Improving Resource Estimation of Narrow Vein Gold Deposits using Discrete Fracture Networks

Junkin, W.R.[1,2], Ben-Awuah, E.[1]

[1]Bharti School of Engineering, Laurentian University, Sudbury, ON [2]MIRARCO Mining Innovation, Sudbury, ON
wjunkin@laurentian.ca

Narrow Vein Gold Deposits

Narrow vein gold deposits are often characterized by an irregular distribution of gold throughout a mineralized vein. Epithermal gold deposits occur as veins and mineralization follows through three primary modes: open vein type deposits with deposition at depth, hot-spring/sinter type deposits occur as open vein type deposits with additional deposition at surface and replacement type deposits occur as geothermal fluids interact with reactive rocks (Simmonds, 2009).

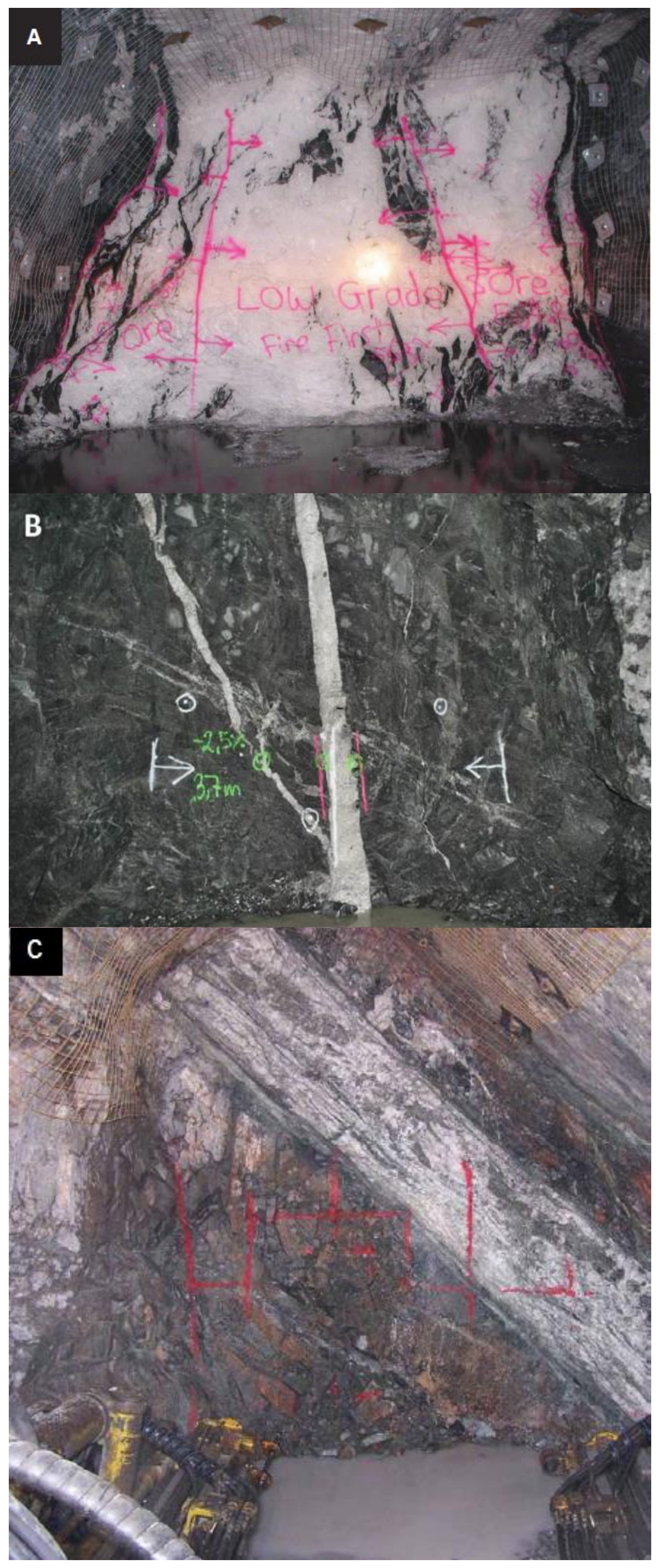

Figure 1. (A) Bendigo gold mine, Australia, pink circles showing location of visible gold, ideal candidate for selective blasting. (B) Narrow splitting gold-quartz vein at the Bjorkdal mine, Skelleftea, Sweden. (C) Gold-Quartz-Sulfide lode in the Imperial mine, Queensland, Australia.
Reproduced from Dominy (2014)

Geological Nugget Effect

The nugget effect is a geostatistical term that refers to the variability of grade within an orebody, sometimes at very close proximity (Isaaks & Srivastava, 1989). An orebody with a high nugget effect has high variability of grade within it.

Narrow vein structures are often characterized by a high geological nugget effect (Dominy 2014). The combination of an irregular distribution of gold throughout mineralization and the uncertainty associated with the location of the mineralization within the host rock contribute to the difficulty in characterization. Narrow vein gold deposits have deposition restricted to the vein structures so mapping these structures along with the distribution of gold within a vein are vital for determining the nugget effect of an orebody (Mooney and Boisvert, 2016).

Variogram models for ordinary kriging can be compared that differ only in their nugget effect. This allows for an estimation of grade where sampling has not occurred (Isaaks & Srivastava, 1989). A spatial point process can also be used to model nuggets within a mining unit as a Poisson or Cox process (Mooney and Boisvert, 2016). Both of these methods for estimating grade can be applied to the nodes of a fracture network.

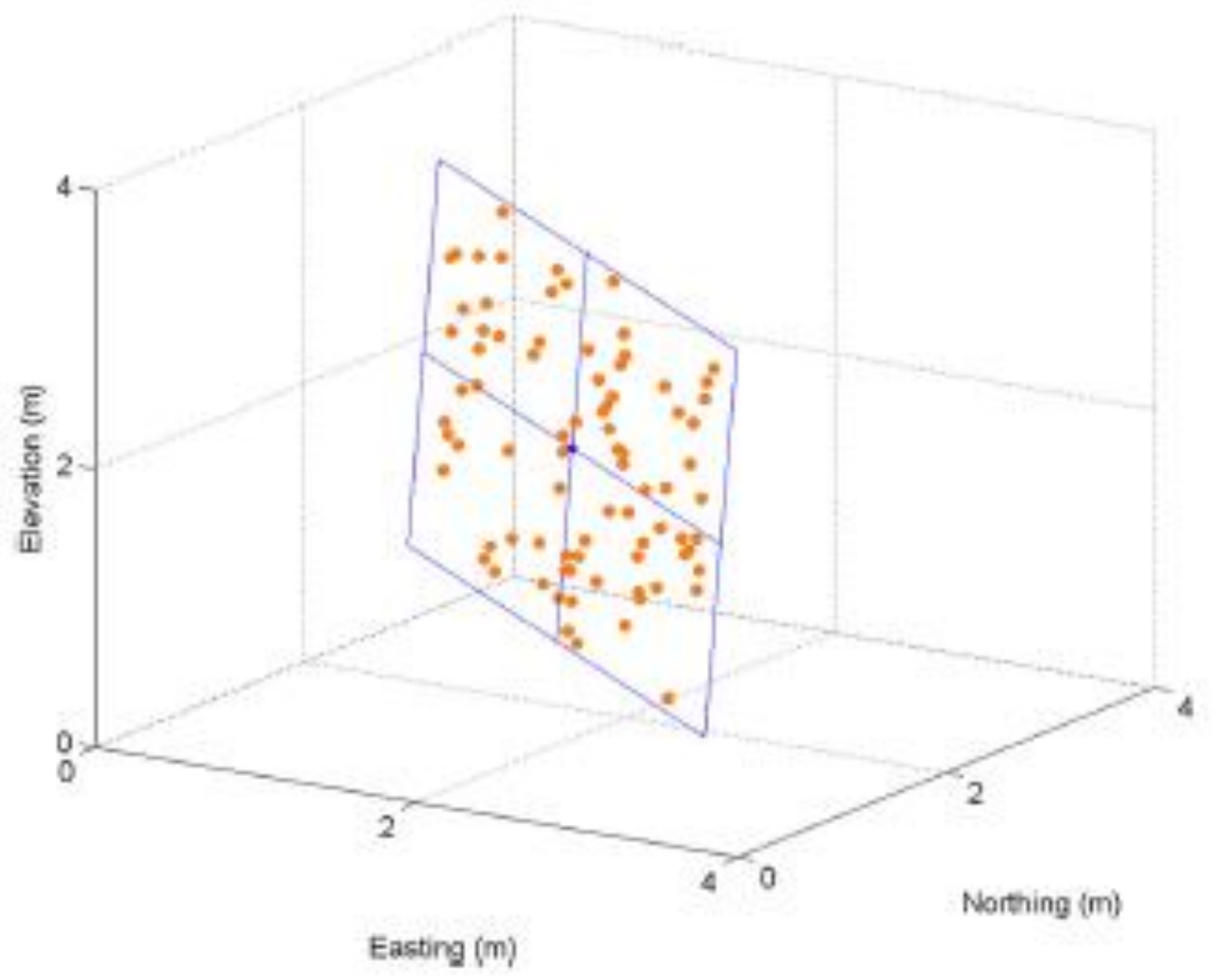

Figure 2. Discrete particles ("nuggets") of gold placed at points using a Poisson process within a vein (blue square) that is defined by a plane.
Reproduced from Mooney and Boisvert (2016)

Discrete Fracture Networks

Mapping narrow vein structures generally results in simplification where veins are mapped as planar feature. For modelling these structures, required inputs are orientation, intensity and length. These inputs are provided as probability distributions that condition a simulated rockmass to represent collected data (Mooney and Boisvert, 2016).

Discrete Fracture Network (DFN) modelling is a form of mapping discontinuities within a rockmass. Discrete features can be generated probabilistically within a model or deterministically, based on mapped structures. This allows for a DFN model to be created for a mine site and continually updated as more mapped data become available.

MoFrac prioritizes mapped data for modelling and provides undulation to structures through tessellation. This undulation is defined by a relative variable for individual discontinuities during modelling. With an undulation of 50% 5 m of variance is expected for a 1000 m long feature at 10 m from mapping and 100 m of variance can be expected for the same discontinuity 50 m from the mapping.

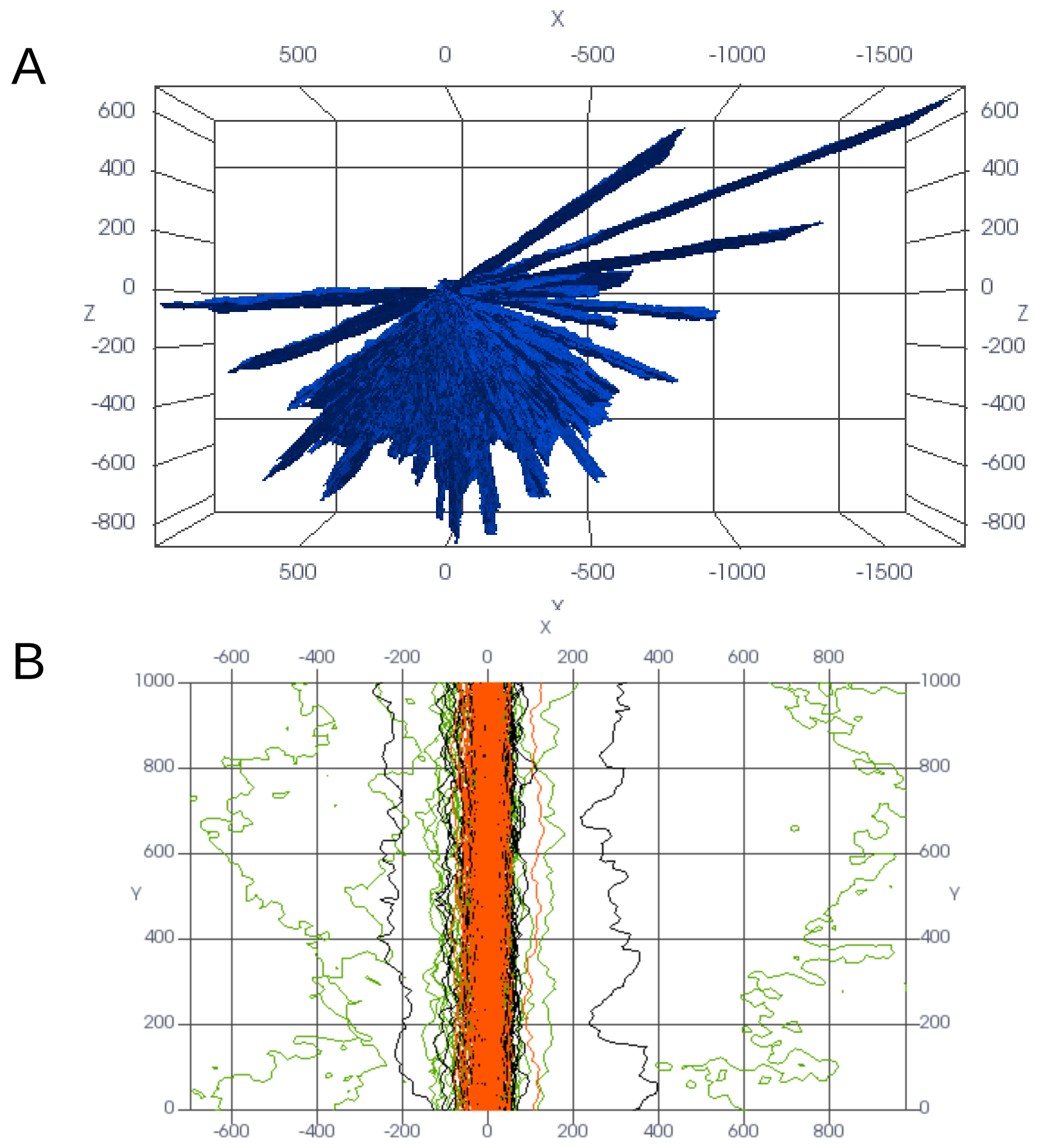

Figure 3. (A) One hundred realizations of a vein modelled as a tessellated mesh using MoFrac. A 1 km long straight line trace oriented horizontally is propagated with a dip of 90° (Standard deviation of 30°) and a 0.5 undulation factor. (B) Traces of veins at 50 m from mapping, with dip of 90° (SD 30°) and undulation factor of 0.5 in green, dip of 90° (SD 15°) and undulation factor of 0.5 in black and a dip of 90° (SD 15°) and undulation factor of 0.25 in orange.

Applications to Resource Estimation

DFN modelling allows for any attribute to be assigned to individual discontinuities. These attributes can define thickness, certainty, grade and characteristics of the surrounding rock. By incorporating models estimating the nugget effect of narrow vein orebodies with DFN modelling of the same orebody an improved model can be realized. MoFrac generated DFN models provide features to modelled structures that can be useful for resource estimation and mine planning.

By modelling geological structures with undulation to simulate waviness together with an orientation distribution MoFrac generates more realistic fracture network models compared to simplified models where features are simulated as planes.

The ability to predict the potential locations of a vein in a vein-hosted gold deposit allows for more efficient mine planning and exploration. The ability to model the structure of a vein through the host rock with undulation also provides an opportunity for more selective blasting and customized blast plans that are optimized based on the structure of the rock.

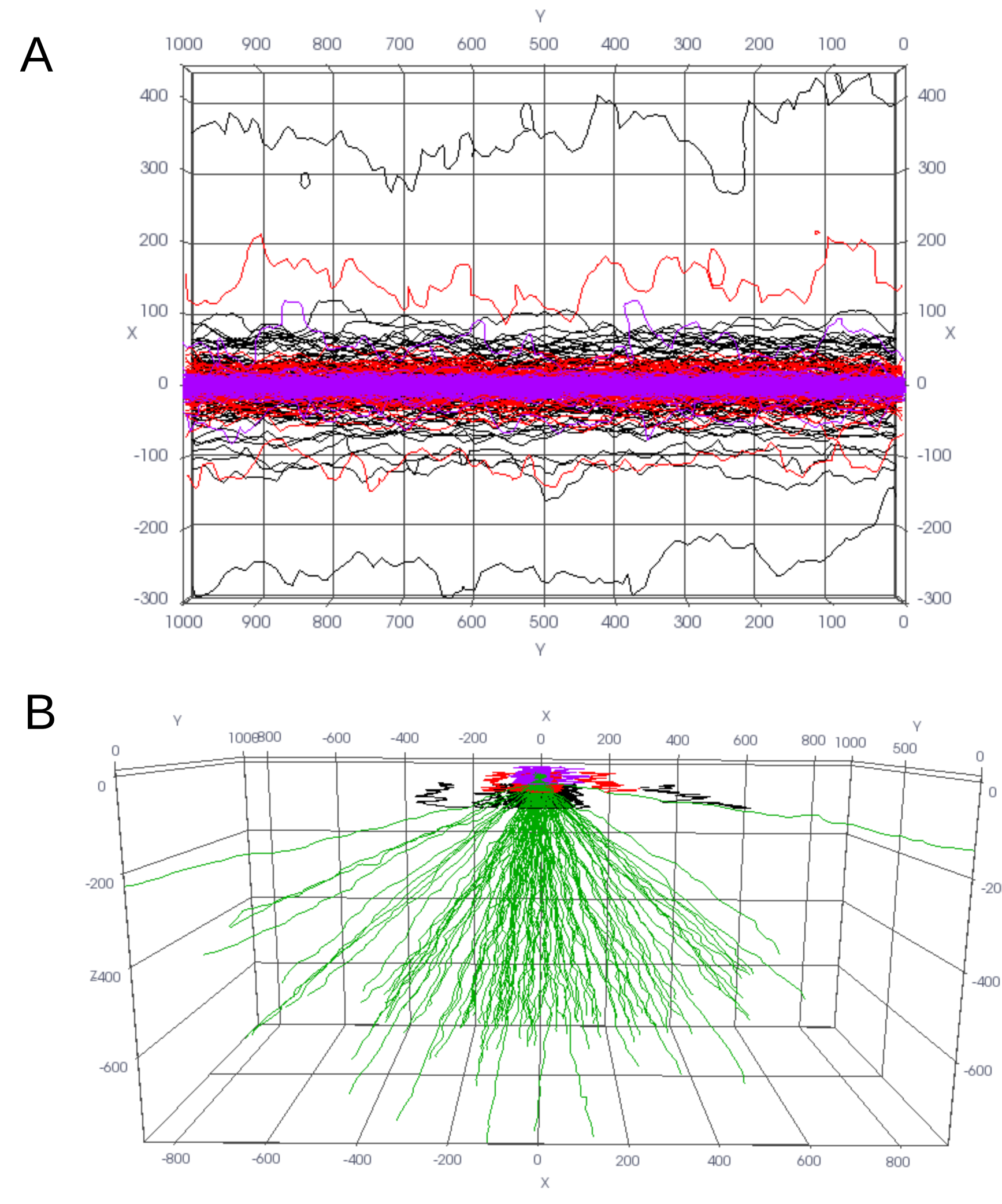

Figure 4. (A) Slices taken at 10 m (purple), 25 m (red) and 50 m (black) depth of one hundred realizations of a vein modelled with a dip of 90° (SD 15°) and a 0.5 undulation factor. (B) The same traces shown longitudinally with a vertical slice showing their paths of propagation.

References

Dominy, S. (2014) Predicting the Unpredictable – Evaluating High-Nugget Effect Gold Deposits In A.C. Edwards (Ed.), *Mineral Resource and Ore Reserve Estimation (pp. 659-678).* Melbourne, Australia, The Australasian Institute of Mining and Metallurgy.
Isaaks, E.H. & Srivastava, R.M. (1989) An Introduction to Applied Geostatistics. New York, New York: Oxford University Press.
Mooney, C.R. & Boisvert, J.B. (2016) Using a Discrete Fracture Network and Spatial Point Process to Populate Veins and Model Grade in a Coarse Gold Deposit. *Natural Resources Research*, 25(3), pp. 255-268.
Simmonds, S-J. (2009). The Nugget Effect: In describing the variability of an ore deposit. Thesis for MSc. Exploration Geology, Rhodes University, Grahamstown, S.A. Retrieved from https://www.researchgate.net/publication/316878381_The_nugget_effect

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