Developments in the statistical analysis of compositional data over the last two decades have made possible a much deeper exploration of the nature of variability and the possible processes associated with compositional data sets from many disciplines. In this paper, we concentrate on geochemical data. First, we explain how hypotheses of compositional variability may be formulated within the natural sample space, the unit simplex, including useful hypotheses of sub-compositional discrimination and specific perturbational change. Then we develop through standard methodology, such as generalised likelihood ratio tests, statistical tools to allow the systematic investigation of a lattice of such hypotheses. Some of these tests are simple adaptations of existing multivariate tests but others require special construction. We comment on the use of graphical methods in compositional data analysis and on the ordination of specimens. The recent development of the concept of compositional processes is then explained, together with the necessary tools for a staying-in-the-simplex approach, such as the singular value decomposition of a compositional data set. All these statistical techniques are illustrated for a substantial compositional data set, consisting of 209 major oxide and trace element compositions of metamorphosed limestones from the Grampian Highlands of Scotland. Finally, we discuss some unresolved problems in the statistical analysis of compositional processes.