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Hardcap alteration in banded iron formation: Sulfur as an indicator

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Rock at or near the surface of the earth is prone to weathering resulting in simple to very complex physical and mineralogical changes in the parent rock. Most iron ore deposits around the world, whatever the mode of origin, experience varying degrees of secondary weathering. The Precambrian banded iron formations (BIF) of the Hamersley Iron Ore Province, Pilbara Craton, Western Australia, underwent an extensive period of secondary weathering with the development of a weathered/altered ferricrete zone. The upper 1-2 m thick ferricrete zone, known as “carapace”, may retain many of the original BIF textures. Beneath this is a 30-40m thick hydrated zone, locally referred to as “hardcap”, which in extreme cases can occur to depths of >80m.

Historically, hardcap has presented a significant value-realisation risk to the iron ore industry. Complex geometry in conjunction with variable mineralogy and chemistry, typically occurring within short distances (<5m), pose a significant challenge for resource estimation and grade control during mining. This necessitates accurate delineation of the hardcap domain during geological modelling, namely the boundary between weathered and unweathered iron ore. Traditionally, interpreting the base of hardcap was quite subjective and the boundary was demarcated based on a combination of the following: topography; occurrence of cavities/vugs; variable density and natural gamma response; destruction of BIF texture by dissolution of hematite and precipitation of goethite; presence of vitreous goethite, textureless clay or secondary quartz; variable and erratic trend of Fe; elevated but variable Al_2O_3, TiO_2, SiO_2 and loss-on-ignition. This led to major inconsistencies between models which often translated into mine planning inefficiencies and poor reconciliation against resource models.

Sulfur in the hardcap was believed to be contained in gypsum, but a poor matrix correlation of Ca and S indicates other sulfur bearing minerals. Sulfur does show a good correlation with goethite when plotted against the goethite and (goethite+hematite) end members, analysed from infra-red spectra, indicating the affinity of sulfur for goethite in the hardcap zone.

A comparison of sulfur distributions from bore hole assays drilled into the Brockman Iron Formation along the Packsaddle Range at BHP Billiton’s Mining Area C operations shows; 1) a bimodal sulfur distribution in the hardcap vs. non-hardcap zones, and 2) a distinct increase in sulphur values in the hardcap zone (average 500ppm) with respect to the non-hardcap (average 128ppm) zone. Similar sulfur distribution in the hardcap zone has also been observed in analyses conducted on other deposits and iron formations within the Hamersley Basin. Thus the sulfur signature, supported by other qualitative parameters, provides a quantitative means by which to define the hardcap domain more accurately and consistently than has been possible in the past. This has the greatest potential for integration into a machine learning system for geological interpretations.