# Scherrer Width and Topography of Illite as Potential Indicators for Contrasting Cu-Recovery by Flotation of a Chilean Porphyry Cu (Mo) Ore

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**Abstract.** Two contrasting feeds in terms of copper recovery from a Cu (Mo) porphyry deposit but with similar overall mineralogy have been characterized by X-ray diffraction for their <1 µm fraction illite crystallinity, Scherrer width and by atomic force microscopy for surface roughness. The unfavorable feed displayed slightly higher crystallinity, larger Scherrer width and surface roughness factors, than the feed with good Cu recovery. As Scherrer width is an easy and cheaply to determine parameter it is suggested as complementary information to particle size distribution analyses when dealing with feeds where illite may affect pulp viscosity or gangue adhesion to bubbles during flotation.

**Keywords:** Illite · Scherrer width · Surface roughness · Flotation · Sericite · Atomic force microscopy

## 1 Introduction

For over half a century, illite crystallinity has been used as an indicator of mineral maturity in metasediments between the transition of diagenesis to very low temperature metamorphism and the incipient low-grade metamorphism or epizone (Frey 1999). Illite crystallinity (later Kübler Index) measured at full width half medium height (FWHM) of the basal XRD-reflection is also an indirect indicator for the size of the jointly diffracting illite sheets, also known as Scherrer width, which has been directly visualized with the widespread availability of Transmission Electron Microscopy (Frey 1999). Superimposition of metamorphic and hydrothermal alteration processes, paired with time consuming analytical routines, has limited the application to alteration halos of ore deposits; an exception is the study by Beaufort et al. (2005) on the East Alligator River Uranium deposit in the Northern Territory, Australia, due to its abundance of chlorite and illite gangue. Sericitic alteration (muscovite/illite) also represents widespread gangue for Andean Cu (Mo) porphyry ore deposits, but systematic studies of phyllosilicate crystallinity or Scherrer width within ore deposit areas are not available.

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Cheng and Peng (2018) suggest negative effects for low crystallinity kaolinite rich ore, much of the work being based on artificial ore-gangue mixtures. However Jorjani et al. (2011) single out illite and vermiculate as key gangue affecting flotation for the Iranian Sarcheshmeh porphyry copper deposit. The present exploratory study has been sparked by the effort to develop a formula for blending ore based on mineralogical-chemical parameters of a giant porphyry copper deposit in Chile. Ore with similar sericitic alteration and chalcopyrite dominated ore phases, were identified by the concentrator operation as favorable (F) and unfavorable (UF) floating feed, the latter entering the concentrator only as blend. Given this overall mineralogical similarity, it was decided to characterize the contrasting feeds based on their illite crystallinity – Scherrer width and concomitant surface roughness.

## 2 Methods and Approaches

Triplicate samples of favorable (F) and unfavorable (UF) floating ore were prepared for X-ray diffraction (XRD) analysis of the clay size fraction (>0.45 <1 µm) based on the recommendations of Moore and Reynolds (1997). XRD measurements were carried out on a Bruker D4 diffractometer operated with Ni-filtered Cu-radiation. Illite crystallinity and Scherrer width were determined on the 001 basal reflection following Lorentzian adjustment using the Origin 8.5 program. Atomic Force Microscope (AFM) measurements of topography were carried out with an AIST-NT equipment in contact mode on a 5 × 5 µm surface. WSxM5.0 software was used for calculating Ra (arithmetic average) and Rrms (root mean square) roughness factors (Horcas et al. 2007; Erinosho et al. 2018).

## 3 Results and Discussion

Illite crystallinity values of both samples (F: 0.15 Δ° 2Θ, UF: 0.12 Δ° 2Θ) correspond to epizone values, and for the unfavorable feed are at the sensitivity limit of this method (Frey 1999). Though values for the favorable feed are marginally lower, nevertheless this difference is expressed in an increased Scherrer width or crystallite size (F: 48.8 nm, UF: 62.6 nm) for the unfavorable feed.

Topographic images of sample surfaces show different roughness, being the favorable feed (F) the smoother. Roughness factors were calculated for different surfaces scanned by AFM. As a mean, 10 sample surfaces were measured and statistically compared, giving values of $Ra = 57 \pm 20$ and $Rrms = 66 \pm 23$ for the favorable feed and $Ra = 68 \pm 18$ and $Rrms = 86 \pm 19$ for the unfavourable feed sample. Undoubtedly, different scales of images analysed imply changes in the surface parameters. To avoid this, images with the same size have been compared. As it can be observed in the Fig. 1, roughness parameters confirm the XRD results.

Despite the difficulties of differentiating between illite generations in rocks with sericitic overprint in porphyry (and other) ore deposits, this simple XRD measurement permits concomitant calculation of coherently diffracting particle sizes or Scherrer width for a given geometallurgical unit. The correspondence observed for this

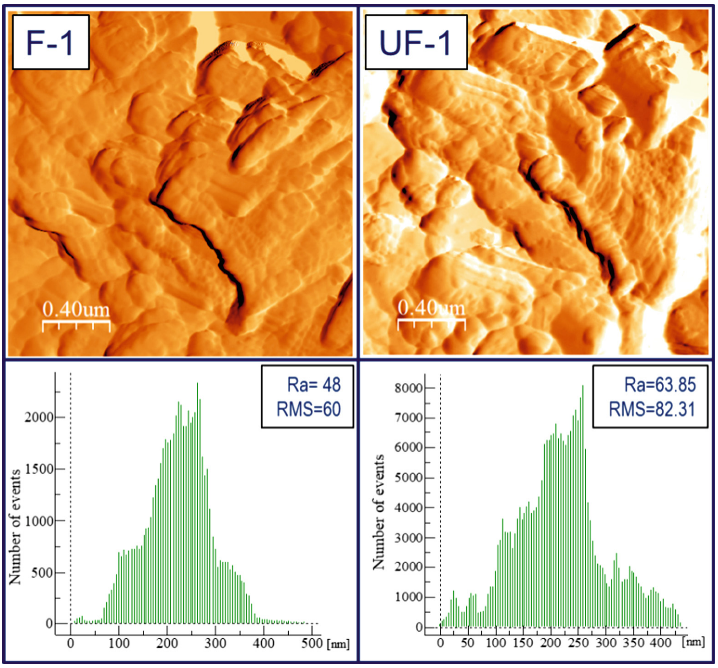

**Fig. 1.** Topographic aspects of F-1 sample (left) and UF-1 sample (right)

exploratory study between increased Scherrer width and higher AFM measured surface roughness, recommends the XRD based value as an easily available tool to assess difference in flotation for samples where traditional methods like optical microscopy, automated mineralogy, and semi-quantitative whole rock mineralogy do not reveal obvious mineralogical differences between feeds with contrasting flotation behavior. Farrokhpay and Ndlovu (2013) discussed the effect of clay particle size on pulp rheology; here the X-ray coherent Scherrer width is suggested as a complementary indicator to the particle size distribution measurements by laser diffraction in the clay size range. The scale of surface roughness as a factor impacting on particle adhesion to bubbles has been studied by Nikolaev (2016). However, direct AFM measurements are still no routine procedures to define geometallurgical units within an ore deposit, whereas XRD information can be generated faster and in a more standardized fashion.

## 4 Conclusions

Illite crystallinity, Scherrer width and AFM-determined surface roughness have been determined for two flotation-feed of a Cu (Mo) porphyry copper deposit with contrasting Cu-recovery. Samples did not display any mineralogical difference allowing a straightforward explanation of this difference. For this exploratory study case, Scherrer width is considered an easy to obtain parameter that points to differences in surface roughness of illite particles in the <1 μm fraction and thus may influence pulp viscosity and/or particle adhesion to bubbles during flotation.

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