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Lithology and mineralogy recognition from geochemical logging tool data using multivariate statistical analysis

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HIGHLIGHTS

- Cross plot and PCA were applied for lithology characterization and mineralogy description.
- Oxide logs provide information for accurate lithological and mineralogical description.
- Geochemical log can be an outstanding complement to in situ physical logs and core data for geological interpretation.

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ABSTRACT

The availability of a deep well that penetrates deep into the Ultra High Pressure (UHP) metamorphic rocks is unusual and consequently offers a unique chance to study the metamorphic rocks. One such borehole is located in the southern part of Donghai County in the Sulu UHP metamorphic belt of Eastern China, from the Chinese Continental Scientific Drilling Main hole. This study reports the results obtained from the analysis of oxide log data. A geochemical logging tool provides in situ, gamma ray spectroscopy measurements of major and trace elements in the borehole. Dry weight percent oxide concentration logs obtained for this study were SiO_2, K_2O, TiO_2, H_2O, CO_2, Na_2O, Fe_2O_3, FeO, CaO, MnO, MgO, P_2O_5 and Al_2O_3. Cross plot and Principal Component Analysis methods were applied for lithology characterization and mineralogy description respectively. Cross plot analysis allows lithological variations to be characterized. Principal Component Analysis shows that the oxide logs can be summarized by two components related to the feldspar and hydrous minerals. This study has shown that geochemical logging tool data is accurate and adequate to be tremendously useful in UHP metamorphic rocks analysis.

1. Introduction

The availability of a deep well that penetrates deep into the Ultra High Pressure (UHP) metamorphic rocks is unusual and consequently offers a unique chance to study the metamorphic rocks. One such borehole is located in the southern part of Donghai County (Jansu province), in the Sulu UHP metamorphic belt of Eastern China, from the Chinese Continental Scientific Drilling Main hole (CCSD-MH) (Fig. 1). This hole penetrates through 5158 m of UHP metamorphic rocks. It is by far the deepest well drilled into the metamorphic in China. According to lithologic studies of the cores (Luo and Pan, 2010), the CCSD-MH consists mainly of orthogneiss, paragneiss, eclogite, amphibolite and ultramafic rock. Well logging was one of the most significant phases and key technologies in the CCSD project. CCSD-MH was logged immediately after drilling. The petroleum industry logging methods were utilized to investigate the entire section of the main hole continuously. Geophysical and geochemical logs were run by Shengli Petroleum Logging Company. Great emphasis has already been on geophysical log data studies (see e.g. Niu et al., 2004; Pan et al., 2005; Wang et al., 2005; Xu et al., 2006; Salim et al., 2008; Luo and Pan,

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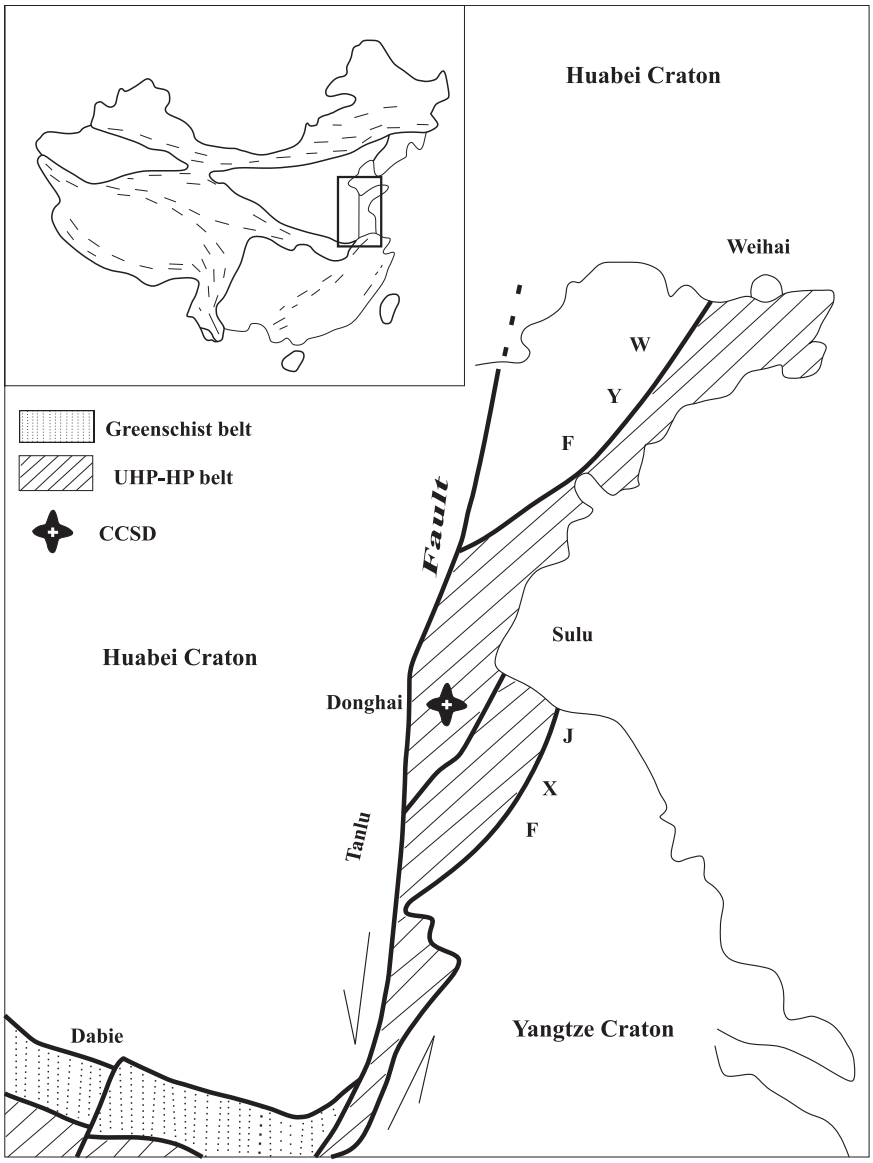

Fig. 1. Location of Chinese Continental Scientific Drilling (CCSD) main hole (after Yang, 2009). WYF: Wuliang–Yantai Fault; JXF: Jiashan–Xionshui fault.

2010; H. Pan et al., 2010; H.P. Pan et al., 2010; Luo et al., 2011; Konaté et al., 2015a, 2015b; Yang et al., 2016). These previous studies provided understanding on the lithology and the physical properties of the rocks from CCSD-MH. However, successful scientific drilling entails a more complete description of the borehole rocks. So, it is important to study both geophysical and geochemical log data in order to fully understand the log signature of CCSD-MH. Consequently, here we concentrated on geochemical logs (oxide logs) interpretation. The dry weight percent oxides were obtained by converting the measured relative elemental yields produced from the geochemical logging tool. The variation in dry weight percent of the major elemental oxides are estimated by assuming that approximately 50% of all rock is oxygen by weight (Hertzog et al., 1987). Here, the geochemical data were processed by CCSD logging engineer staff. The geochemical logs which will be discussed in this study are from 100 to 2010 m (Fig. 2). The analysis of these logs are vital for understanding of in-situ variations of chemical properties in the Sulu UHP metamorphic rocks. This is because little is known about geochemical logging interpretation in these rocks. H. Pan et al. (2010) earlier studied the oxide logs of the CCSD-MH (100 – 1000 m) and published in Chinese, which is unknown to the international geoscientist community.

The geochemical logging tool was originally developed by the oil industry for use in sedimentary rock and is now put to use in crystalline rocks during scientific drilling research. The tool string (Anderson et al., 1990) is lowered into a well to provide in situ, gamma ray spectroscopy measurements of the relative concentrations of major and minor elements. In turn, continuous elemental and dry weight percent oxide abundances are derived at 0.15 m intervals throughout the well. The geochemical log data collected, therefore, offer one possibility for obtaining more accurate lithology and mineralogy description (Anderson et al., 1988). More details on geochemical logging technique can be found in (Hertzog et al., 1989).