Gregory DERING, Steven MICKLETHWAITE, Stephen J. BARNES, Marco FIORENTINI, Alexander CRUDEN and Eric TOHVER, 2016. An Elevated Perspective: Dyke-Related Fracture Networks Analysed with Uav Photogrammetry. *Acta Geologica Sinica* (English Edition), 90(supp. 1): 54-55.

An Elevated Perspective: Dyke-Related Fracture Networks Analysed with Uav Photogrammetry

Gregory DERING[1,2*], Steven MICKLETHWAITE[1,3], Stephen J. BARNES[2], Marco FIORENTINI[1], Alexander CRUDEN[3] and Eric TOHVER[1]

1 School of Earth Sciences, ARC Centre of Excellence for Core to Crust Fluid Systems, University of Western Australia, 6009, Crawley, Australia
2 Mineral Resources Flagship, CSIRO, Kensington, 6151, Australia
3 School of Earth, Atmosphere, and Environment, Monash University, Clayton, 3800, Australia

An abundance of data from seismic and geodetic monitoring has provided new insight into dyke propagation and emplacement mechanisms. These studies show that faulting and fracturing is part of the magma emplacement process, preceding and accompanying intrusion on timescales of hours and days. Unfortunately, the precision of earthquake hypocentre locations is typically limited to tens or hundreds of meters, which cannot resolve whether the hypocentres relate to strain of wall rock fragments within the dykes, in a process zone around the intrusion or peripherally in the country rock.

To better understand the distribution and role of brittle deformation associated with dyke emplacement we examine an exceptionally well exposed swarm of 19 dolerite dykes, along a swath of coastline near the town of Albany, Western Australia. The dykes are vertical and emplaced in Neoproterozoic monzogranite of the Albany-Fraser orogen. The age of the dykes is poorly constrained, but probably post-dates the onset of regional exhumation of the monzogranite at 1.1 Ga (Scibiorski et al, 2015). Faults and fractures cross cut foliation in the monzogranite. The fault rocks are cataclasites containing granitic host rock fragments, and no mafic material. An early dyke within the swarm is faulted, whereas other dykes have solidified against the faults. This suggests faulting was on-going during the earliest phase of dyking, but preceded the bulk of magma emplacement.

We use Structure-from-Motion photogrammetry and an unmanned aerial vehicle (UAV) for accurate, high resolution 3D reconstruction of outcrop and extraction of structural data. The model is constructed from 1099 images collected from a digital camera mounted to the body of a small quadcopter, flying semi-autonomously over a survey area of ~10,000 m^2. Commercial photogrammetry software (Agisoft Photoscan Pro) was used to construct a dense point cloud. From the point cloud, a ground resolution cell size of 3.5 mm was achieved by construction of an orthorectified image mosaicked from the field images, draped on a digital elevation model (DEM) of the same resolution. Internal model accuracy is constrained in 3D by the use of ground control points surveyed with a total station (30-90 mm measurement precision). The locations and orientation of faults, fractures, and dyke margins were sampled along a digital scanline oriented orthogonal to the dyke swarm. Planes were fit to the vertices of 3D fault and fracture traces using a Random Sample and Consensus (RANSAC) algorithm and least squares regression analysis implemented in Java (Thiele et al., 2015).

The cumulative thickness of the 19 dyke segments is ~35 m (average aperture 1.8 m) emplaced over a distance of 105 m, measured perpendicular to strike. The first critical observation is that dyke emplacement is accommodated by mode one extension but the faults and fractures are parallel with the dykes, with a total dispersion of <20°. Secondly, the number of faults/ fractures increase into the dyke swarm, which has 2.2 ± 0.7 more fractures, per unit length of scanline, in host rocks intruded by dykes relative to the background value. This suggests a broad damage zone developed around the dyke swarm. However, thirdly, within the swarm fractures are heterogeneously distributed such that there is no measurable systematic distribution of faults and fractures relative to individual dyke segments. Instead, shear failure

---

* Corresponding author. E-mail: gregory.dering@research.uwa.edu.au

Fig. 1. High resolution UAV photogrammetry orthoimage of dyke tips emplaced in granitic host rock (left). Geologic map of same outcrop showing relations of dykes to faults and fractures (right).

and fracturing is widely distributed through the volume of host rock affected by dyke emplacement. Faults with measurable displacement have mostly accommodated 10 – 40 cm of dextral shear with a maximum measured displacement of 1.2 m.

These results confirm the surprising observation that dyke-parallel shear failure is closely associated with intrusion events in the middle and upper crust (White et al., 2011; Smith et al., 2004). Our findings differ from numerical models of overpressured dyke propagation in brittle-elastic rock that predict shear failure on faults oriented approximately 30° to the dyke plane (Pollard and Rubin, 1989). We further provide the first evidence that dyke-parallel shear failure occurs in the damage zone associated with a dyke swarm but appears to be unrelated to elevated tensile stress at the leading edges of propagating dykes. Indeed, theoretical predictions of dyke-induced damage suggest damage should decay to a negligible amount over a distance of less than one dyke width perpendicular to the dyke wall (Meriaux et al., 1999). In contrast, we find no systematic variation of damage distribution in the near-field of individual dykes. We suggest the dyke swarm occupies a network of faults and fractures that nucleated prior to and ahead of propagating dykes and remained active during the early stages of emplacement. The mechanics of how such a process operates is not well explained by current theory and remains an outstanding problem.

References

Meriaux, C., Lister, J. R., Lyakhovsky, V., and Agnon, A., 1999. Dyke propagation with distributed damage of the host rock. Earth and Planetary Science Letters 165, 177-185.

Rubin, A. M., and Pollard, D. D., 1988. Dike-Induced Faulting in Rift Zones of Iceland and Afar. Geology 16, 413-417.

Scibiorski, E., Tohver, E., and Jourdan, F., 2015. Rapid cooling and exhumation in the western part of the Mesoproterozoic Albany-Fraser Orogen, Western Australia. Precambrian Research 265, 232-248.

Smith, K. D., von Seggern, D., Blewitt, G., Preston, L., Anderson, J. G., Wernicke, B. P., and Davis, J. L., 2004. Evidence for deep magma injection beneath Lake Tahoe, Nevada-California. Science, 305 1277-1280.

Thiele, S. T., Micklethwaite, S., Bourke, P., Verrall, M., and Kovesi, P., 2015. Insights into the mechanics of en-echelon sigmoidal vein formation using ultra-high resolution photogrammetry and computed tomography. Journal of Structural Geology 77, 27-44.

White, R. S., Drew, J., Martens, H. R., Key, J., Soosalu, H., and Jakobsdottir, S. S., 2011. Dynamics of dyke intrusion in the mid-crust of Iceland. Earth and Planetary Science Letters 304, 300-312.