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Pseudosections, pseudo P-T paths and pseudo petrology: the difficulty of defining the reactive system when solving disequilibrium problems with an equilibrium method

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Modern petrological studies involve not only the determination of the formation conditions of a rock but also how these conditions were achieved geodynamically and how the rock then reached its present-day sampling location (e.g. outcrop or borehole). These seemingly simple tasks are beset by a major problem: determination of pressure-temperature (PT) formation conditions relies on applying equilibrium thermodynamics to measured mineral compositions and assemblages whereas solving geodynamic progression and pathways necessarily requires understanding disequilibrium i.e. the identification of multiple stages of partial re-equilibrium in a sample. The determination of PT conditions has improved remarkably in the last decades with the development of internally-consistent thermodynamic datasets combined with software allowing rapid calculation of equilibria for natural mineral or whole rock compositions (e.g. Thermocalc, Theriak-Domino and Perplex). The use of P-T pseudosections, one of these applications allowing mineral assemblages, compositions and molal proportions to be determined for a fixed bulk rock composition, has become almost de rigueur in modern metamorphic petrology. This is an extremely valuable tool for the petrologist but too many studies using the pseudosection approach seem to have forgotten the basic limitation of such diagrams and attempt to use a single diagram to document the prograde and/or retrograde path, as well as the metamorphic peak, from a single diagram. Numerous studies demonstrate the sensitivity of assemblage fields in such diagrams to small changes in bulk composition therefore it is remarkable how often mineral zonation on the prograde path is ignored even though it significantly changes the effective bulk composition at peak conditions. Likewise, retrograde reactions localised at specific grain boundary sites also represent localised effective bulk compositions and cannot simply be read from the same pseudosection as utilised for the peak assemblage. For example, many retrograded eclogites show distinctly different feldspar (from albite to anothite) and amphibole (from tremolite to tschermakite or even taramite) compositions in garnet, omphacite, kyanite and zoisite/clinozoisite domains even though they all probably formed at about the same time. Also, many eclogites were demonstrably free of matrix amphibole before this phase was produced, mostly at the expense of clinopyroxene, by fluid influx during decompression. Such rocks commonly also show hydrous phases as inclusions in garnet grown on the prograde path. Thus the water content of the rock was not constant along the P-T path and a pseudosection calculated with the water content of the present-day bulk rock offers little to enhance our understanding of the prograde, peak or retrograde history of the rock. Although problems still exist with activity-composition models for important rock-forming minerals (garnet, clinopyroxene, feldspar, amphibole and mica models are all suspect to some degree) it is not the equilibrium diagram tools themselves that are hindering progress in petrology but their general application. The identification of minerals in the optical microscope is a dying art as geoscience curricula reduce basic rock and mineral studies as they expand to include more and more non-traditional content. Thus the electron microprobe has become the modern microscope and detailed study of thin sections for characteristic reaction textures has become less common. However, with a bulk composition, a laptop and freely available software packages, many consider themselves capable of determining rock PT history. This new field of pseudo-petrology, if allowed to continue unabated, will destroy all the advances in understanding of the earth in the last decade that came from innovations in microanalysis combined with the development of the equilibrium thermodynamic modelling tools.