

## **Geology and Mineralisation of the Chatree Epithermal Gold-Silver Deposit, Petchabun Province, Central Thailand**

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### **ABSTRACT**

Gold and silver mineralisation at the Chatree low sulphidation deposit is hosted in andesitic volcanic and volcanoclastic rocks and characterised by multiple hydrothermal alteration assemblages and quartz-carbonate (chlorite-adularia) replacements, veins and breccias. The ore-bearing veins are influenced by intersecting structures and host rock lithologies. Emplacement of the host succession occurred at  $250 \pm 6$  Ma (dated with Laser Ablation ICP-MS U-Pb zircon techniques), which was closely followed by mineralisation at  $250.9 \pm 0.8$  Ma based on the analysis of adularia from coarse-grained quartz-sulphide (chalcopyrite-pyrite-sphalerite) veins using laser ablation Ar-Ar methods.

### **INTRODUCTION**

The Chatree epithermal gold-silver deposit, central Thailand, is associated with a volcanic centre that spans approximately 7.5 by 2.5 km. The deposit consists of seven defined prospect areas and multiple open cut pits. The mineral resource contains 1.6 g/t of Au and 13 g/t of Ag, and together with the previously mined ore, totals almost five million ounces of gold, making it the largest hard-rock Au resource in Thailand. Studies of the sulphide mineral assemblages have classified the deposit as low sulphidation epithermal (based on Heald, Foley and Hayba, 1987) with sulphide content generally less than 3 % and low base metal contents (<300 ppm of copper, zinc, and lead). Veins display crustiform to colloform vein textures, typical of low-sulphidation conditions. Gold-silver ratios vary between prospect areas and are in the range of 5:1 to 20:1. Chatree is an unusual epithermal deposit due to the association of Au with chlorite-bearing veins.

This extended abstract explains the regional and deposit geology and describes the timing and nature of host volcanic succession, alteration and mineralisation.

## REGIONAL GEOLOGY

The Chatree deposit is located on the eastern edge of the Tertiary Chao Phraya Basin, 280 km north of Bangkok (Figure 1). The deposit is located in the Loei-Petchabun volcanic belt, which represents the remnant oceanic and continental arc complexes that developed before and during the suturing of the Shan-Thai and Indochina Terranes (Chausiri *et al*, 2002). A thick Carboniferous to Early Permian sedimentary sequence composed of conglomerate, sandstone, shale and limestone dominates the district-scale geology. The deposit is hosted in Early Triassic intermediate to felsic volcanoclastic rocks that form a coherent andesitic to rhyolitic centre, which interfingers and overlies fine-grained volcanoclastics and epiclastic siltstone, mudstone and fossiliferous limestone. Alteration in the region is associated with volcanic centers and major NE-SW fault systems (Corbett, 2006; Crossing, 2006).

The Triassic rocks are gently folded with dips less than 45° and are intersected by NE-SW trending faults. Granodiorite intrusions associated with these faults postdate mineralisation in the area. Approximately 80% of the region surrounding the deposit is overlain by thick laterite and unconsolidated sediments.

## DEPOSIT SCALE GEOLOGY

### The host succession

The host succession includes a gently folded 350 m thick volcanic package that is divided into four main stratigraphic units. These include (from lowest to highest in the stratigraphy):

Unit 1: Polymictic and monomictic andesitic breccias; calc-alkaline andesite flows with isolated dacite dome complexes;

Unit 2: Thick domains of polymictic and monomictic andesitic breccia;

Unit 3: Monomictic and polymictic rhyolitic breccias and fine epiclastic sedimentary rocks (quartz rich fiamme breccia); and

Unit 4: Lithic-rich fiamme breccia.

Petrographic, lithofacies characteristics and an interpretation of the principal lithofacies of the Chatree volcanic facies are shown in Table 1. Summary graphic logs for each prospect are shown in Figure 2. The highest gold grades are associated with the finer grained sedimentary facies and rhyolite breccia intervals (Unit 3) as well as the marginal areas between the monomictic andesitic breccia and coherent andesite facies (Unit 1). Based on non-mobile trace elements, it has been proposed that the tectonic setting of the succession was a continental arc type environment (Dedunczuk, 1998; Cumming, 2004; Krompkhun, 2005). A detailed analysis of the stratigraphy and volcanic architecture indicates that the earliest volcanic eruptions were subaqueous and effusive and evolved to mixed effusive and explosive eruption styles as magma compositions changed from intermediate (andesitic) to silicic (dacitic to rhyolitic) compositions.

## Vein characteristics

Au and Ag are hosted in multiple hydrothermal alteration assemblages, and occur as veins and breccias. Vein zones are orientated along NW-SE, NE-SW and N-S striking, moderate to steeply dipping faults with the position of mineralised veins strongly controlled by host rock competency. A chronology of the six different types of veins has been established on the basis of cross-cutting relationships (illustrated in Figure 3). A detailed account of the vein phases is included below:

*Stage 1, silica replacement:* Silicification occurs as both veins and pervasive alteration in zones where fine-grained volcano-sedimentary rocks predominate. Isolated, narrow zones also occur in coarser volcanoclastic rocks.

*Stage 2, quartz-sulphide replacement:* Grey microcrystalline quartz and minor pyrite are distinctive where the vein/alteration from Stage 1 is absent. Quartz-sulphide domains occur as matrix to hydrothermal breccia zones 3-5 m in width.

*Stage 3, gold-bearing quartz ± carbonate-sulphide veins and breccias:* The major gold-bearing stage contains quartz ± carbonate ± chlorite-pyrite ± sphalerite ± chalcopyrite ± galena-electrum veins/veinlets and breccia. Weakly banded crustiform, colloform textures and moderate to well-banded textures that range from quartz-rich, carbonate-rich to chlorite-rich as well as quartz-sulphide veins, quartz-carbonate-sulphide and quartz-carbonate-chlorite-sulphide veins characterize this stage. Gold forms mostly as electrum and is closely associated with pyrite, sphalerite, chalcopyrite and galena. Chlorite is a fine to coarse-grained component in colloform-banded veins and occurs as infill in open-space. Banded chalcedony is also common in this vein stage.

*Stage 4, quartz-carbonate-adularia-(K-feldspar?)-chlorite-epidote veins:* Post-mineralised quartz-carbonate-adularia-(K-feldspar?)-chlorite-epidote veins display spectacular pink-orange adularia margins, white to creamy carbonate, pale grey to white quartz and rare chlorite and epidote with pyrite and rare chalcopyrite patches and layers. Quartz ranges from microcrystalline to euhedral and comb quartz textures occur.

*Stage 5, colloform and crustiform banded quartz ± carbonate veins:* Colloform and crustiform banded quartz±carbonate veins occur throughout the deposit. Mineralised zones that have been crosscut by this vein stage have significantly lower gold grades. It is thought that this stage quickly followed the gold-bearing stage and diluted the ore grade.

*Stage 6, zeolite-quartz-carbonate-veins:* Zeolite-quartz-carbonate-veins occur in the faults and fractures of cross cutting (post mineralised) dykes and contain distinctive pink to red zeolites, quartz, carbonate and minor epidote and chlorite.

## Alteration

Geologic mapping and field observations show that ore-bearing veins and alteration assemblages are influenced by the contrasting textures and components in the dominantly volcanic host succession. Across the vein field, alteration assemblages are zoned from chlorite±epidote-calcite-pyrite (propylitic) to intermediate argillic alteration assemblages in the south, and silica, chlorite ± epidote - calcite-pyrite (propylitic) and sericite-illite-quartz-pyrite (phyllic) alteration in the north. Spatial variations in mineralogy and

alteration intensity correspond to finer-grained (< 0.1 to 2 mm) volcanoclastics in the north, and coarse-grained chlorite-altered volcanoclastic rocks (namely monomictic and polymictic andesitic breccias) in the southern areas.

### **Timing of mineralisation and emplacement of the host succession**

A variety of chronologic techniques constrain the absolute timing of mineralisation as Early Triassic ( $250.9 \pm 0.8$  Ma) based on the analysis of adularia from coarse-grained quartz-sulphide (chalcopyrite-pyrite-sphalerite) veins by laser ablation Ar-Ar methods (Salam *et al*, 2008; this volume). The host volcanic succession has been dated using Laser Ablation ICP-MS U-Pb zircon techniques to reveal an age of  $250 \pm 6$  Ma. The succession and mineralisation is crosscut by a  $244 \pm 7$  Ma xenolithic diorite dyke (dated using ICP-MS U-Pb zircon techniques). A granodiorite intrusion south of the mine is anomalous in copper and is shown to have intruded during the Middle Triassic (with a Re – Os age of  $244 \pm 1$  Ma). The age dates show that gold deposition and associated hydrothermal alteration is related to a different regional magmatic source rather than the granodiorite. If correct, such findings imply that the district-scale mineralisation was initiated from a distinct, hydrothermal source.

## **CONCLUSIONS**

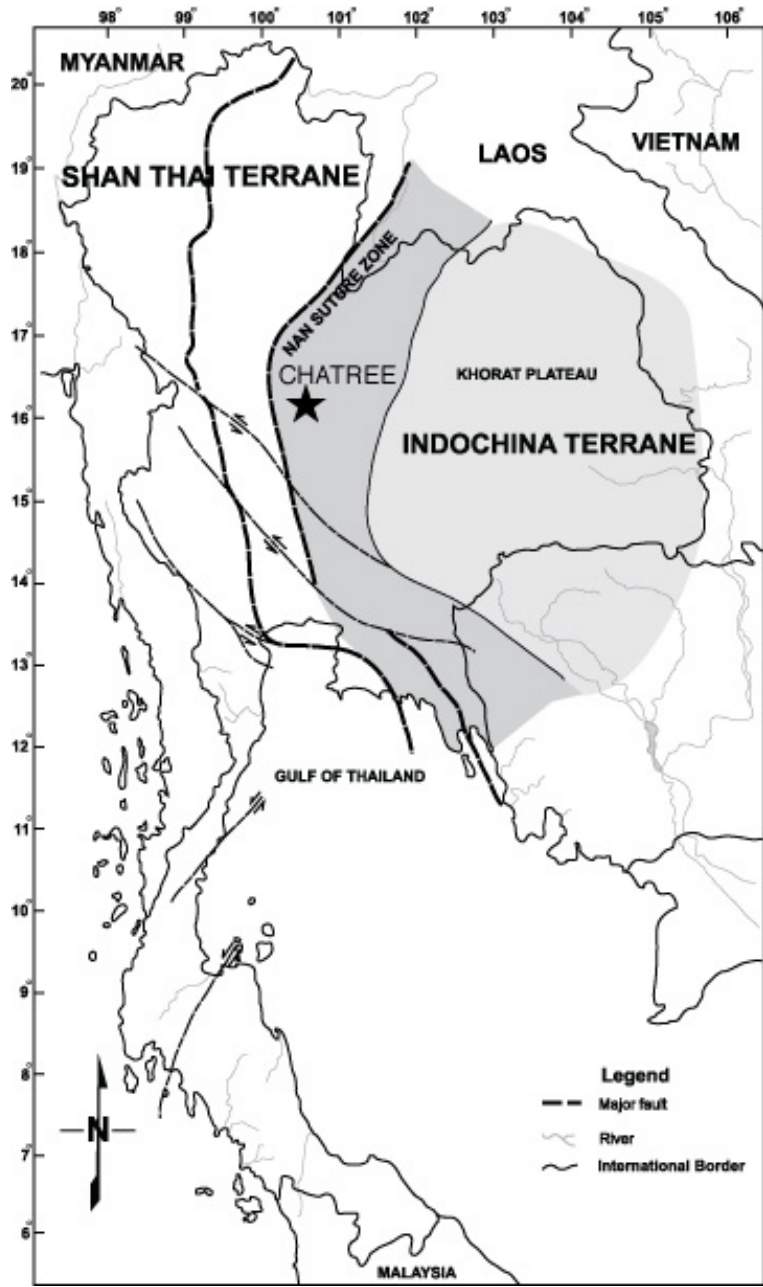
The Chatree epithermal deposit is hosted in a dominantly calc-alkaline succession composed of andesite flows and associated autobreccia, polymictic breccias, fine sedimentary facies with rhyolite, dacite and fiamme breccia. Mineralisation is structurally and stratigraphically controlled, and the ore bearing veins are quartz  $\pm$  carbonate  $\pm$  chlorite-pyrite  $\pm$  sphalerite  $\pm$  chalcopyrite  $\pm$  galena-electrum. Pervasive silica is associated with higher gold grades and is widespread in finer grained volcanic, epiclastic and felsic rocks. Silica-rich fluids prepared the brittle conduits for ore deposition in stratigraphic intervals (Unit 1, 3).

Age dating shows that the timing of mineralisation ( $250.9 \pm 0.8$  Ma) is close to the emplacement of the host succession (Early Triassic). The granodiorite to the south of the mine and the dykes that crosscut the succession post date the development of epithermal gold-silver mineralisation in the district. The source for the mineralising fluids is not constrained.

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Figure 1. Map of Thailand showing the location of the Chatree deposit in which the Nan Suture Zone binds Thailand's Loei-Petchabun Volcanic belt between Shan-Thai and Indochina Terranes. The volcanic belt represents the remnant oceanic and continental arc complexes that developed prior to and in association with the suturing of the Shan-Thai and Indochina Terranes (modified from Chausiri *et al*, 2002).



**TABLE 1. Petrographic, deposit characteristics and interpretation of the principal lithofacies of the Chatree volcanics.**

<i>Lithofacies</i>	<i>Characteristics</i>	<i>Interpretation</i>
Lithic rich fiamme breccia	Moderately vesicular aphyric to plagioclase phyric blocky to lenticular 0.5 – 2cm chlorite and clay altered fiamme. The fiamme, and lithic clasts are supported in a fine cream colored silt matrix (containing less than 5 % quartz and 15 % plagioclase feldspar (15%). Beds are > than 100 m thick, with a lithic rich base, massive fiamme and lithic rich interior and finely laminated, finer grained fiamme rich siltstone upper.	Voluminous and rapid emplacement by subaqueous silicic syn - eruptive pyroclastic processes.
Polymictic mud matrix breccia	Grey – green variably altered quartz phyric mudstone matrix supports variably hydrothermally altered poorly sorted, sub-rounded to angular, pebble to boulder andesite, rhyolite, mudstone, clastic clasts and chlorite altered fragments. Beds are 10 - 20 m thick, with finer base, coarse interior and fine upper portion	Deposition from mass flow processes.
Quartz rich fiamme breccia	Lens – ragged shaped Fiamme are 1 – 4 cm across and composed of quartz (30% ), plagioclase (30%). Beds are 40 – 60 m thick with a lithic rich base, a massive fiamme rich interior and fine laminated upper portion. Lateral extent is no more than 750m from south to north.	Rapid emplacement by subaqueous silicic syn-eruptive pyroclastic processes from a dome seated eruption.
Volcaniclastic sandstone	Less than <2mm rounded to angular plagioclase crystals, andesite lithic fragments and Fe-Ti oxide grains, carbonaceous fragments, thinly bedded, well sorted and interbedded with or gradational to laminated siltstone and mudstone beds.	Sourced from localized reworking and weathering of an andesitic centre and deposited by turbidity currents and the waning phase of local mass flows.
Carbonaceous Laminated Mudstone, Calcareous siltstone	Dark grey – black, finely laminated to thinly bedded (1 cm – 30 cm) with flame structures micro – collapse/slump features and micro – fault features. Carbonaceous material occurs as fragment and black discoloration. Coral fragments, brachiopods and ooids occur in dark grey – black calcareous siltstone/mudstone	Sourced from elsewhere on the palaeoslope on a shallow tropical sea nearby.
Monomictic and Polymictic Rhyolite Breccia	Quartz phyric (30 % quartz) monomictic domains, jigsaw fit textures and apparent rounding (when a hydrothermal matrix is present), highly irregular, fluidal and ragged clast margins, porphyritic clasts and domains of variably pyrite altered and chlorite replaced fragments in a grey silica or laminated silicified mudstone matrix. Polymictic domains comprise angular to rounded quartz phyric rhyolite clasts and plagioclase to hornblende phyric andesite clasts in a sandstone – siltstone matrix.	Monomictic domains are proximal zones to the rhyolite dome complex. Chlorite altered fiamme rich domains signify the once glassy, pumiceous part of the dome. Polymictic domains indicate reworking and redeposition of the dome complex
Polymictic andesitic (and locally basaltic) breccia	The 20-50m thick, poorly sorted beds are dominated by subangular to angular plagioclase phyric andesite, plagioclase and hornblende phyric andesite, rare mudstone, aphyric amygdaloidal basalt and chlorite replaced clasts/fragments. Clasts vary in phenocryst content, vesicularity and alteration. Coarse massive lower and middle portions and finer volcaniclastic sandstone and mudstone and occur interbedded and in the upper portions of the Polymictic Andesitic Breccia	Blocky angular clasts and granulated aggregates consistent with the fracturing, quench fragmentation and autobrecciation of variably vesicular lava. Poorly sorted, massive beds are consistent with rapid deposition from debris flow processes.
Monomictic andesitic breccia	Non stratified, poorly sorted, clast supported, matrix poor with blocky, irregular jagged shaped clasts displaying jigsaw fit texture. The facies has a close association with the plagioclase phyric andesite and hornblende phyric andesite. It is 4 – 20m thick with gradational margins into neighboring lithofacies. Some domains have undergone intense hydrothermal alteration	Autobrecciated part of an andesitic lava (or shallow sill)
Plagioclase phyric and hornblende phyric andesite Dacite and Dacite Breccia	Porphyritic plagioclase (30 – 40 %) and hornblende phyric (20 – 40 %), variably vesicular andesite has gradational margins into monomictic andesitic breccia. Isolated zones (<7 m thick) dacite (10 % quartz) and thick (10m) coherent to jigsaw fit and monomict – polymictic margins. These bodies are flow – banded in and have undergone intense silicification.	Andesite flow and/or shallow sill complexes. Dacite dome and autobreccia

Figure 2. Simplified stratigraphic columns, showing the distribution, associations, and interrelationships of the volcanic facies of the Chatree succession with reference to the approximate location of the ore zone. The columns are given in the format of graphic logs.

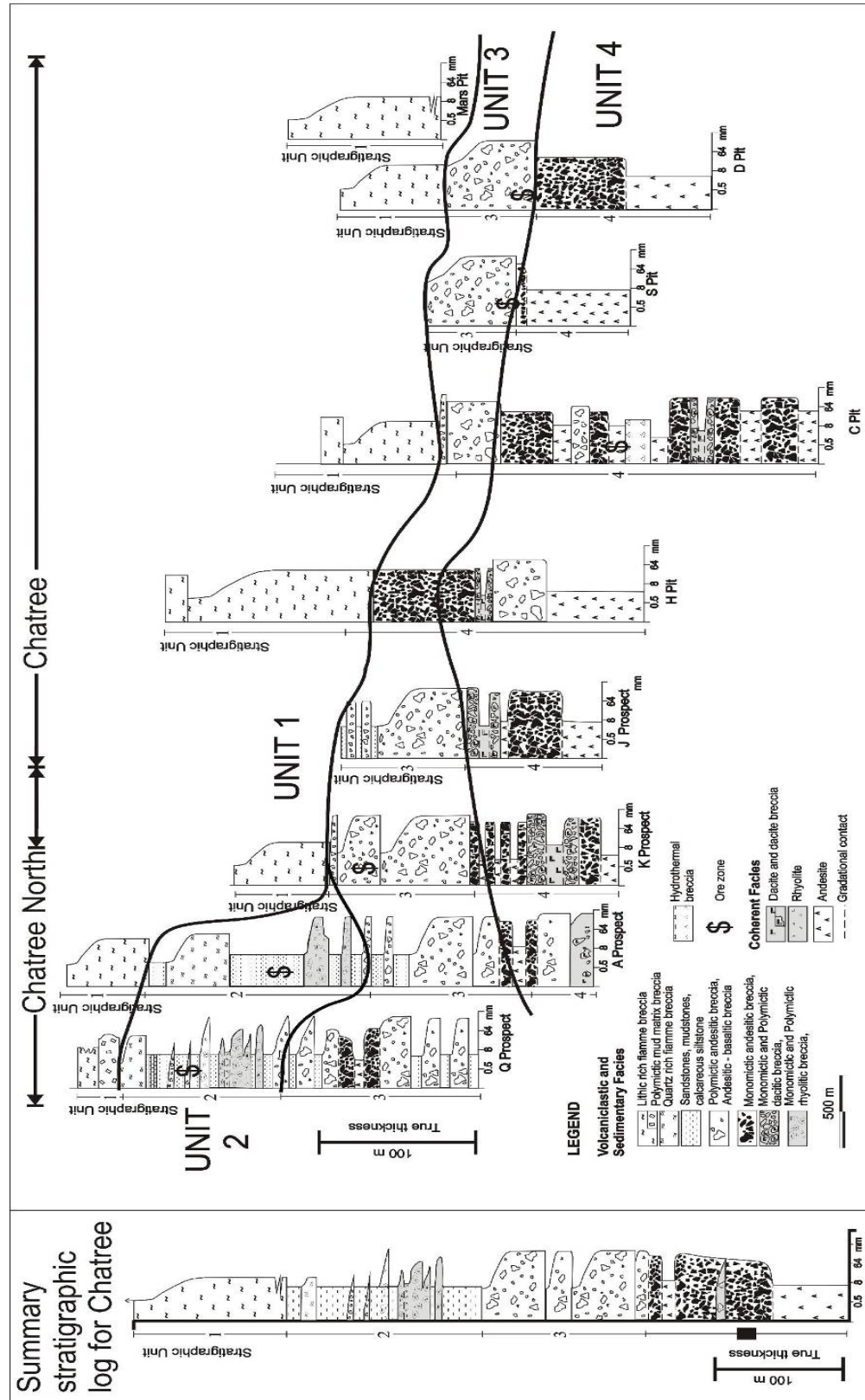
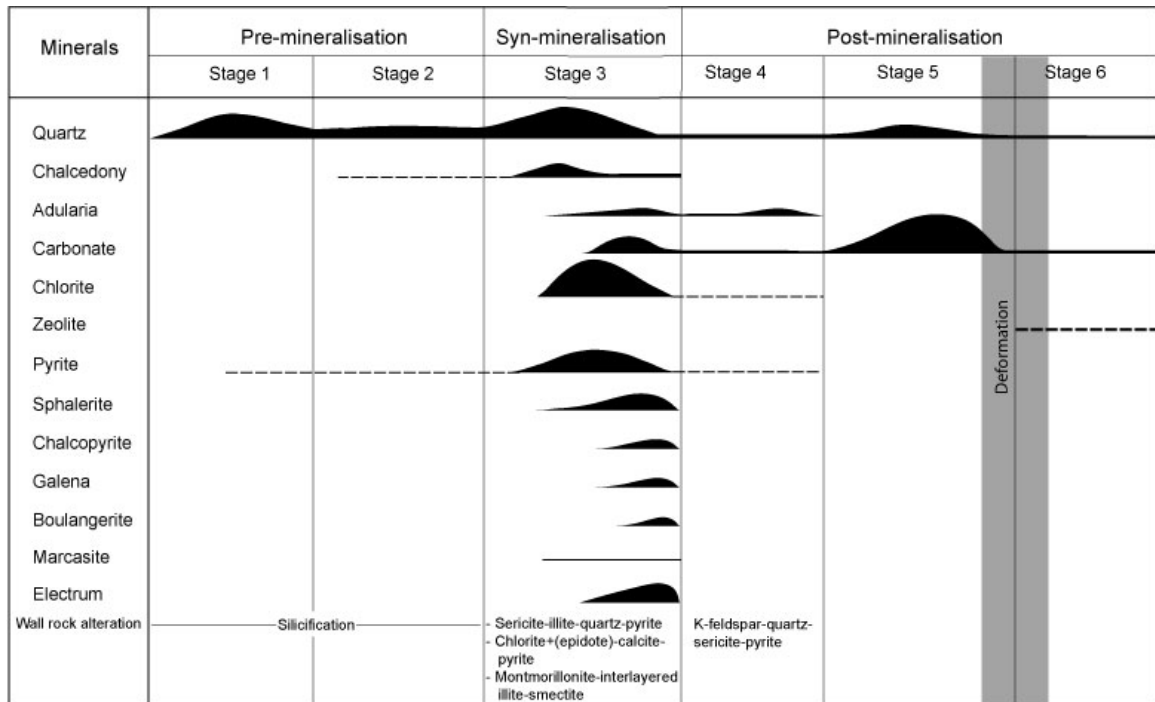


Figure 3. Paragenetic sequence for vein assemblages and alteration facies for the Chatree deposit.



Remarks: Stage 1 Pervasive silica emplacement  
 2 Silica breccia filling  
 3 Quartz+carbonate±chlorite-sulphide-electrum vein breccia  
 4 Quartz-carbonate-adularia±chlorite veins  
 5 Carbonate±quartz veins/veinlets  
 6 Zeolite-quartz-carbonate veins/veinlets