Pre-Seismic Hydro-Chemical Anomalies in Water of Well Liaogu-1 in Shandong Province, China

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Since its formal operation in 1981, the Well Liaogu-1 has showed good capability to reflect earthquakes with Ms≥5.0 within certain range around even the pre-seismic abnormal changes of hydro-chemical constituents are quite different for each earthquake. Based on fault dislocation theory and rock mechanics experiments with the data collected more than 30 years, some major results were summarized.

1, the well Liaogu-1 at a special tectonic position with good hydrogeological and borehole conditions is reliable for continuous observation, and a wealth of valuable actual observation data are obtained. Abnormal changes of hydro-chemical constituents reflected well to earthquakes Ms≥5.0 in a range of 500km around the well.

2, The synchronous abnormal changes of multiple hydro-chemical constituents in the well before the Heze Ms5.9 earthquake(1983) were caused by the intensifying activity of the Liaokao fault from random to ordered fracturing, indicating local increase of tensile stress and corresponding pressure reduction around the borehole. The appearance of a complete set of medium-term, short-term and imminent anomalies is a reflection of the preparation process of the source stress field.

3, some single hydrochemical parameter displayed obvious abnormal change before the earthquakes of Datong Ms5.8(1991), Ningjin Ms5.8(1981), South Yellow Sea Ms5.3(1992) and Cangshan Ms5.2(1995), reflecting the intensification of regional tectonic stress field and the response of the tectonic sensitive area where the well Liaogu-1 located in.

4, various field-source seismic precursor characteristics of multiple constituents are of certain prediction significance. The appearance of source precursors means that earthquake with Ms≥5.0 may occur in the near future at some tectonic position on the same active fault. The appearance of field precursors means that the activity of regional stress field is intensifying and earthquake with Ms5.0 may occur in a couple of weeks or months on some other active fault zone. Therefore, to distinguish field precursor and source precursor is greatly important for earthquake forecast and prediction.

Lower continental crust residue in Mesozoic EM1-type basalts from the North China craton

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The origin of Enriched Mantle 1 (EM1) end-member has been in great controversy. In order to investigate the role of the lower continental crust (LCC) in generation of EM1 basalts, the Early Cretaceous (~125 Ma) Yixian and Sihetun basalts (MgO >10%) from the North China craton were collected, and their major, trace element and Sr-Nd-Pb isotopic compositions were measured. These basalts show low $\varepsilon_{Nd}(t)$ (-1.48 to -11.8), low initial $^{206}Pb/^{204}Pb$ ratios (<17.306), and slightly high initial $^{87}Sr/^{86}Sr$ ratios (0.70622 to 0.70679), pointing to an origin of EM1. Enrichment of K, Pb and Sr, and depletion of Nb and Ta are also shown in these basalts. These features can not be explained by recycling of subducted oceanic crust with sediments which was usually regarded as the origin of EM1 OIBs, because dehydration will lead to depletion of K, Pb and Sr and enrichment of Nb, Ta in subducted residue that was shown in global EM1 OIBs. We suggested that involvement of ancient LCC components in the mantle source could be responsible for the generation of the above isotopic and trace element signatures.

High Mg# values (>72), low CaO/Al_2O_3 ratios (<0.65) and high Fe/Mn ratios (56-70) with low CaO (<8.5 wt%) and FeO^T (<9 wt%) contents suggest that these basalts could have been derived from a pyroxenite source produced by hybrid interaction between peridotite and Si-rich melts from subducted MORBs or foundered eclogitic LCC. MORBs have much higher $^{143}Nd/^{144}Nd$ and lower $^{87}Sr/^{86}Sr$ ratios compared to these basalts. Thus, subducted MORBs could not have been the source of the hybridizing melts. Instead, the source of the melts were most likely to be foundered eclogites that originated from ancient lower continental crust of the NCC.

Collectively, recycling of the foundered lower continental crust during the peak (~130Ma) of the lithospheric thinning of the North China craton could have played a significant role in production of the Mesozoic intraplate EM1 magmatism. Such lower continental crust components may be also present for some OIBs, especially those with continent-like trace element compositions (e.g. Aphanasey Nikitin Rise) [1, 2].

[1] Borisova *et al* (2001) *J Petrol* **42,** 277-319. [2] Mahoney *et al* (1996) *Geology* **24,** 615-618.

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