

USE OF MAJOR ION RATIOS AND SATURATION INDICES TO DETERMINE MINE INFLOW SOURCES IN CENTRAL VICTORIA, AUSTRALIA

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Aims

The Augusta Mine is a narrow vein gold/antimony mine, located near Costerfield, Victoria, Australia. Historically, water inflow to the underground workings was sporadic, and unpredictable, both in volume and location. The intention of this work was to determine the main flow directions and sources of the groundwater, and the locations of the main water bearing structures. This would make dewatering both more efficient and predictable. Due to the complexity of the fracture system, determining the small scale flow system by physical means is not possible. This work uses major ion ratios as a tracer to track water flow paths from various potential sources into the underground workings.

The geology is made up of low permeability turbidite siltstone, highly fractured. These fractures are the host to mineralisation consisting of gold bearing quartz and calcite veining, with stibnite mineralisation. The main fracture system is north west-south east trending. The Augusta deposit comprises three main, stacked lodes; C, W and E lodes, arranged in an en-echelon pattern. A fourth structure, the I lode, exists in between W and E lodes, and extends to the west near the base of the workings. This lode is not economic, but consists of a thick layer of higher porosity sandstone.

Most groundwater inflows have been concentrated around W lode. At the time of this work, groundwater inflows were concentrated in the deeper levels of the southern part of the mine. Previously, waters were assumed to be flowing from the north only, along the W lode, as this is where most of the inflows were located. As the mine deepened, a greater prevalence of water began to enter the workings from the south. When the workings reached the depth of the I lode, overall water inflows increased dramatically.

Many water bearing structures exist surrounding the mine site, mostly fractures of varying sizes. The effect of the I lode as a water bearing structure is largely unknown, as is the influence of water permeating from the surface. The major aim of this study was to determine the influence of this potential source.

Methods

The groundwater chemistry surrounding the site is high in sodium and chloride. This controls the field parameters, making chemical differentiation of the groundwaters only possible using ionic ratios. Samples were taken from all underground inflows, several times over a six month period during 2011. Of particular note, some of the samples were taken directly from the I lode, some shallow, and others deep. Samples were analyzed for all major ions, nitrate, nitrite, bromine, and phosphorous. Field parameters included EC, pH, ammonia and DO. The dataset also included data from the routine monitoring of groundwater chemistry surrounding the site. Groundwaters were differentiated using major ion ratios, field parameters, and saturation indices. Saturation indices were modeled using PHREEQC (Parkhurst and Appelo 1999). Differing clay and carbonate chemistry of individual water types was a key indicator of different water sources.

Results

The results from deeper groundwaters show a distinct difference between waters from the south and waters from the north relative to the underground workings. Waters from the south are higher in magnesium carbonates, whilst waters from the north are higher in

potassium and sodium salts. Mine water samples show that most of the waters entering the mine are a mixture of the two.

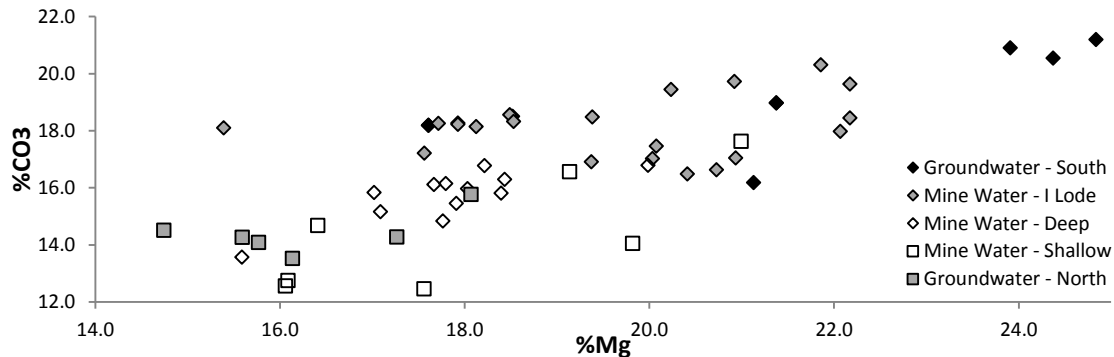


Figure 1: Prevalence of Mg and CO₃ in each of the water types. Note the mine water samples as a mixture of the waters from the north and the south.

Saturation index modelling shows the presence of clays in most groundwaters, indicating that ion exchange occurs in most of the groundwaters. Upon inspection, most fractures contain clays, matching the particular clay content of the waters sampled from similar areas. In waters from the south, a higher proportion of potassium is found, though the interaction with potassium bearing clays such as illite and sericite. Waters from elsewhere have shown an abundance of sodium, presumably from sodium-bearing clays, such as montmorillonite.

Saturation index modelling also showed that both of the water types would be oversaturated in several ions when they to enter the oxygenated redox state. These differ depending on the water source. Waters from the south are oversaturated in sulphates and carbonates. Both water types are oversaturated with iron. This is visible underground where water enters the mine, mineral precipitation is common. Waters from the south precipitate gypsum and iron sulphate, whilst waters from the north precipitate hematite and goethite.

Conclusions

The water samples taken from the I lode show a clear resemblance to the groundwater samples taken from further to the south. Waters from below the I lode, and a majority of the shallower samples reflect a mixture of waters from the north. These are the waters that are sourced from the north, with the W lode acting as a conduit. Waters from the I lode are strongly influenced by waters from the south, with the more porous I lode acting as the pathway. It would appear that the high porosity of this unit is connecting the underground workings with other fractures and abandoned exploration drill holes, creating a flow path from a source further away to the south. The high flow rates and large extent of this layer make it a prime target for future dewatering activities. This study showed that this type of analysis can be customised and used to trace groundwater flow paths in complex fractured rock systems. This analysis can be used to determine dewatering targets where conventional methods cannot be applied due to the overall complexity of the groundwater system.

References

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