GRADE DISTRIBUTION OF THE GIANT OK TEDI Cu-Au DEPOSIT, PAPUA NEW GUINEA—A REPLY

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Sir: We welcome the contribution of Pollard (2014) to van Dongen et al. (2013). Pollard's main comment is that his observations at Ok Tedi imply a "very different picture of the relationships between intrusive rocks, host rocks, and mineralization" than the one we proposed. We would argue that his observations are actually broadly consistent with our model, but our interpretation was more concerned with the deposit-scale picture, as this better served the main aims of our paper. One of our primary aims was to present a 3-D geologic model and grade distribution images, as this is rare in *Economic Geology*. Our second aim was to concisely point out the link between the skarn and the porphyry system and our ideas as to how this might have been controlled by host rock distribution.

The first point of Pollard (2014) centers on perceived inaccuracies in describing the nature of the main intrusive bodies. He correctly observed (cf. Fig. 1, Pollard, 2014) that we simplified the geologic maps that were available to us in the following ways: we lumped together breccia zones within and on the margins of the Fubilan monzonite porphyry, and we lumped together the Sydney monzodiorite, the Porphyritic monzodiorite, and the thin sliver of monzonite porphyry in between those two bodies. We did this to present the reader with an easy visualization of the two main composite stocks (the Fubilan monzonite porphyry and the Sydney monzodiorite), to provide a basis from which to inspect the marked difference in country rocks encapsulating the two stocks.

The second point raised relates to our contention that the Fubilan monzonite porphyry and Sydney monzodiorite are essentially identical rocks, altered to different degrees. It is worth emphasizing that, firstly, alteration has changed the prealteration modal contents. For example, we have encountered assemblages similar to those described in Pollard (2014) but found evidence that anhedral K-feldspar altered plagioclase in moderately altered rocks (e.g., Fig. 2D, van Dongen et al., 2010a) and, therefore, argue that mafic minerals such as pyroxene and hornblende were altered to biotite. Furthermore, we have demonstrated elsewhere that the lower rare earth element (REE) content of the Sydney monzodiorite when compared to the Fubilan monzonite porphyry results from REE mobilization during alteration (van Dongen et al., 2010a), as opposed to magmatic fractionation, which would increase the REE content. Isocon analysis substantiates that the Fubilan monzonite porphyry can indeed be considered a more altered version of the Sydney monzodiorite. Notwithstanding that characterization of intrusive pulses by prealteration modal contents could perhaps be possible by detailed petrography, and several authors cited by Pollard (2014) have tried to do so, we consider that adding this amount of detail obscures our simple point that the spatial relationship between host rocks and intrusion controlled the distribution of mineralization: small variations in intrusion mineralogy are not relevant to this conclusion.

Thirdly, and where we welcome his contribution most, Pollard (2014) suggests that the hydrothermal intrusive breccia played a significant role in controlling the distribution of mineralization. We were unaware of its importance, as we did not have the continued access to the mine that he enjoyed as a geological consultant, nor did we have access to maps or 3-D models of these breccia zones, so we had no means of evaluating their importance. A map showing their relationship to grade distribution, and particularly to the rings of high grade, would be a great addition to our documentation of the ore geometry. More importantly, though, we argue here that the presence of these breccia zones within the Fubilan monzonite porphyry further supports our model that, on the deposit scale, the Fubilan monzonite porphyry acted as the main fluid conduit and locus of mineralization, and not the impermeable wall-rock siltstone.

In response to our claim that alteration of the Fubilan monzonite porphyry host rocks, the Ieru siltstone, is characterized by local silicification and pyritization, Pollard presents a variety of observations of different styles of wall-rock alteration and mineralization directly associated with the intrusive contact and up to 80 m away from it. He also states that copper-gold mineralization occurs hundreds of meters away from the contact. We acknowledge that our observations were limited to the pit walls and limited drill core within the siltstone along the contact, and we therefore welcome the additional detail about the nature of the alteration and mineralization in the Ieru siltstone farther from the contact. However, our understanding is that mineralization outside the Fubilan monzonite porphyry is limited to irregular occurrences of skarn-style mineralization, insignificant compared to the resource within the Fubilan monzonite porphyry. It is currently impossible for us to estimate the extent to which the siltstone became mineralized, or to what extent this impacts substantially on the resource model without Pollard presenting grade models or numbers. On the scale of the maps and 3-D models that are presented in van Dongen et al. (2013), we expect that the additional detail described by Pollard (2014) actually represents volumetrically minor resources compared to the bulk of the porphyry-style resources that sit within the volumetrically dominant Fubilan monzonite porphyry and not in their host rocks, whereas the Sydney monzodiorite is still largely devoid of significant resources, which are instead hosted in the surrounding country rock as skarn.

Additional detail and useful discussion are provided by Pollard (2014) on the timing and nature of hydrothermal events. In particular, our claim that the simplest interpretation is a contemporaneous skarn and porphyry mineralization event is shown by new data of detailed veining and overprinting

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relationships to be a generalization. We have purposefully ignored this level of detail in our paper in order to focus on the larger picture. Van Dongen et al. (2010b) showed, based on zircon U-Pb and K-Ar data from the deposit, that the total time span between magmatic crystallization of the oldest dated intrusion in the Ok Tedi complex and the youngest K-Ar cooling age is very short, just 0.5 m.y., and this would reduce to an even shorter time span when only using zircon crystallization ages from the Sydney monzodiorite and Fubilan monzonite porphyry. One could argue that on a geologic timescale, the various fluid events, obvious in core and outcrop as various overprinting vein and alteration events, resulted from a more or less continuous degassing event from a batholithic magma chamber that happened instantaneously on the geologic timescale, especially when compared to some other, longer-lived porphyry systems (e.g., Cadia-Ridgeway; Wilson et al., 2007). Hydrothermal evolution at Ok Tedi would be more similar in nature to Butte, where the sequence of distinct veining events resulted from a single fluid composition (Reed et al., 2013), not necessitating compositionally distinct and, by inference, temporally strongly punctuated fluid expulsions.

In summary, the additional details and discussion presented by Pollard (2014) enriches the model we presented in van Dongen et al. (2013). In our opinion, the discussion highlights some of the inevitable disagreements between “lumpers and splitters.” In this particular case, the detail presented by Pollard (2014) adds to but does not challenge our fundamental conclusion that the Fubilan monzonite porphyry acted as a conduit for fluids and mineralization was kept mostly within the stock by impermeable siltstone country rocks, whereas the fluids that permeated through the Sydney monzodiorite mineralized the reactive limestone country rock. This contrasting country rock response to the fluid system led to distinct differences in mineralization style and grade distribution on the deposit scale.

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