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Application of the multivariate canonical trend surface method to the identification of geochemical combination anomalies

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ABSTRACT

In geochemical exploration, geochemically observed data are generally multidimensional. Due to the geochemical characteristics and the diversity of geological conditions, elements often show correlated, structural and singular characteristics in the spatial distribution. In a local mineralization block, these three characteristics are particularly strong. A group correlation between elements is represented by main mineralization factors. The spatial variation of elements under the large-scale condition mostly shows nonlinear characteristics. Based on the canonical correlation principle with spatial observation data, this paper presents a multivariate canonical trend surface method, which expresses a geochemical element multivariable by a regional canonical variable. This regional canonical variable is taken as the main mineralization factor. We combine the main mineralization factor and two-dimensional trend surface constituted in a plane right angle coordinate system with the maximum correlation, to obtain the canonical correlation coefficient. This method reflects not only the correlation between elements, but also the spatial structure and singularity. It must be stated that since this method is a statistical method established by treating spatial observation data, it is not suitable for the simulation of dynamic processes in ore-forming systems, but it can be somehow used to effectively treat spatially discrete observation data. Therefore, the Xichuan District in Baishan City, Jilin Province, northeastern China is chosen as a study area, in which we processed and analyzed 7675 geochemical samples using the proposed multivariate canonical trend surface method. The results using the multivariate canonical trend surface method show that the location of the identified multivariate geochemical anomaly is consistent with the location of the known mineral deposits in the study area. Since the proposed multivariate canonical trend surface method cannot be used to simulate the dynamic processes involved in an ore-forming system, the computational simulation method in the emerging computational geoscience discipline should be used as the first choice in future research, especially for the prediction of deep ore deposits.

1. Introduction

In geochemical exploration, separating geochemical anomalies from the geochemical background is very important (Cheng and Xie, 2006; Galuszka, 2007; Hao et al., 2014; Li et al., 2003; Pereira and Neves, 2012). Geochemical data are generally multidimensional. The influence of geochemical characteristics and the diversity of geological conditions contribute to the characteristics of correlation, structure and singularity. Correlation refers to a close relationship in space reflected by the elements' geochemical characteristics, structure refers to the superimposed effect of elements as a result of multi-stage diagenetic and ore-forming processes, and singularity refers to the uneven effect of the elements' combination in the spatial distribution caused by geological imbalance. In a mineralization block, these characteristics among elements are particularly strong (Gong et al., 2013).

The spatial distribution of elements is the reflection of stages in diagenesis and ore-forming processes, or because of various geological processes, such as diagenesis, weathering and sedimentation, which cause comprehensive results. The computational simulation of diagenesis and ore-forming often reflects the processes, whereas the elements' spatial anomaly estimation often reflects spatial variation characteristics of the elements. Ore deposits within the upper crust of the Earth are the direct consequences of nonlinear dynamic interactions between rock deformation, pore-fluid flow, heat transfer, mass transport and chemical reaction processes (Gow et al., 2002; Hobbs et al., 2000, 2008c,d; Ju et al., 2011; Lin et al., 2006; Liu and Zhao, 2010; Liu et al., 2005, 2008, 2011; Ord et al., 2002; Schaubs and Zhao, 2002; Schmidt Mumm et al., 2010; Sorjonen-Ward and Zhang, 2002; Zhao et al., 2008, 2009, 2010a). For the formation of an ore deposit, computational geoscientists often adopt scientific and predictive methods (such as dynamic process computational simulation methods) relevant to contemporary geoscience research, instead of the traditional qualitative description methods (Zhao et al., 2009). For this reason, Zhao and his coworkers have conducted extensive and systematic work (Zhao, 2009, 2014;

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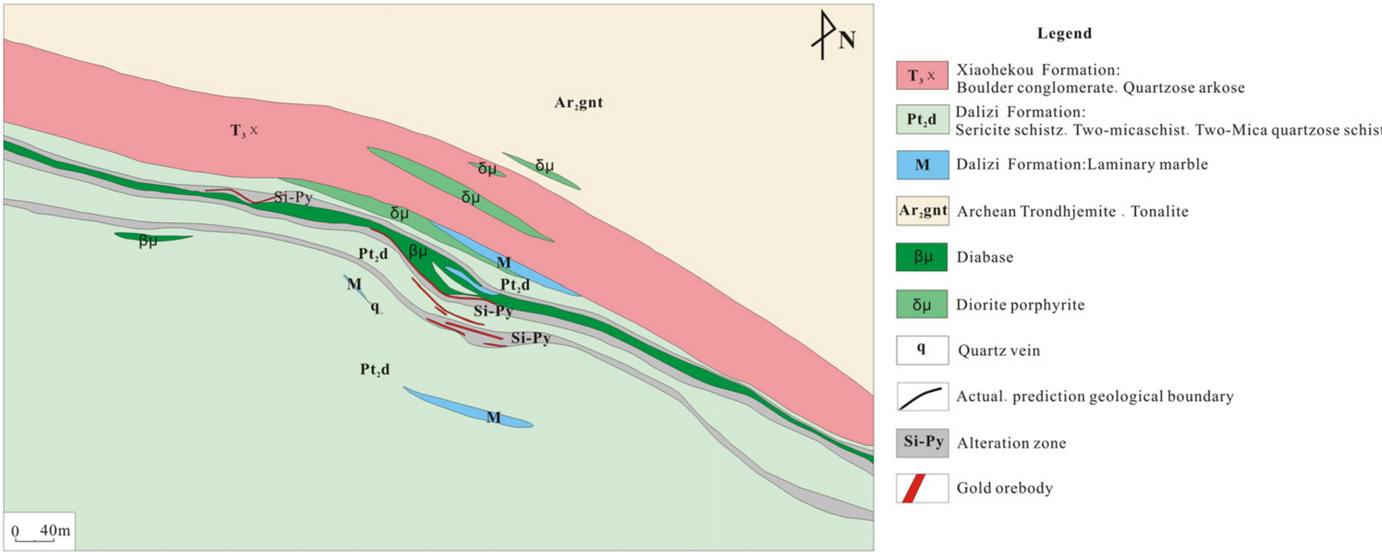

Fig. 1. Simplified geological map of the study area.

Zhao et al., 1997, 1998, 1999, 2008, 2009) during the past two decades or so. In respect to diagenesis and ore-forming dynamic system simulation, their pioneering and systematic work has created the emerging computational geosciences with the characteristic of simulating nonlinear dynamic processes involved in ore-forming systems within the upper crust of the Earth (Awadh et al., 2013; Charifo et al., 2013; Khalil et al., 2013; Mügler et al., 2012; Schmidt Mumm et al., 2010; Sung et al., 2012; Zhao et al., 2009, 2010a, 2012a,b). In particular, the proposed computational geoscience simulation methods have been widely used not only to solve many mineralization problems in geosciences (Gow et al., 2002; Hobbs et al., 2000, 2008c, 2010; Ord et al., 2002; Zhao et al., 2010a, 2012a, 2014a), but also to solve a large number of problems in other scientific fields (Alt-Epping and Zhao, 2010; Awadh et al., 2013; Charifo et al., 2013; Hobbs et al., 2004, 2007, 2008a,b; Khalil et al., 2013; Lei et al., 2013; Lin et al., 2003, 2008, 2009; Mügler et al., 2012; Poulet et al., 2013; Sung et al., 2012; Xing and Makinouchi, 2008; Yan et al., 2003; Zhang et al., 2003, 2008, 2011a; Zhao, 2009, 2014; Zhao et al., 2010b, 2011, 2013a,b, 2014b,c).

Because the dynamic simulation of diagenesis and ore-forming processes involves many geological parameters and mechanisms (Zhao et al., 2012a, 2014a), the obtained results can reflect geological processes from deep to shallow. Therefore, computational simulation

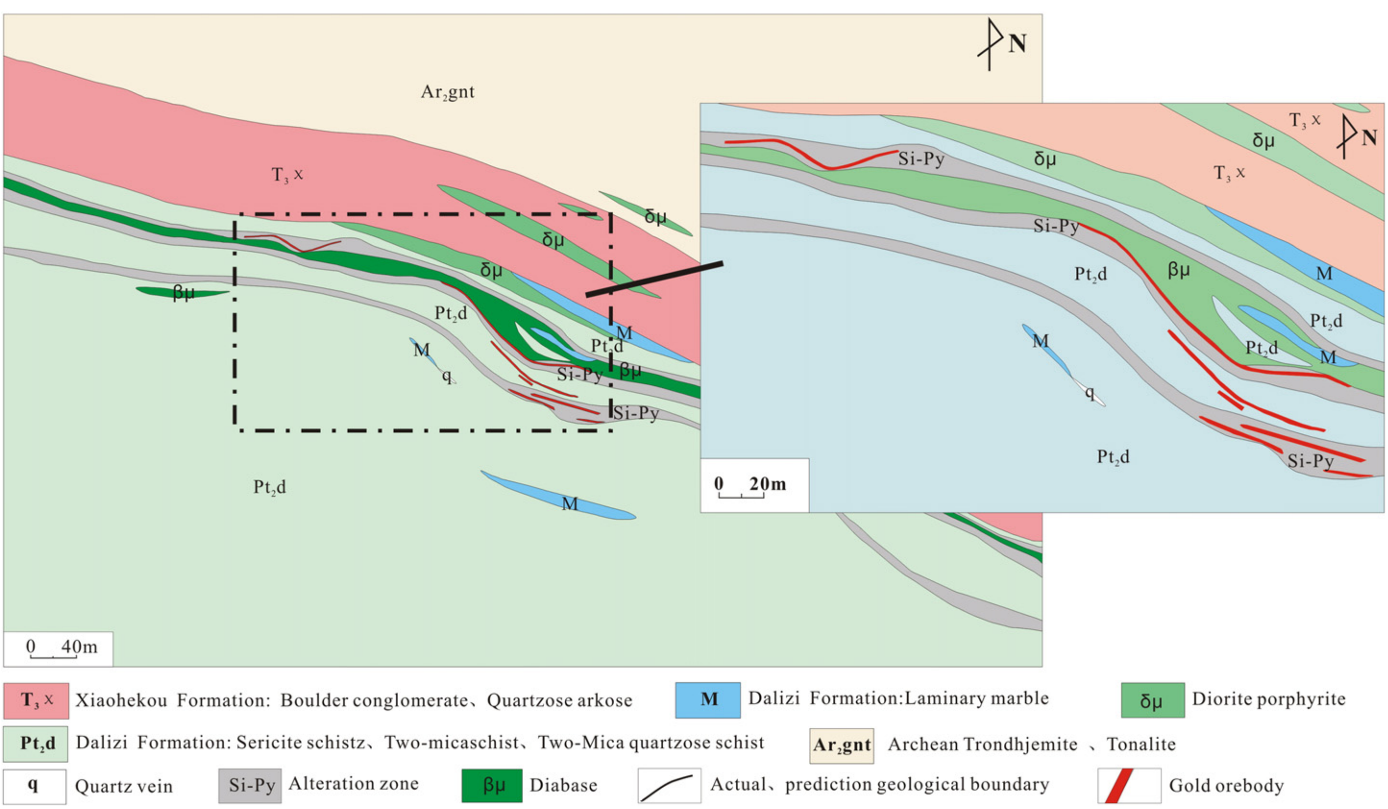

Fig. 2. Gold ore body map in the study area.