

3D geological model for Tampia gold deposit – overview and list of components

P Duuring

Introduction

The Tampia gold deposit, located in the Youanmi Terrane about 245 km east of Perth (Fig. 1), is representative of granulite-hosted gold mineralization in the region. To better understand its geological features, a 3D geological model has been created by integrating pit mapping and drillhole data. The resultant model allows us to visualize and analyse the relationships among different rock types, mineralization and structures within the deposit.

Gold zones within the Tampia deposit are primarily found in mafic gneiss, with some occurrences in felsic gneiss. These lithologies are intruded by leucogranite, granodiorite and diorite, whereas shear zones and pegmatitic quartz veins locally intersect these intrusive rocks (Fig. 1). The dimensions of the geological model are about 1100 m from north to south, 960 m from east to west, and 380 m from the current surface to the base of the model.

Drillhole data play a crucial role in constructing the geological model. Grade-control drillholes are densely spaced within the Tampia pit shell on an 8 x 8 m grid, providing detailed information about the deposit's characteristics. Beyond 100 m from the pit walls, exploration drillholes are spaced 25 m apart along east–west traverses, with a north–south interval of 100 m between traverses. Infill drilling has been conducted within an area about 100 m outboard of the pit perimeter, with drillholes spaced about 40 x 40 m.

The generation of the 3D geological model involved a systematic workflow. The drillhole data, including collar, survey, lithology, assay and oxidation information, underwent minor harmonization. These data were then integrated with GIS geology maps, structural orientation data and drone imagery of the pits using Leapfrog Geo, version 2023.1, geological modelling software <www.seequent.com/products-solutions/leapfrog-geo/#overview>.

The software's interpolation algorithms were utilized to create a categorical geological model, producing isosurfaces for different categories such as the Fault System, Erosion, Vein System and Intrusion surface models. Detailed descriptions of the model's isosurfaces and their construction methodologies are documented in Tables 1 to 6.

An iterative process was employed to refine the generated isosurfaces. This process involved comparing the isosurfaces with information gathered from drillhole and pit mapping observations. Furthermore, Leapfrog Geo numerical models were developed to represent attributes such as gold, arsenic, sulfur and oxidation intensity. The advantage of using numerical (instead of categorical) models is their ability to project this information onto the geological model as translucent layers, preserving the underlying polygons rather than replacing them entirely.

The 3D geological model for the Tampia gold deposit can be accessed and explored using the free Leapfrog Viewer software <www.seequent.com/products-solutions/leapfrog-viewer/>. This software enables users to manipulate the model by rotating, selectively hiding specific volumes, and creating sliced projections. Figures 2 to 6 provide visual examples of these manipulations. Additionally, the model supports the generation of serial cross-sections, long sections and horizontal slices, which assist in visualizing the geology of the Tampia deposit, identifying trends and testing hypotheses.

Overall, the 3D geological model of the Tampia gold deposit offers valuable insights into the deposit's geology and its complex relationships. It serves as a powerful tool for researchers and geologists to study and understand the deposit, which will aid decision-making processes related to mining operations and further exploration activities.

The study presented in this metadata report is the result of a collaborative MRIWA research project, M10433, 'Detection of Distal Footprints of Minerals Systems in the southwest of Western Australia: Linking basement and Cover,' between the Geological Survey of Western Australia (GSWA) and CSIRO, Minerals Research Institute of Western Australia (MRIWA), Anglo American Ltd and Ramelius Resources Ltd.

The principal objective of this research is to build a contextual framework to help more efficient mineral exploration protocols in the southwest region of Western Australia. This research aims to better understand how the basement and cover variability of the area are linked, and how these links can be used to vector mineral systems at depth and in the cover.



Acknowledgement of Country

We respectfully acknowledge Aboriginal peoples as the Traditional Custodians of this land on which we deliver our services to the communities throughout Western Australia. We acknowledge their enduring connection to the lands, waterways and communities and pay our respects to Elders past and present.



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Figure 1. An interpreted solid geology map for the Tampia deposit, incorporating drillhole lithological information

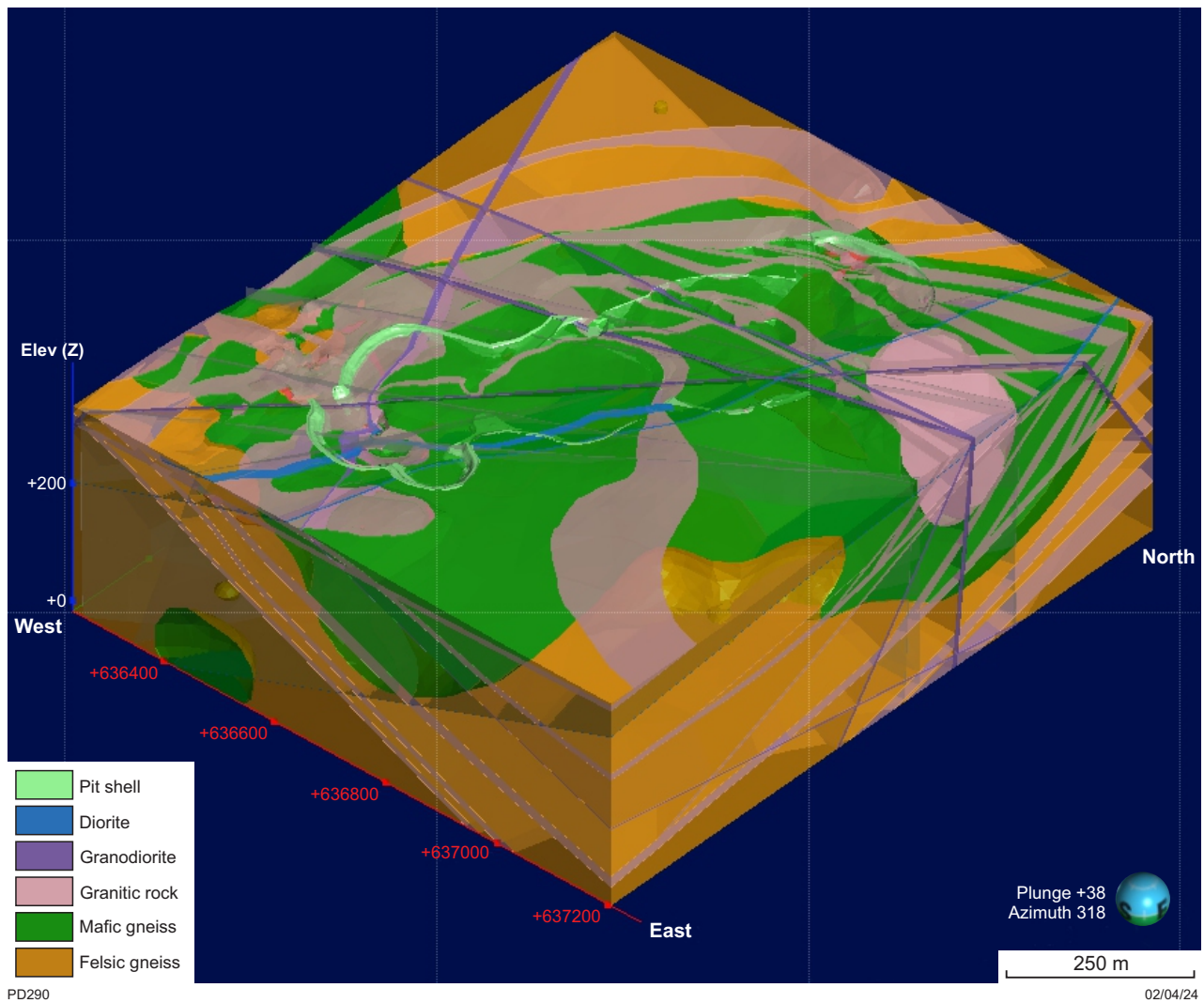


Figure 2. The Tampia geological model showcasing the distribution of major rock types. The view is downward facing and towards the northwest. The light-green outline of the final Tampia pit shell as of October 2023 is included for reference

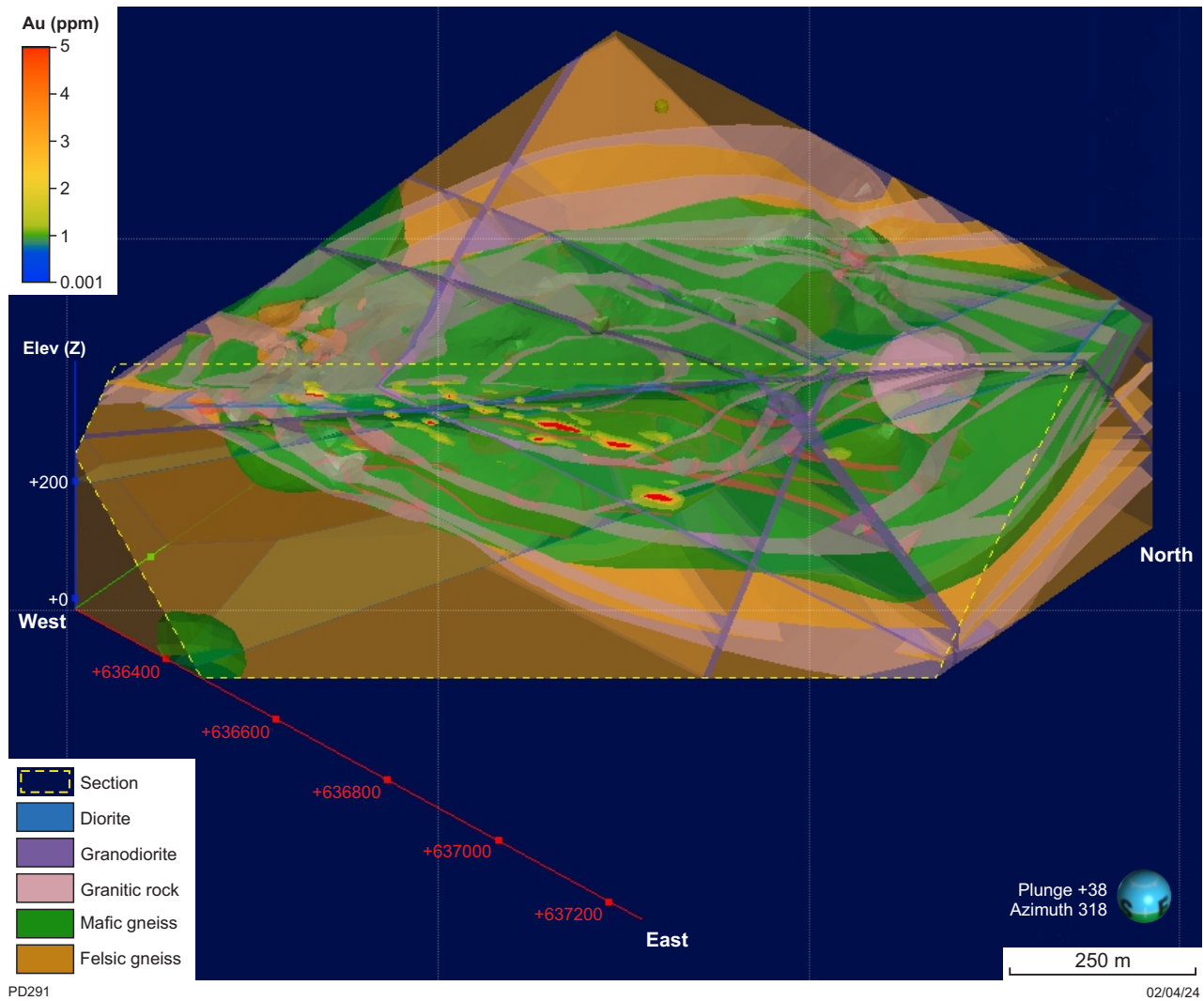


Figure 3. The identical perspective to Figure 2; however, in this image high-grade Au zones are included and the front portion of the model has been removed to reveal east-dipping gold zones (bright red lenses) hosted by mafic gneiss (green). The view is downward facing and towards the northwest

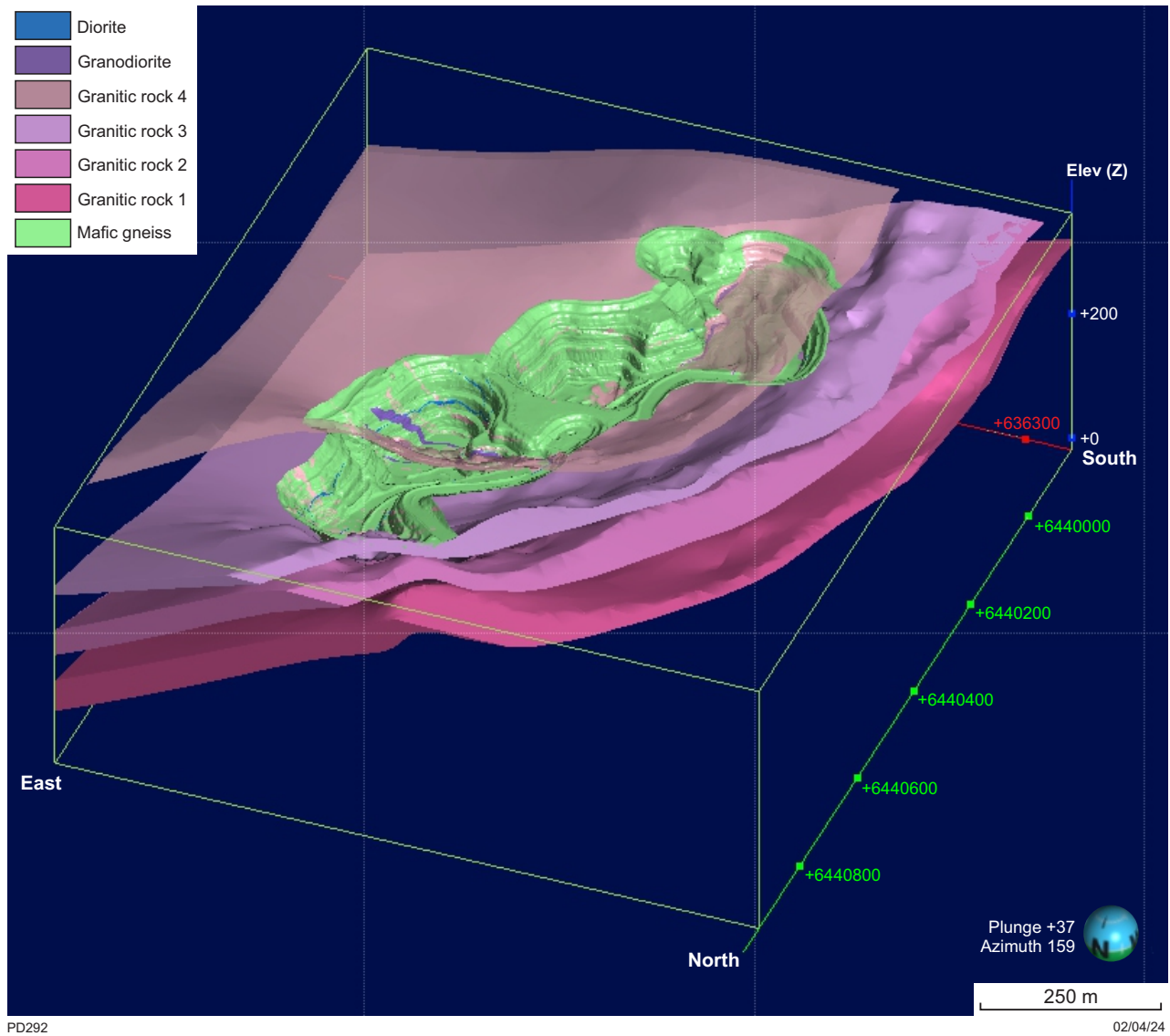


Figure 4. The geological model demonstrates the stacked layer geometry of east-dipping leucogranite intrusions (in shades of pink). The view is downward facing and towards the south-southeast

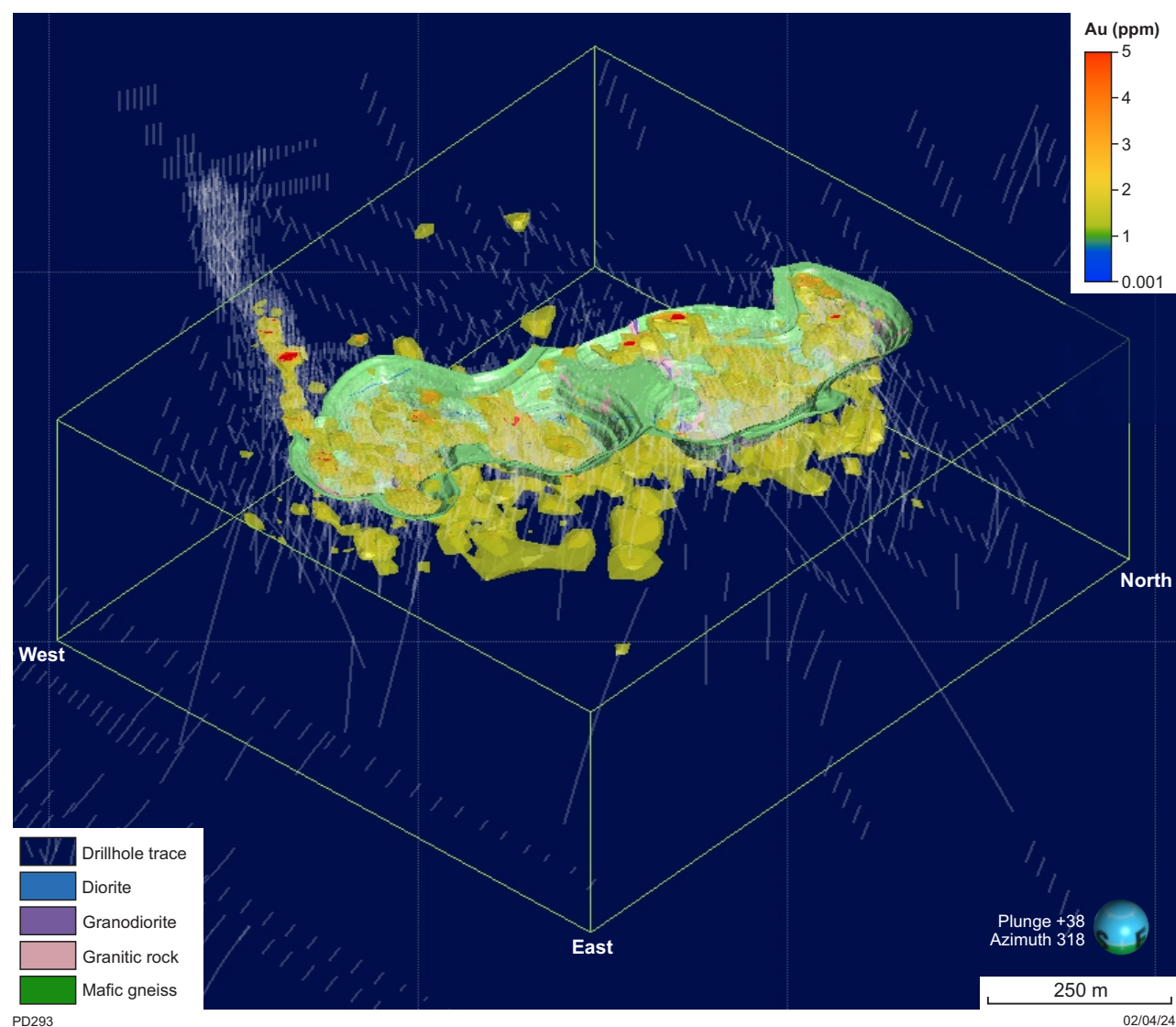


Figure 5. The geological model shows the distribution of east-dipping, high-grade Au isosurfaces (in yellow and red). Drillhole traces are displayed as grey lines. The view is downward facing and towards the northwest

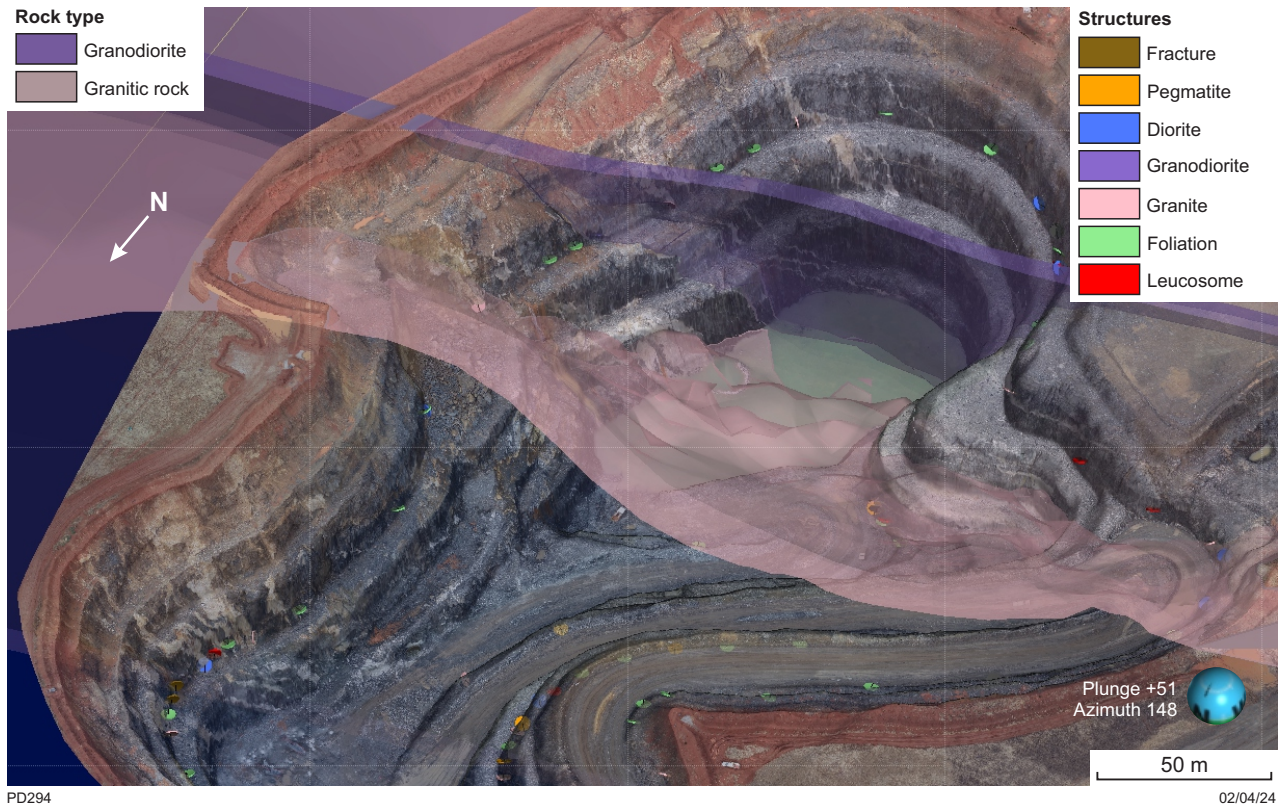


Figure 6. Close-up view of the eastern wall of the North pit intersected by leucogranite (pink) and granodiorite (purple) intrusions. The drone image is draped over the pit shell, and structural measurements are represented as coloured discs. The view is downward facing and towards the southeast

List of components

Table 1. Geological model – descriptions and specifications for geological components of the model

| <i>Object</i> | <i>Description</i> | <i>Model specifications</i> | <i>Feature category</i> | <i>Spatial type</i> |
|----------------------|--|---|-----------------------------|---------------------|
| Boundary | The boundary of the geological model is a rectangular prism defined by the pre-mining topographic surface. It extends about 150 m beyond the Tampia pit in the north, south, west and east directions, aligning with the shift from closely spaced grade-control drilling to wider spaced exploration drilling. The vertical limit of the model is roughly twice the depth of nearby exploration drillholes at the Tampia pit | | Reference frame | Reference frame |
| Fault system | Five major fault zones were identified during mapping. Fault intersections in pit walls were used to model five corresponding fault surfaces. These fault surfaces are extended to the boundary margins of the geological model, without applying any relative chronology | Layer names are <i>GM_Tampia: Fault_1</i> , <i>GM_Tampia: Fault_2</i> , <i>GM_Tampia: Fault_3</i> , <i>GM_Tampia: Fault_4</i> , <i>GM_Tampia: Fault_5</i> The faults have a surface resolution of 30 m with adaptive isosurfacing applied | Geology, Mapping | Isosurface |
| Transported material | Drillholes intersect transported material, which represents an erosional surface with oxidized in situ rock | Layer name is <i>GM_Tampia: Transported material</i> The Erosion Model employs a surface resolution of 30 m and utilizes adaptive isosurfacing. It is specifically snapped to drilling data, with a maximum snap distance of 15 m, to ensure alignment with the available drilling information for accurate representation | Geology, Drillhole | Isosurface, Volume |
| Diorite | Drillholes intersect three main diorite intrusions. These diorite intervals were labelled as Diorite_1 to Diorite_3 and modelled as distinct components of a Vein System Model. No chronology was applied to them. Diorite_1 and Diorite_2 are visible in the pit walls | The layer name is <i>GM_Tampia: Diorite</i> The Vein System Model features a surface resolution of 30 m, utilizing adaptive isosurfacing without applying any snapping to data. To achieve a continuous surface, a minimum thickness of 1 or 2 m is applied during the generation process | Geology, Drillhole, Mapping | Isosurface, Volume |
| Granodiorite | Drillholes intersect four granodiorite intrusions labelled as Granodiorite_1 to Granodiorite_4. These intrusions were also observed in the pit walls | The layer name is <i>GM_Tampia: Granodiorite</i> The Vein System Model utilizes a surface resolution of 30 m. It employs adaptive isosurfacing, which is snapped to all available data, including drillholes and user-generated polylines that describe the hangingwall and footwall margins of mapped intrusions. The maximum snap distance is about 6 m, facilitating accurate alignment. In certain instances, a minimum thickness of less than 8 m is applied to guarantee the continuity of the surface. Isosurfaces are projected to boundary extents | Geology, Drillhole, Mapping | Isosurface, Volume |
| Leucogranite | Pit mapping demonstrated the existence of numerous 0.5 to 5 m-wide, leucogranite intrusions. Leucogranite intervals in Lithology logs indicate great complexity, most likely because of mafic gneiss fragments within intrusions, or the presence of thin felsic dykes. To simplify the geological model, these complex occurrences were combined and treated as single wide intrusions. Thirteen leucogranite intrusions were modelled (Leucogranite_1 to Leucogranite_13) by attributing these names to the Lithology log and then modelling each intrusion individually | The layer name is <i>GM_Tampia: Leucogranite</i> The Vein System Model has a surface resolution of 30 m. It utilizes adaptive isosurfacing, which is snapped exclusively to drilling data, with a maximum snap distance of about 6 m. In certain cases, user-generated polylines are employed to describe the hangingwall and footwall margins of mapped intrusions. To ensure continuous surfaces, a minimum thickness of 5–10 m is maintained. Isosurfaces for Leucogranites_6 to 10 are terminated against Leucogranite_11 to represent splays originating from a larger intrusion. Similarly, narrow intrusions 3 and 4 are terminated against intrusion 5 | Geology, Drillhole, Mapping | Isosurface, Volume |

Table 1. continued

| Object | Description | Model specifications | Feature category | Spatial type |
|-----------------|--|--|--------------------|--------------------|
| Leucogranite_14 | Drillholes located east of the North pit intersect extensive intervals of granitic rock, ranging from 50 to 110 m in length. An isosurface has been generated using the Intrusion Model to create a rounded morphology | The layer name is <i>GM_Tampia: Leucogranite_14</i> The Intrusion Model has a surface resolution of 15 m. It uses adaptive isosurfacing, which is snapped to drilling data, with a maximum snap distance of 8 m. A Spheroidal interpolant is employed (with a Base Range of 300 m, which is about twice the average drillhole spacing in this area of the deposit) | Geology, Drillhole | Isosurface, Volume |
| Leucosome | Before applying the Vein System algorithm for modelling, leucosomes in mafic gneiss were categorized into one of 12 leucosome classes. Pit mapping observations reveal that these leucosomes appear as stacked narrow sheets parallel to the foliation within the mafic gneiss. This layer combines all modelled leucosome occurrences | The layer name is <i>GM_Tampia: Leucosome_1</i> The Vein System Model features a surface resolution of 30 m and utilizes adaptive isosurfacing snapped to drilling data, with a maximum snap distance of about 15 m. In some cases, a minimum thickness of less than 2 m is applied to ensure continuous surfaces. The model conveniently groups multiple surfaces without requiring priority or interaction rules since the leucosomes do not intersect each other. Instead of projecting the isosurfaces to boundary extents, manual clipping is applied near the drill data to maintain the condition that the leucosomes are hosted by mafic gneiss and do not extend into distant rock types | Geology, Drillhole | Isosurface, Volume |
| Mafic gneiss | Mafic gneiss is the dominant exposed rock type in the Tampia pit. At greater depths beneath the pit it is in lithological contact with felsic gneiss. To achieve a rounded morphology, the mafic gneiss was modelled as an intrusion. The exclusion of all younger rock types minimized the likelihood of generating internal contacts within the mafic gneiss | The layer name is <i>GM_Tampia: Mafic gneiss</i> The Intrusion Model has a surface resolution of 15 m and utilizes adaptive isosurfacing, which is aligned with drilling data and has a maximum snap distance of 8 m. To achieve an equidimensional shape, a Linear interpolant is applied, with a Base Range of 300 m and a Total Sill of 90 m | Geology, Drillhole | Isosurface, Volume |
| Felsic gneiss | Although felsic gneiss is not exposed in the Tampia pit, its presence is inferred based on drilling data. Despite this limitation, the model benefits from a satisfactory distribution of drillhole intersections, which instils confidence in the interpretation of the modelled surface | The layer name is <i>GM_Tampia: Felsic gneiss</i> The Intrusion Model has a surface resolution of 15 m and utilizes adaptive isosurfacing, which is aligned with drilling data and has a maximum snap distance of 15 m. A Linear interpolant is applied, with a Base Range of 300 m and a Total Sill of 60 m. Felsic gneiss is not selected in the chronology list and fills most of the remaining (lower) regions of the geological model | Geology, Drillhole | Isosurface, Volume |

Table 2. Numerical models – descriptions and specifications for geochemical components of the model

| <i>Object</i> | <i>Description</i> | <i>Model specifications</i> | <i>Feature category</i> | <i>Spatial type</i> |
|---------------|--|--|-------------------------|---------------------|
| As_ppm | Drillhole arsenic values are modelled using the Leapfrog Geo FastRBF interpolant. Isosurface values are adjusted to emphasize areas with high arsenic values | Layer names are <i>As_ppm</i> : < 200.0, <i>As_ppm</i> : 200.0 – 500.0, <i>As_ppm</i> : 500.0 – 1500.0; <i>As_ppm</i> : 1500.0 – 3000.0; <i>As_ppm</i> : > 3000.0 The numerical model was enhanced by incorporating a structural trend based on a mesh surface that captures the varying orientation of leucosomes within the mafic gneiss. This specific structural trend was favoured over a global trend. A Spheroidal interpolant was utilized, with a Base Range of 70 m, which is about twice the average grade-control drillhole spacing in most parts of the deposit. To represent arsenic distribution, five isosurfaces were generated. Background values for the Tampia deposit were defined as <200 ppm. The maximum isosurface value of 3000 ppm was chosen to ensure that significant trends could still be observed within the modelled data | Geochemistry, Drillhole | Isosurface, Volume |
| Au_ppm | Drillhole gold values are modelled using the Leapfrog Geo FastRBF interpolant. Isosurface values emphasize areas with high gold values | Layer names are <i>Au_ppm</i> : < 0.5, <i>Au_ppm</i> : 0.5 – 1.0, <i>Au_ppm</i> : 1.0 – 2.0; <i>Au_ppm</i> : 2.0 – 4.0; <i>Au_ppm</i> : > 4.0 Following a similar rationale as the arsenic model, a structural trend was incorporated into the gold model using the leucosome mesh. A Spheroidal interpolant with a Base Range of 70 m was employed. For the gold model, five isosurfaces were generated. The background level was set at <0.5 ppm, while the upper threshold was defined as >4 ppm | Geochemistry, Drillhole | Isosurface, Volume |
| S_pct | Drillhole sulfur values are modelled using the Leapfrog Geo FastRBF interpolant. Isosurface values emphasize areas with high sulfur values | Layer names are <i>S_pct</i> : < 0.35, <i>S_pct</i> : 0.35 – 0.6, <i>S_pct</i> : 0.6 – 1.0; <i>S_pct</i> : > 1.0 The sulfur model incorporated the leucosome mesh as an input for the structural trend. A Spheroidal interpolant with a Base Range of 70 m was employed. Four isosurfaces were utilized, with the background level defined as <0.35% and the upper threshold set at >1.0% | Geochemistry, Drillhole | Isosurface, Volume |
| Oxidation_pct | Oxidation intensity is reported in drillhole logs as categorical data, namely Oxidized, Transitional or Fresh. To create a numerical model for oxidation intensity, these categorical values were converted to numerical equivalents: >50 for Oxidized, 20 to 50 for Transitional and <20 for Fresh. The benefit of a numerical model is the ability to project this information onto the geological model as translucent layers, preserving the underlying polygons rather than replacing them entirely | Layer names are <i>Oxidation_pct</i> : < 20.0, <i>Oxidation_pct</i> : 20.0 – 50.0, <i>Oxidation_pct</i> : > 50.0 An interpolant with a spheroidal shape was utilized, having a Base Range of 400 m. The surface resolution was set at 30 m, and adaptive isosurfacing was applied. To encourage the formation of a flat surface for oxidation isosurfaces, a structural trend based on the weathering surface's bottom was employed. Isovalues below 20 indicate fresh rocks, values between 20 and 50 represent transitional zones, and values exceeding 50 indicate oxidized rocks | Geology, Drillhole | Isosurface, Volume |

Table 3. Meshes – descriptions and specifications for the Tampia pit and surface topographic components of the model

| <i>Object</i> | <i>Description</i> | <i>Model specifications</i> | <i>Feature category</i> | <i>Spatial type</i> |
|-------------------|--|---|-------------------------|---------------------|
| Pit outline | The Tampia pit 3D shell includes the North and South pits, along with the shallower western extension known as the Mex pit, which has mostly been backfilled and so was not mapped. A drone flown over the pits on 23 March 2023 captured an image that is draped over the pit shell. The drone survey was conducted within a few weeks of the closure of the mine, providing a good approximation of the pit's final design. The survey took place on an overcast day, between periods of heavy rain showers, resulting in clean walls and good photographic conditions | See layers <i>Lithology_interpreted</i> , <i>Lithology_observed</i> Ramelius Resources has provided the pit shell and drone image. During the drone survey, the camera position remained fixed and faced downward. As a result, the steeply inclined pit walls exhibit vertical striping of the pixels | Imagery | Mesh, Raster |
| Tampia_topography | The topographic surface provided by Ramelius Resources encompasses the boundary of the Tampia geological model, extending outward in all directions to distances from 40 to 800 m | See layer <i>GM_Tampia: Transported material</i> This surface is derived from the collar positions of exploration drillholes, which originate from the present day surface | Topography | Mesh, Isosurface |

Table 4. GIS data – descriptions and specifications for shapefile components of the model

| <i>Object</i> | <i>Description</i> | <i>Model specifications</i> | <i>Feature category</i> | <i>Spatial type</i> |
|------------------------|---|--|-------------------------|---------------------|
| Lithology_observed | Tampia North and South pits were mapped at 1:500 scale in May 2022 and March 2023. Observations were made from exposed walls while pit mapping and from drone imagery | The layer name is <i>Lithology_observed</i> The original shapefiles were created using ArcGIS and subsequently imported into Leapfrog Geo. They were then draped over the Pit outline mesh, resulting in the overlay of the shapefile data onto the mesh representation | Geology | GIS, Polylines |
| Lithology_interpreted | Interpreted geology refers to the geological information that is not directly observed but inferred from drillhole data or extrapolated from trends in rock contacts | The layer name is <i>Lithology_interpreted</i> The original shapefiles were generated using ArcGIS and imported into Leapfrog Geo, then draped over the Pit outline mesh | Geology | GIS, Polylines |
| Structures_observed | Structures were mapped in pit walls at 1:500 scale and are represented by Shear zones and Pegmatitic quartz veins | The layer name is <i>Structures_observed</i> ArcGIS shapefiles were imported into Leapfrog Geo and draped over the Pit outline mesh | Geology | GIS, Polylines |
| Structures_interpreted | Structures are projected from structures directly observed in the walls, down to pit floors and through berms | The layer name is <i>Structures_interpreted</i> ArcGIS shapefiles were imported into Leapfrog Geo and draped over the Pit outline mesh | Geology | GIS, Polylines |

Table 5. Structural modelling – descriptions and specifications for geological structure components of the model

| <i>Object</i> | <i>Description</i> | <i>Model specifications</i> | <i>Feature category</i> | <i>Spatial type</i> |
|-----------------------|--|--|-------------------------|---------------------|
| Structures_planes | Planar structures such as fractures, faults, pegmatitic quartz veins, foliation, leucosome zones and intrusions are directly measured from pit walls | The layer name is <i>Structures_planes</i> Structural planes are reported with dip and azimuth angles, following right-hand rule (thumb down) conventions. Positions were originally recorded using a handheld GPS devices with Northing and Easting accurate to about 2 m, while elevation accuracy is poor at around 30 m. Elevation measurements were repositioned using the drone pit image and pit shell as guides | Geology | Points |
| Structures_lineations | Lineations were recorded for flattened leucogranite intrusions and leucosome zones, measuring the plunge direction of boudins | The layer name is <i>Structures_lineations</i> Lineation trends and plunges are reported. Northing and Easting locations are accurate to <2 m, while elevation positions have been relocated to the base of pit walls | Geology | Points |

Table 6. Drillhole data – descriptions and specifications for components in the model related to drilling

| <i>Object</i> | <i>Description</i> | <i>Model specifications</i> | <i>Feature category</i> | <i>Spatial type</i> |
|---------------|---|---|-------------------------|---------------------|
| Collar | Collar values include the starting positions of 6778 drillholes from the Tampia project area, comprising air core, diamond, grade control and exploration reverse circulation, rotary air blasting, and water bores | The layer name is <i>Drillholes: collar</i> Minor pre-processing fixes were applied to the original data provided by Ramelius Resources (database extraction date: 19 April 2023) | Drillhole | Points |
| Survey | Downhole survey data (36 967 rows) for drillholes | The layer name is <i>Drillholes: traces</i> Minor pre-processing fixes were applied to the original data provided by Ramelius Resources (database extraction date: 19 April 2023) | Drillhole | Points |
| Assays | Gold, sulfur and arsenic values for 1 m sample intervals (233 396 rows), determined by fire assay laboratory techniques | The layer name is <i>Drillholes: DH_AssaysGC_20230419</i> Minor pre-processing fixes were applied to the original data provided by Ramelius Resources. New categorical columns were created (Au_category, As_category, and S_category) indicating low to high values for each element (database extraction date: 19 April 2023) | Drillhole | Points |
| Lithology | Simplified rock type categories based on the reported company logged drillhole intervals | The layer name is <i>Drillholes: DH_Lithology_20230419</i> Pre-processing included the conversion of shorthand lithology codes to conventional lithological names (database extraction date: 19 April 2023). A new Intervals_lithology column was created containing merged rock categories and renaming of rocks to GSWA nomenclature conventions in some cases | Drillhole | Points |
| Oxidation | Categorical (Fresh, Transitional or Oxidized) data for drillholes (77 314 rows) | The layer name is <i>Drillholes: DH_Oxidation_20230419</i> Minor pre-processing fixes were applied to the original data provided by Ramelius Resources (database extraction date: 19 April 2023) | Drillhole | Points |

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Recommended reference

(a) For reference to this overview document

Duuring, P 2024, 3D geological model for Tampia gold deposit – overview and list of components, *in* 3D geological model for Tampia gold deposit, 2024: Geological Survey of Western Australia, 3D Geomodel Series, <www.demirs.wa.gov.au/3Dgeoscience>.

(b) For reference to the 3D product

Duuring, P 2024, 3D geological model for Tampia gold deposit, 2024: Geological Survey of Western Australia, 3D Geomodel Series, <www.demirs.wa.gov.au/3Dgeoscience>.