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Hydrothermal mineralising systems as critical systems

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Hydrothermal mineralising systems are presented as large, open chemical reactors held far from equilibrium during their life-time by the influx of heat, fluid and dissolved chemical species. As such they are nonlinear dynamical systems and need to be analysed using the tools that have been developed for such systems. Hydrothermal systems undergo a number of transitions during their evolution and this paper focuses on methods for characterising these transitions in a quantitative manner and establishing whether they resemble first or second (critical) phase transitions or whether they have some other kind of nature. Critical phase transitions are characterised by long range correlations for some parameter characteristic of the system, power-law probability distributions so that there is no characteristic length scale and a high sensitivity to perturbations; as one approaches criticality, characteristic parameters for the system scale in a power law manner with distance from the critical point. The transitions undergone in mineralised hydrothermal systems are: (i) widespread, non-localised mineral alteration involving exothermic mineral reactions that produce hydrous silicate phases, carbonates and iron-oxides, (ii) strongly localised veining, brecciation and/or stock-work formation, (iii) a series of endothermic mineral reactions involving the formation of non-hydrous silicates, sulphides and metals such as gold, (iv) multiple repetitions of transitions (ii) and (iii). We have quantified aspects of these transitions in gold deposits from the Yilgarn craton of Western Australia using wavelet transforms. This technique is convenient and fast. It enables one to establish if the transition is multifractal (and if so, quantify the multifractal spectrum) and determine the scale dependence of long range correlations or anti-correlations. The availability of long drill holes with detailed chemical analyses and mineral abundances derived from hyperspectral data enables individual ore bodies to be characterised in a quantitative manner and constraints placed on whether the various transition are possibly critical or of some other form. We also present some simple nonlinear models that produce the multifractal character and correlation scaling relations observed in these data sets,