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Controls of paleochannels on groundwater arsenic distribution in shallow aquifers of alluvial plain in the Hetao Basin, China

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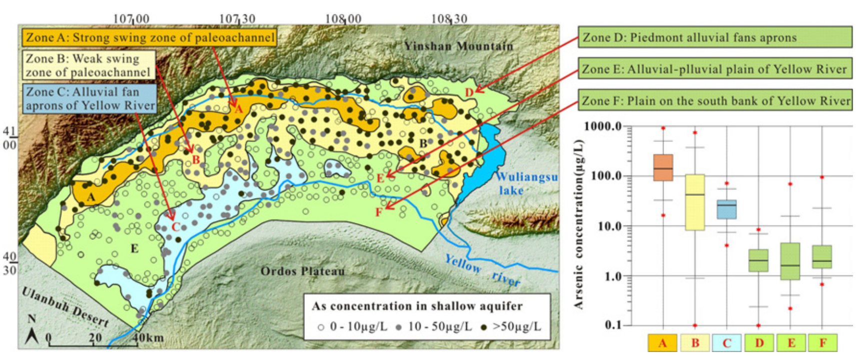
HIGHLIGHTS

- A new concept of Swing Intensity Index (S) of river courses is presented.
- S is firstly used to explain the spatial distribution of high arsenic groundwater.
- Groundwater As concentrations are directly proportional to swing intensity index.
- Swing zones of paleochannel represent strong reducing conditions and low infiltration recharge.

GRAPHICAL ABSTRACT



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ABSTRACT

Less is known about controls of sedimentary structures in groundwater As distributions in sedimentary aquifers, and quantitative description of relationship between sedimentary environment and high As groundwater (according to WHO, As > 10 μg/L) is a challenging issue. Three hundred and eighty-two hydrogeological borehole loggings (well depths of 50–300 m) were collected and four hundred and ninety nine groundwater samples were taken to investigate controls of paleochannels on groundwater arsenic distribution in shallow aquifers of alluvial plain in the Hetao Basin. Results showed that the swing zone, formed by bursting, diversion and swing of ancient Yellow River course since the Late Pleistocene, has an obviously corresponding relationship with spatial variability of groundwater As in the Hetao Basin. "Swing Intensity Index" (S), which is firstly defined as the sum of clay-sand ratio (R) and the number of clay layers (N), can be used as the sedimentary facies symbol to establish the new recognition method for hosting high As groundwater. There is a positive correlation between the swing intensity index (S) of paleochannels and groundwater As concentrations. The swing zones of paleochannels with high S values represent hydrogeochemical characteristics of the strong reducing environment, serious evaporation, strong cation exchange, and the low infiltration recharge of surface water, which lead to enrichment of groundwater As in the shallow aquifers.

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1. Introduction

High As groundwater has been widely found in China (Guo et al., 2014). The Hetao Basin in Inner Mongolia is one of the typical areas, hosting high As groundwater, with the morbidity rate of water-borne endemic arsenism around 15.54% (Jin et al., 2003). Groundwater As concentrations were quite patchy, varying from drinking water standards to several hundred μg/L in the wells with several meters apart from each other (Guo et al., 2012). The situation is similar to West Bengal and Bangladesh (BGS/DPHE (British Geological Survey and Department of Public Health Engineering, Bangladesh), 2001; Van Geen et al., 2010). The causes of uneven distributions of groundwater As have received considerable attentions from the scientists.

It has generally been accepted that the differences in terrain, physiognomy and depositional environments result in uneven distribution of high As groundwater (As > 10 μg/L) (Guo et al., 2008). Geogenic groundwater arsenic contamination normally tends to be associated with anoxic environments of poorly drained aquifers in young alluvial-pluvial sediments with flat topography and high salinity (Smedley and Kinniburgh, 2002; Wang et al., 2009; Rodríguez-Lado et al., 2013; Guo et al., 2016), such as the Ganges-Brahmaputra-Mekna-Ganges alluvial fan aquifers (Zheng et al., 2004; Van Geen et al., 2008; Neidhardt, 2012), the Mekong and Red River alluvial plains in Southeast Asia (Berg et al., 2001; Schmoll et al., 2006;Berg et al., 2007; Winkel et al., 2008; Chanpiwat et al., 2011; Lawati et al., 2012), the Mississippi alluvial plain aquifer (Sharif et al., 2008), the Skelter River alluvial plain aquifer (Chapagain et al., 2009), and South America's Salí River alluvial plain in Argentina (Nicolli et al., 2010). In China, groundwater As concentrations in some flood plains along the Yellow River and the Yangtze River were found to be abnormally high (CGS (China Geological Survey), 2010; Zhang et al., 2013). Conditions that affect the migration and release of As in sedimentary aquifers include redox conditions, spatial distributions of metal oxide minerals (such as Fe, Mn, Al oxides and hydroxides), exchangeable As in sediments, distribution and contents of sedimentary organic matter, and aquifer permeability (Nickson et al., 2000; Smedley and Kinniburgh, 2002; Swartz et al., 2004; Guo et al., 2008; Xie et al., 2013). Distribution of high As groundwater is related to the shallow lake facies, marsh facies and depressive facies of sedimentary structures (Guo et al., 2010). In addition, flushing history also served as a hydrogeological control on regional distribution of As in shallow groundwater of the Bengal Basin (Van Geen et al., 2008). The above-mentioned conditions are mostly controlled by sedimentary environment features. However, less is known about controls of sedimentary structures in groundwater As distributions in sedimentary aquifers.

Groundwater As in the Hetao basin has been generally believed to occur naturally in Later Pleistocene–Holocene alluvial–lacustrine aquifers (Generally between 10 and 50 m) (Smedley et al., 2003; Guo et al., 2008; Deng et al., 2009; Guo et al., 2014). The Pleistocene–Holocene sedimentary environment of the Hetao Basin is directly connected to the formation and evolution of the Yellow River (Pan et al., 2012; Li et al., 2017). Investigations of lacustrine strata in outcrops and drill cores have revealed that the lake environment may have existed

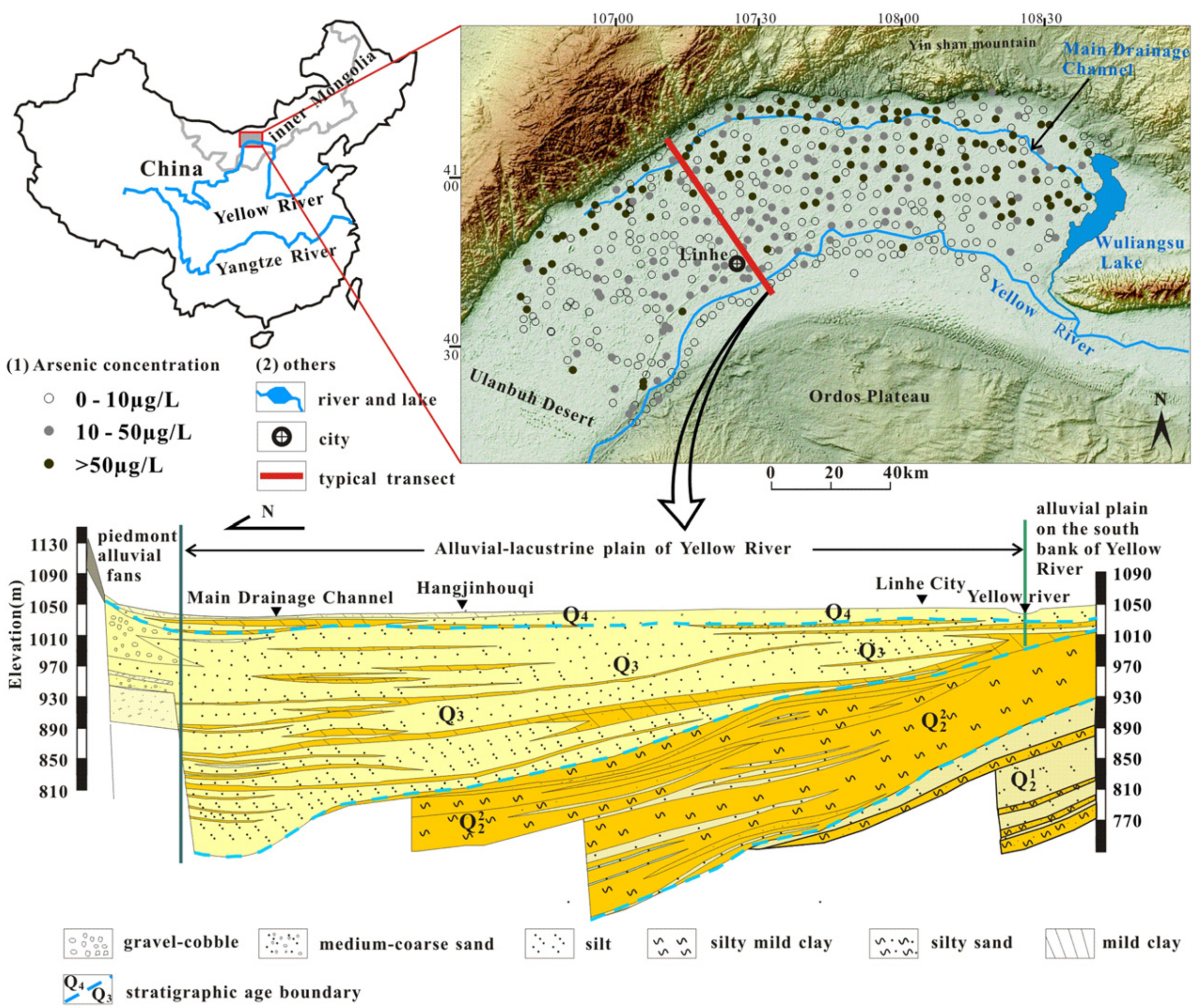

Fig. 1. Spatial distribution of As and the sedimentary structure of Hetao Basin.