Hydrothermal system models: A great tool for understanding challenging geology

by Mark Lindsay, Former Chief Geologist at GBM Resources

GBM Resources Limited recently acquired the Twin Hills project that comprises the 309 and Lone Sister ore deposits and in 12 months grew the resources by 58% from 633 000 oz Au to around 1 Moz Au (see GBM ASX Release: 05/12/2022, Twin Hills Gold Project Upgrades to ~1 Moz Mineral Resource).

Though the geology of Lone Sister was well documented by previous workers, the geology and controls on mineralization at 309 were poorly understood. Constructing an observation-driven hydrothermal system model by systematically recording the key features of the deposit facilitated a new understanding of the 309 Deposit geology and importantly, provided a significant increase in resource confidence. Here's how we did it.

Clear your calendar

The best way to undertake this process is to have time to concentrate on the geology for long periods every day. You'll need time to think about the rocks, the relationships you're seeing, and how they might fit together.

Understand the challenge

The key challenge for GBM was to resolve the geology and controls on the distribution of mineralization at the 309 Deposit in order to develop a new resource estimation model. Previous workers variably interpreted the host rocks as a prograding alluvial fan, diatreme/maar complex, and phreatic/phreatomagmatic breccia in a graben, with mineralization described as fault-controlled, breccia-controlled, epithermal, and components of mesothermal. The historic logging was inconsistent within programs and between companies and several logging codes combined lithology with mineralization and brecciation. Initial attempts to use historic logging as the basis for interpretations quickly indicated a relog with revised codes was required.

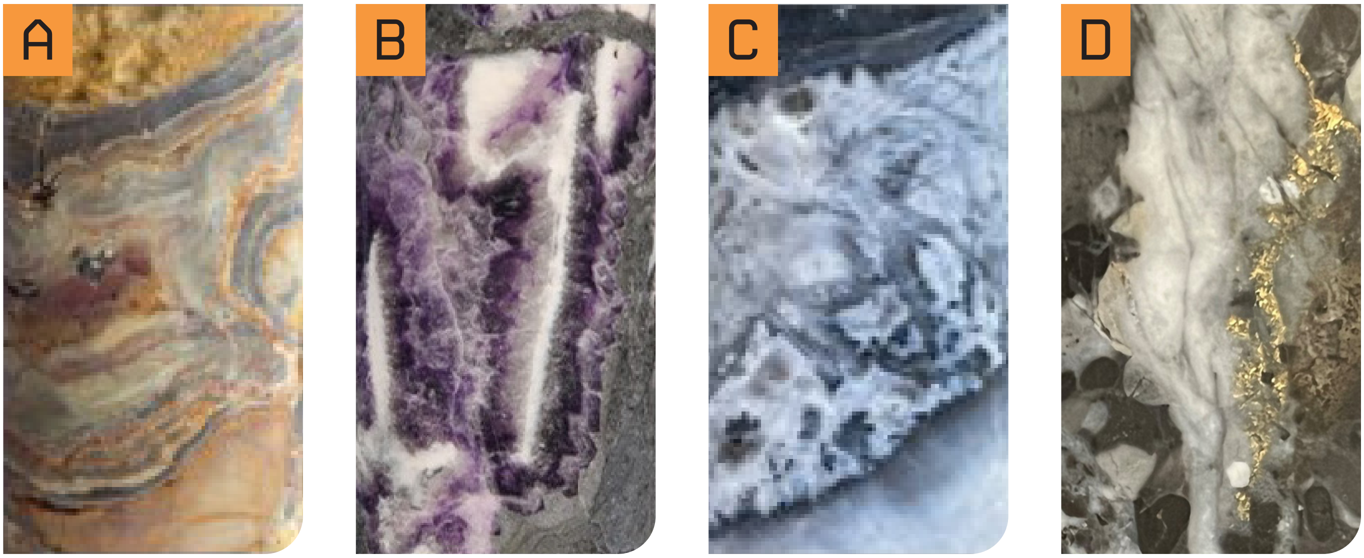
Geological model versus Hydrothermal system model

Geologists generally record most features of ore deposits in substantial detail, particularly if diamond core is being logged. The abundance of data is then viewed on screen and detailed models of various aspects of deposits are created, often in isolation from other deposit features. A Hydrothermal System Model as discussed here aims to show the broad patterns of the key aspects of a hydrothermal system in a single simplified model. The overall geometries and patterns are used to resolve the geological setting and broad controls on the distribution of mineralization.

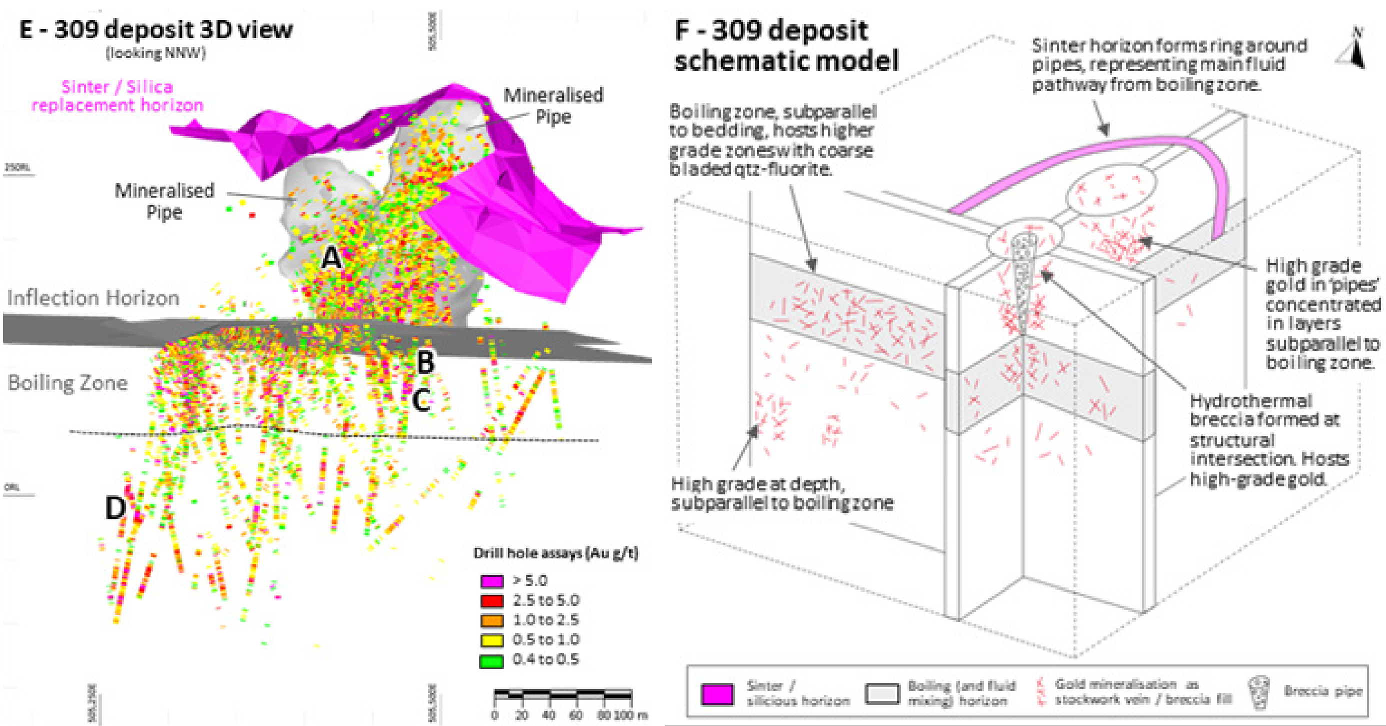
Selecting features to log

Selecting the features to log is a significant step, but the process of building the model will help to define which features are important. The features that are logged will likely change as the work proceeds so don't feel that you must get it right immediately.

Start by laying out the core from a selection of drill holes that pass from the least to most altered/mineralized parts of the system and encompass the main features of the deposit. Look through each drill hole and note the main features you see; this will form the basis for logging. The key features of the hydrothermal system will vary between systems but usually include various types of Lithology, Structure, Brecciation, Alteration, Mineralization, and the nature of Contacts between the logged features. Alteration was not logged for the 309 Deposit model as the entire system is overprinted by strong to intense silicification with little evidence of other alteration styles in the hand specimen. Mineralization was simplified into four main types of veins and breccia fills. More than 20 lithologies were initially recorded



↑ A – THRCD814 72 m, 1 m @ 449.0 g/t Au and 997.0 g/t Ag from 72 m (236 ft). Ginguro banding with visible gold in breccia pipe.
B – 3209DD22002 139.7 m, 79 m @ 1.09 g/t Au from 131 m (430 ft). Coarse bladed fluorite.
C – 309DD22003 128.5 m, 15 m @ 3.96 g/t Au from 118 m (387 ft). Quartz-chalcedony-pyrite replacing bladed fluorite.
D – 309DD22005 327 m, 1 m @ 129.4 g/t Au and 55.4 g/t Ag from 327 m (1073 ft). Abundant visible gold as electrum. Mineralization is hosted by chalcedony veins that cut earlier-formed breccia.



↑ Figure 1 – 309 Deposit Hydrothermal system model. 1A–D show variation in mineralization styles across the deposit with sample locations shown on 1E. Abundant bladed fluorite and fluorite replaced by silica forms in a distinct zone that we interpret to result from boiling. The fluorite-rich boiling zone marks an inflection point in deposit geometry above which mineralization forms two pipe-like bodies along ax NNE trend (1E and F). Note that elevated gold grades form in layers sub-parallel to the inflection horizon/boiling zone. 1F schematic model displays the spatial relationships of key mineralization features at 309.

to reflect the complexity of host rocks evident in the drill core. These were simplified into eight types after the sedimentary and volcanic facies relationships were resolved during logging. The nature and orientation of contacts between logged features can be very important and resolve the genesis of specific lithologies (e.g., breccia pipe vs. mass flow) or controls on the distribution of mineralization (e.g., fault vs. lithological).

Logging

Basic observations and interpretations of relationships between key features of the system and how those features change across the deposit are fundamental to building a great model. If there is a heavily altered rock type that you don't understand, then can you find a less altered rock with the same textures elsewhere in the deposit? Is there a recognizable unit that you've seen in a few holes that could be used as a marker bed? Logging core is not just about recording various geological features, there are plenty of automatic core logging machines that can do that, it's about recognizing patterns and making interpretations.

If time permits, several sections through the deposit should be relogged and preferably with at least one section that is perpendicular to the other sections. Ensure that the sections selected are representative of the deposit geology including the unaltered/unmineralized parts and where possible select sections from across the length of the deposit. In most instances, initial logging will need to be on the drill core. Once you can easily recognize the key features of the system, then logging can proceed using core photographs. Logged units should be recorded at a scale that can be easily displayed on a section with recorded intervals preferably > several meters thick. The aim is to illustrate the overall geometry of system components, not the detail. Exceptions to this may include planar features such as contacts, faults, dykes, lodes, and marker beds.

To aid interpretation, it is useful to compile a reference library of photos with notes (I use PowerPoint for this as it's easy to annotate and sort the photos) showing key relationships, logged lithologies, alteration, mineralization, and any other significant features or interpretations. There were plenty of rocks that we did not understand when we started relogging the 309 Deposit core. By compiling a reference photo library, we were able to identify gradational variation from sedimentary to volcanic facies. Combined with structural and geometrical data, we could interpret the environment of formation.

Interpretation

The hydrothermal system model is developed by combining observations and interpretations of the relationships between various features of the system made whilst logging in conjunction with other drill hole information, such as geochemistry and mapped surface geology. As is often the case, the key to unraveling the 309 Deposit wasn't the focus of previous explorers and the real answer lay in compiling lithology, veining, and gold distribution data.

Mapping out lithology showed that the 309 Deposit is hosted by a simple sequence of calcareous and variably carbonaceous well-bedded siltstones with abundant sedimentary structures that are progressively interlayered upwards with ash, crystal, and crystal lithic tuff that starts as occasional beds 1–5 cm (0.39–1.97 in) thick and increases to tuff layers that are several meters thick. A marker bed was also identified within the interbedded siltstones and tuffs and helped correlation across the deposit. The siltstones and tuffs are cross-cut and overlain by a thick unit of breccia. Historically described as 'milled matrix breccia', this breccia is typically matrix-supported and comprises a rock flour matrix with angular to sub-rounded clasts of the underlying siltstones and tuffs. The basal contact of the milled matrix breccia is broadly parallel to bedding and we interpret this unit to represent a mass flow. Thus, we have the first part of our model, the host stratigraphy.

Plotting 309 Deposit mineralization styles in 3D showed that sinter crops out along an arcuate trend that rings near surface gold mineralization. Bonanza grade ginguro style colloform banded chalcedony veins are present at the top of the system (Figure 1A). Spectacular bladed fluorite-chalcedony-quartz ± adularia-pyrite-gold veins (Figure 1B) and breccia fill form throughout the deposit but are most common in the middle and upper parts of the deposit. The fluorite-bearing veins are progressively replaced by later stages of silicification (Figure 1C) and corresponding higher gold grades. Quartz-chalcedony-pyrite veins with visible gold as electrum and bonanza grades > 100 g/t Au (Figure 1D) appear to post-date most other mineralization and were observed in the deeper parts of the deposit. Thus, we have the second part of our model, mineralization styles suggesting a vertically zoned epithermal system.

Gold, or whichever commodity you are working on, is arguably the most important part of the hydrothermal system. The overall distribution of high grades often outlines the fluid conduits and likely reflects key controls on the system. A plot of gold grades >0.4 ppm Au at the 309 Deposit displays a complex shape. At depth, gold mineralization is predominantly focused along WNW and, to a lesser extent, NNE structural zones as stockwork veins and breccia fill. The best grades form in two 50–70 m (164–230 ft) high layers broadly sub-parallel to bedding and presumably the palaeo surface (Figure 1 E). Comparison with logged mineralization styles shows that the uppermost of the two zones contain abundant bladed fluorite-chalcedony-quartz veins and breccia fill. The bladed fluorite suggests this zone may represent a boiling and/or fluid mixing zone with associated abundant silicification potentially having formed a cap that allowed later gold-rich fluids to be concentrated.

The fluorite-rich zone also marks an inflection point in deposit geometry above which near-surface gold mineralization forms in two pipe-like bodies along an NNE trend (Figures 1E and F). A hydrothermal breccia with rounded pebble-sized clasts has formed at the intersection of the WNW and NNE structural zones and marks the center of the southern pipe (Figure 1F). The northern pipe is elongated parallel to the NNE structural zone. This pipe comprises shatter breccia and stockwork veins, but a clearly defined breccia conduit was not seen. Thus, we have the third part of our model, structural and hydrothermal controls on the distribution of mineralization.

Figure 1 shows the final hydrothermal system model of a structurally controlled hot spring epithermal system with a boiling zone marked by abundant bladed fluorite and pervasive silicification. Two breccia pipes propagate from close to the boiling zone and vent to the surface to produce an arcuate ring of sinter. The distribution of gold mineralization is controlled by structures at depth and boiling and brecciation near the surface.

For more information

Visit: **gbmr.com.au**