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title: # Isotopic constraints on recharge and age of groundwater in the Songnen Plain, Northeastern China

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INTRODUCTION AND STUDY AREA

The Songnen plain (121°21'~128°18'E and 43°36'~49°26'N), lies between the Greater and Lesser Hinggan and the Changbai ranges in northeastern China. it is made up mainly of the alluvial deposits of the Songhua and Nenjiang rivers. The plain covers about 178,000 km^2 and is populated by about 35 million people. It consists of the piedmont plain in the northern and western part, the central low plain, and the high plain in the eastern part. The unconfined aquifer consists of Quaternary coarse-grained gravel and sand with a thickness up to 200 m in the piedmont plain, and fine and silty sand in the central low plain but Cretaceous formation in the high plain with a thickness less than 50 m. The confined aquifer mainly occurs in the central low plain and consists of medium to fine and silty sand, which correspond to the Pleistocene and Tertiary formation. Groundwater movement has historically been oriented primarily from plain margins toward the central part. However, there has been a steady increase in ground-water pumping and resulted in substantial declines in water levels. A depression in the water-level surface is apparent in the vicinity of Daqing and have resulted in ground-water movement being directed into the major pumping centers.

Multiple sources of recharge to the aquifer system are present across the basin. Despite the presence of irrigation has added to the potential sources of recharge. But infiltration through mountain stream channels and shallow subsurface inflow, probably is one of the most important sources of recharge to the plain. In this study, chemical and isotopic data from groundwater and surface water throughout the Songnen Plain, were used together with classical hydrogeological information to study the sources of recharge and estimate groundwater age in the plain.

RESULTS AND DISCUSSION

The tracer data indicated that major sources of water to unconfined aquifer included (1) recharge from mountains along the margins along the west, north and southeast, (2) precipitation inside the plain, (3) seepage from the rivers, (4) irrigation return. Mountain-front recharge probably is one of the most important sources of recharge to the basin. Tracers distribution mainly depth dependend suggested the active groundwater recharge zone has a thickness of ~100 m in the piedmont, ~80 m in the central plain and a less than 50m in the high plain. The recharge rate estimated by tracers were 126 mm/yr, 60 mm/ yr, 59 mm/yr for the piedmont plain, central plain and high plain, respectively. These waters were younger than 50 years and therefore were renewable.

The ranges of δ-values for groundwater within quaternary confined aquifer were close to those of the samples collected from unconfined aquifer. The relationship between δ-values of oxygen-18 and deuterium for samples collected from the area near piedmont and in the central low plain show the different slope of fitted line. Groundwater samples in the western and northern part of the piedmont lay to the right of the LMWL and plot along an evaporation line with slope of 4.9. The original isotope values of the recharge water by extrapolating the evaporation line to the intersection with the LMWL fall in the range of mountain rivers. However, groundwater samples collected from the central low plain plot along an evaporation line with slope of 3.6 which is close to the slope of the evaporation line of unconfined aquifers in the same region. The original isotope values of the water prior to evaporation inferred by extrapolating the evaporation line to the LMWL close to the weighted mean value of Qiqihaer precipitation, which reflects

that recharge water comes from the local precipitation. These findings suggest that two recharge mechanisms for deep groundwater possibly occurred in the Quaternary confined aquifer. One involved recharge via leakage from the unconfined aquifer, and the other involved lateral recharge from mountains through fractures and from the east high plain. Modern recharge for this confined aquifer mainly occurred at the west piedmont plain and the east high plain along Qi'an–Zhaozhou. The recharge rate estimated by tracers was 6.2 mm/yr. Groundwater age dated by carbon-14 range from modern to 10 kaBP.

The groundwater samples of deep Tertiary confined aquifer were mainly collected from the central low plain. These groundwaters are tritium free and have C-14 activity less than 40 pmc. Most samples plot below, but nearly parallel to, the local meteoric water line. The difference of the intercept between the regression line and the one of LMWL probably reflects the different recharge conditions of these paleowaters from the modern waters. Modern recharge of this confined aquifer is limited at the outcrop area in the northwest part of piedmont and recharge rate very low. Ages for groundwater in the central plain dated by carbon-14 range from 10 kaBP to 25 kaBP. This resource is inherently finite and limited.

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