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Dyke thicknesses follow a Weibull distribution controlled by host-rock strength and magmatic overpressure

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Dykes are the primary transport channels of magma through the crust and form large parts of volcanic edifices and the oceanic crust. Their dimensions are primary parameters that control magma transport rates and therefore influence, e.g. the size of fissure eruptions and crustal growth. Since the mechanics of dyke emplacement are essentially similar and independent of the tectonic setting, dyke properties should generally follow the same statistical laws. The measurement of dyke thicknesses is, of all parameters, least affected by censoring and truncation effects and therefore most accurately accessible. Nevertheless, dyke thicknesses have been ascribed to follow many different statistical distributions, such as negative exponential and power law.

We tested large datasets of dyke thicknesses from different tectonic settings (mid-ocean ridge, oceanic intra-plate) for different statistical distributions (log-normal, exponential, power law (with fixed or variable lower cut-off), Rayleigh, Chi-square, and Weibull). For this purpose, we first converted the probability density functions of each dataset to cumulative distribution functions, thus avoiding arbitrariness in bin size. A non-linear, least-squares fit was then used to compute the parameter(s) of the distribution function. The goodness-of-fit was evaluated using three methods: (1) the residual sum of squares, (2) the Kolmogorov-Smirnov statistics, and (3) p-values using 10,000 synthetic datasets. The results show that, in general, dyke thickness is best described by a Weibull distribution. This suggests material strength is a function of the dimensions of included weaknesses (e.g. fractures), following the “weakest link of a chain” principle. Our datasets may be further subdivided according to dyke lithology (magma type) and type (regional dyke vs. inclined sheet), which leads to an increasingly better fit of the Weibull distribution.

Weibull is hence the statistical distribution that universally describes dyke thickness, irrespective of the tectonic setting, type of magmatic sheet intrusion (e.g. regional dykes and inclined sheets), or magma type. Moreover, the Weibull distribution of dyke thickness can be easily explained by the interplay of host-rock strength (i.e. the distribution of weaknesses) and magmatic overpressure.