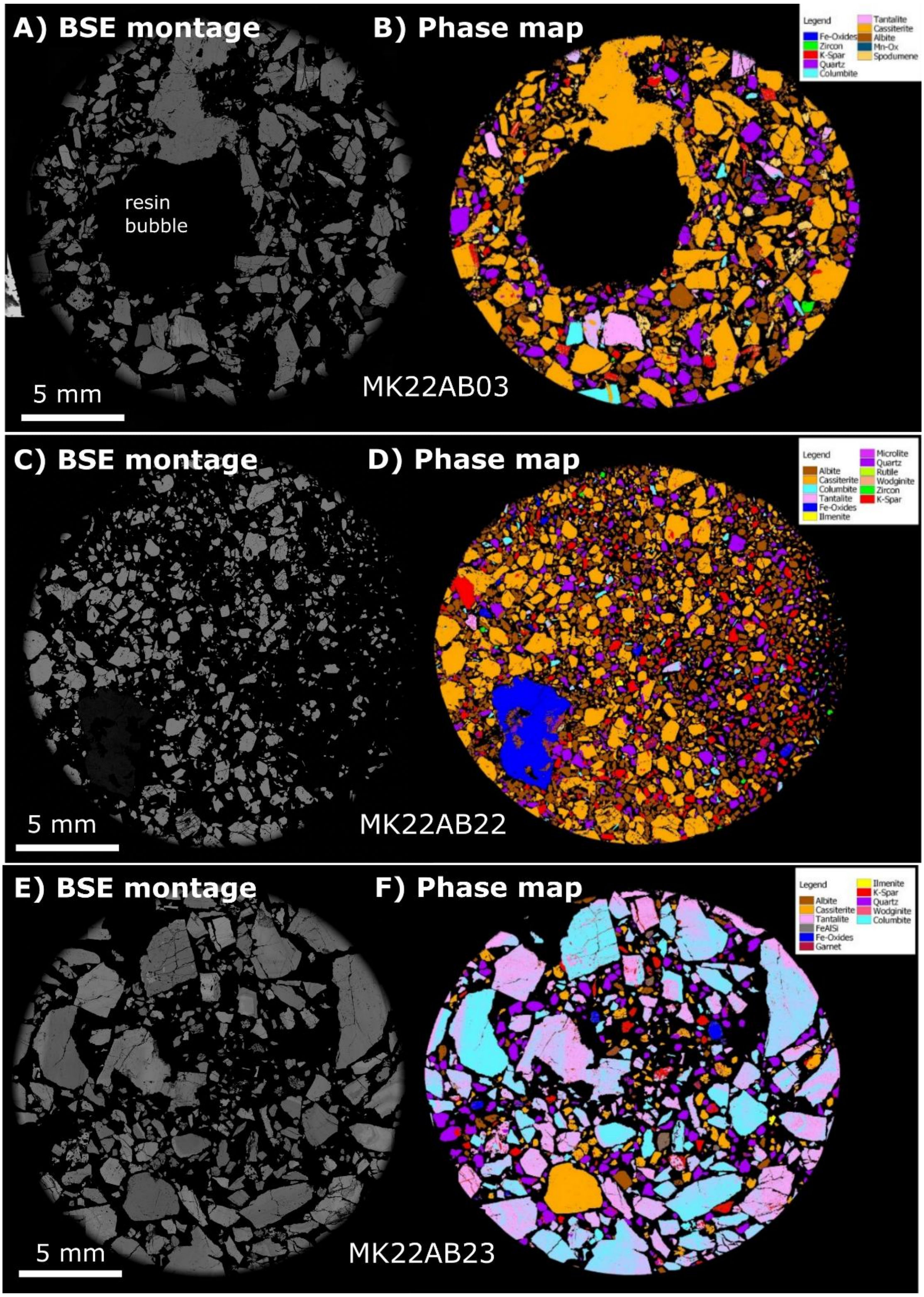

Fig 8. A,C,E) *Backscatter electron images and* ***B,D,F)*** *classified phase maps based on EDS elemental intensity maps for three mineral mounts collected from artisanal miners in the Manono-Kitotolo area. Locations of samples are shown on Fig 2. Modal abundance estimates (Meeus 2025) are provided in the text.*

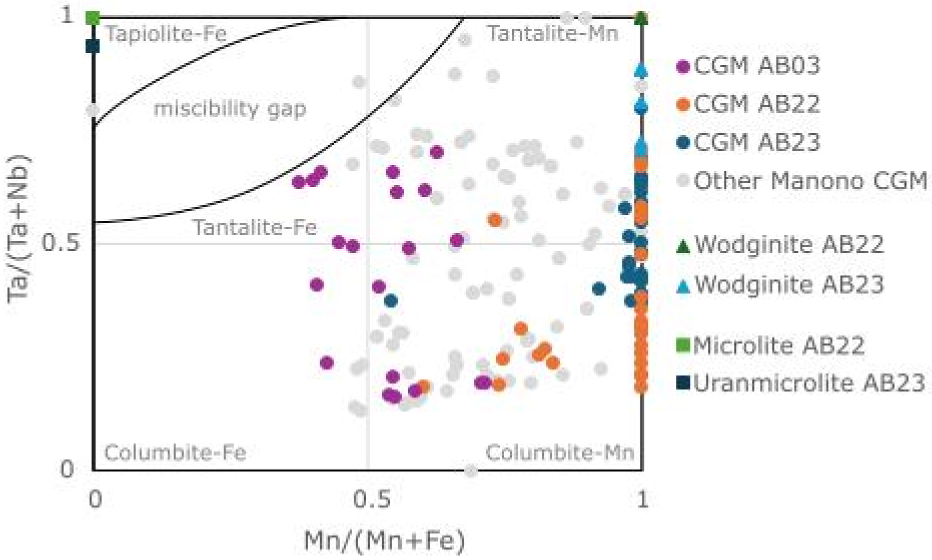

Fig 9. *Quadrilateral diagram of the columbite-tantalite group minerals (CGM) from the artisanal concentrates of the Manono quarries, showing moderate Mn enrichment in MK22AB03 (Lukushi river) compared to dominantly Mn-endmembers in MK22AB22 (Malata) and MK22AB23 (Kahungwe). Locations of samples are shown in Fig 2.*