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Inferring Young Groundwater from Deep Geothermal Water using CFCs and Isotope Data: Implication for Circulation of Groundwater in the Xi'an Geothermal Field, Shaanxi Province, China

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ABSTRACT

Chlorofluorocarbons (CFCs) and isotopic properties of water from wells in the Xian geothermal field, Xian, Shaanxi Province, China, were measured to identify young groundwater from the geothermal system, and to refer circulation of geothermal groundwater. Microbial degradation of CFCs in deep geothermal groundwater (temperature: 35□ to 95□) has not been observed, and this may be interpreted as a temperature effect that has depressed microbial activities. Seven of twenty samples from well in depth of 300 to 3000 meters were determined as CFC-bearing, and the others were CFC-free. Water samples near the Qinling Mountain have the highest fraction of young water, and their stable isotope data fall on the local meteoric water line. The fraction of young water indicates mixing between young and old groundwater. CFCs input to the geothermal water aquifers may relate to surficial or shallow recharge. This may imply that recent infiltration could be responsible for young groundwater into deep geothermal water aquifers. However, the result is inconsistent with tritium concentration of less than 0.32 TU for all of waters. This may be explained by the different transport mechanism for gaseous CFCs and aqueous tritium in a deep groundwater system. Two samples (GZH-9, GZH-20) near the Mountain front have relatively high 14C activities of 50 to 20 pmc, indicating the presence of young recharge. Two groups of waters were identified based on CFCs, stable isotopes and ^{14}C: (1) a regional geothermal water, that is CFC-free, enriched ^{18}O and low ^{14}C; and (2) young groundwater from the Qinling Mt., shallow aquifers and/or the Wei River, that is CFC-bearing, high ^{14}C, and featured by isotopic composition close to precipitation. The recharge of geothermal water is dominated from the Qinling Mountain area and has been taken deep circulation toward inner basin.

1. INTRODUCTION

Thermal groundwaters of the Guanzhong Basin have been used in the Huaqing Pool health spas for more than 1000 years (Liu, 1975), and in addition, for recreation, space heating and fish farming in the last 20 years. It is an important natural resource for tourism in Xi'an, the capital city of Shaanxi province.s are well known. By the end of 2000, 120 exploration and production wells have been drilled in the Xi'an geothermal field, most of them to depths of 1000 m and up to 3000 m, with one of 4000 m maximum depth in Xi'an city (Wu, et al., 2001). The mineable groundwater storage in the Xi'an geothermal field is about 9×10^8 m^3. Over 5×10^6 m^3 geothermal groundwater was produced in 2000, of which over 60% was produced in the Xi'an city.

An understanding of the nature, recharge, and changes of recharge sources of geothermal waters is essential in order to evaluate the potential effects of exploitation and develop suitable management strategies to protect the resources. A young fraction in a confined aquifer can be taken as an indicator, that is, the presence of young water in a deep aquifer suggests possible modern recharge, continuity with surface/shallow waters, or mixing of young and old water. CFCs method is increasingly used in many hydrological tracing studies, whereas reports on application in geothermal fields have not been observed.

The hydrogeologic setting in the Xi'an area provides the possibility of shallow cold groundwater infiltrating into geothermal water aquifers. For instance, recharge from the foreland of the Qinling Mountain may affect geothermal water aquifers during exploitation, especially the presence of over-exploitation; river water and shallow groundwater may mix into geothermal water in some area of the Xi'an geothermal field. Because CFC-bearing young groundwater may mix with old CFC-free geothermal groundwater, CFCs concentrations of groundwater record the mixing between young cold groundwater and old geothermal groundwater.

Vertical movement of water between aquifers can affect the quality and quantity of groundwater. In order to identify if such movement has occurred and identify potential sources of leakage of surface or shallow water into thermal water aquifers, CFCs and isotopic signature of water were investigated. CFCs input to the thermal water aquifer must relate to surficial or shallow recharge, and this provides us a useful tool to recognize the interaction between thermal water aquifers and modern recharge sources, thus allowing us to monitor which processes have taken significant influence on groundwater.

This paper mainly uses CFCs data in conjunction with isotopic data to identify the flowpath of geothermal water.

2. GEOLOGICAL SETTING

The Guanzhong Basin, with an area of 20,000 km^2, is a faulted Cenozoic basin that is predominantly filled with Tertiary fluvial and aeolian sediments and surficial Quaternary loess, to a depth of over 3000 m and a maximum depth of 7000 m. The basement consists of Proterozoic schist and Cenozoic granites. The oldest lithologic unit cropping out to the south of the study area is the Qinling Group, distributed in the basement and to the south of the geothermal field.

The Xi'an geothermal field is located between the Wei River and the southern margin in the Guanzhong Basin (Figure1), with an area of about 1300 km^2, including the cities of Xi'an, Lintong, Chang'an, Zhouzhi and Lintong.

Four geothermal reservoirs have been identified and exploited from 400 m to 3000 m depth (Figure 2).

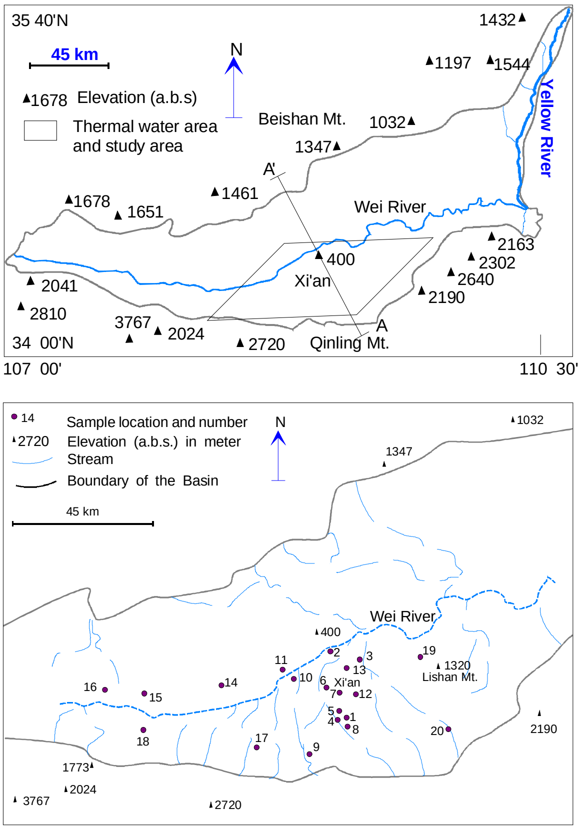

Figure 1. Map of the Xi'an thermal field in the Guanzhong Basin, China. The inset in the upper map shows the location of the study area, detailed in the lower map. The study area is bounded by the Qinling Mountain to the south, the North Mountain to the north, and the Yellow River to the east. "GZH" has been omitted in sample numbers.

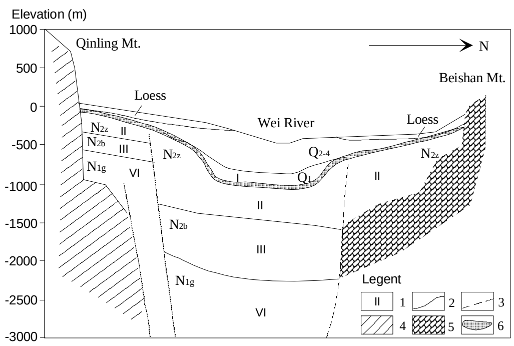

Figure 2 Sketch cross section of the Guanzhong Basin 1:Number of geothermal reservoir; 2: Stratigraphic boundary; 3: Predicted fault; 4: Proterozoic metamorphic rocks (schist, gneiss); 5: Ordovician-Cambrian carbonate; 6: Clay layer as aquitard between quaternary and tertiary aquifer; Q2-4: Late Quaternary alluvial sediment; Q1: Early Quaternary alluvial sediment; N2z: Zhangjiapuo Formation, Late Pliocene, clay interbedded with fine grained sand; N2l : Lantian Formation, Late Pliocene, clay interbedded with medium grained sand; N1g: Guoling Group, Early Pliocene, clay interbedded with fine to medium sand.

The Wei River fault (F1, F2), Chang'an-Lintong fault (F3) and Qinling foreland fault (F4) appear to channel the major discharges of geothermal water based on the distribution of geothermal springs at the surface. Volcanic and seismic activity in Quaternary and modern times caused many faults striking to east-west, north-east-east and north-south with relative movements of 0.4 mm/a to 0.8 mm/a on average and a maximum of 2 to 2.4 mm/a for the Chang'an-Lintong fault (Tao, 1995). The geothermal gradient reaches to 6 to 12 □/100 m along faults south of Wei River, whereas the geothermal gradient is only 3 to 6□/100 m inside faulted blocks (Figure 3).

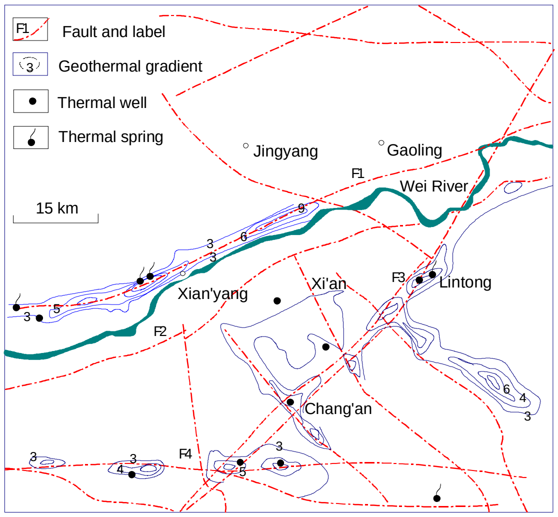

Figure 3. Relationship between geothermal anomaly and geological structure in Xi'an.

3. METHODS

Twenty samples were taken in July to September 2001 and analyzed in November 2001. Each site has at least two samples, to verify each other.

The wells were cased, and perforated in lower part of the case. All wells that equipped with submersible pump and pipe are in production. Water samples were collected in 50 ml glass bottles with aluminum foil as a seal in the cap. In the field, each glass bottle was flushed at least 3 times with pumping water, over two bottles of water samples were collected at each site. The empty glass bottle with the Al-foil cap are put in a metallic tin that is higher than the glass bottle in height. Groundwater for CFC analysis is introduced though a suitable tubing (copper, Teflon, Tygon or Nylon) directly to the bottom of the glass bottle. The groundwater firstly overflows the glass bottle, and then overflows the tin. The flushing has to continue for at least several minutes until all atmospheric air is removed from the sample bottle. After flushing, the tubing is pulled out of the glass bottle and the glass bottle is closed with the cap under water.

The water samples were analyzed for CFC-11, CFC-12 and CFC-113 using purge and trap gas chromatography with an electron capture detector. The instrument was calibrated daily with standard gas. CFCs were determined at the Isotope Hydrology Laboratory, International Atomic Energy Agency (IAEA), Vienna, Austria.

The measurements generally are performed by direct injection of c.a. 20 ml water to the stripping chamber. The weight of water transferred to the stripping chamber is determined by a high-precision balance and calibrated by a fixed systematic dead volume. The transfer gas enters the bottom of the chamber to extract the CFCs from a water sample. The gas stream pass though the desiccant column and into the trap, where CFCs are preconcentrated at –25□. The temperature of the trap is automatically controlled by electrical peltier elements in the range from –25□ to 100 □. Stripping time is 7 min, at flow rate of about 30 cm3 min-1. After 7 min of trapping, the trap is heated to 100□. The Gas stream is directed into GC detector, plotting and integrating of the signal generated by the ECD begins. Calibration is adopted the method similar as Bullister, 1988.

In this study CFC-11, CFC-12 and CFC-113 concentrations of natural waters in air-tight glass bottles remained unchanged even after a long storage. Samples, which were CFC-free, did not contain CFC after five months of storage in air-tight glass bottles.

Reconstruction of the partial ratios of CFC compounds is based on Henry' law using recharge temperatures. The recharge temperature is defined as the temperature at the base of the unsaturated zone (Dunkle et al., 1993). Three methods can be used to determine the recharge temperature: (1) Nitrogen and argon (Heaton, 1981; Heaton and Vogel, 1981; Dunkle, 1993); (2) stable isotope (Van der Straaten and Mook, 1983); and (3) mean annual air or soil temperature (Mazor, 1972; Herzberg and Mazor, 1979; Heaton and Vogel, 1981; Andrews and Lee, 1979).

The annual mean air temperature is 13.6 □ in the Guanzhong Basin. Considering elevation of the Qinling Mountain is up to 3000 meters, the recharge temperature of 10□ was used for calculation of equivalent atmospheric CFC concentrations.

4. RESULTS OF CFC MEASUREMENTS

Seven samples show their CFC concentrations lie close to the N.A. atmospheric CFC mixing line, the others do not contain identified dissolved CFCs. Figure 4 shows CFC-11 and CFC-113 versus CFC-12 atmospheric concentrations at a recharge temperature of 10□ for the samples from the Xi'an geothermal field, where they are also compared with the N.A atmospheric CFC curve. CFCs in water are approximated to equilibrium with the atmosphere for those near the N.A. Atmospheric curve, whereas the others are beyond the range, indicating preferential addition of CFC-12 for samples that fall to the right of this line, and preferential addition of CFC-11 (addition of CFC-113 in same samples) for samples that fall to vertical axis. Loss of CFC-11 and CFC-113 has not occurred through microbial degradation, possibly because high temperature may depress various microbial activities. In contrast, gain of CFC-11 and CFC-113 has occurred through some external anthropogenic sources in wells. CFC-12 in water is relative conservative in natural geothermal system.

The geothermal water samples near the Qinling Mountain have high concentration of dissolved CFCs. Some geothermal water from wells showing great pumping output in the inner basin and near the Wei River have lower concentration of dissolved CFCs.

Sample GZH-9 from a well of 300 m deep located in the foreland of the Qinling Mountain is CFC-bearing. The three CFC concentrations of the sample were closely in equilibrium with air. The CFC-113 apparent ages of the sample GZH-9 younger than CFC-11 and CFC-12 ages signify that binary mixing of young and old water. Calculation based on a binary model indicates the sample contains 58 percent of water with an age of 10 years. Due to tritium content is less than 0.32 TU for the sample of GZH-9, and relatively high depth of the well, gaseous CFC may move faster than tritium in water. It is also possible that gaseous CFCs would be move along faults in the mountain front, whereas tritium may be absorbed.

Sample GZH-20 lies in the east of the sample GZH-9, along the north front of the Qinling Mountain. Three different apparent ages based on piston flow suggest that CFC-11 apparent year is older than the CFC-12, and both are older than the CFC-113, in that its CFC-11, depleted in comparison with CFC-12 and CFC-113, may have been degraded. The young fraction of c.a. 60% is comparative to the young fraction in the sample GZH-9.

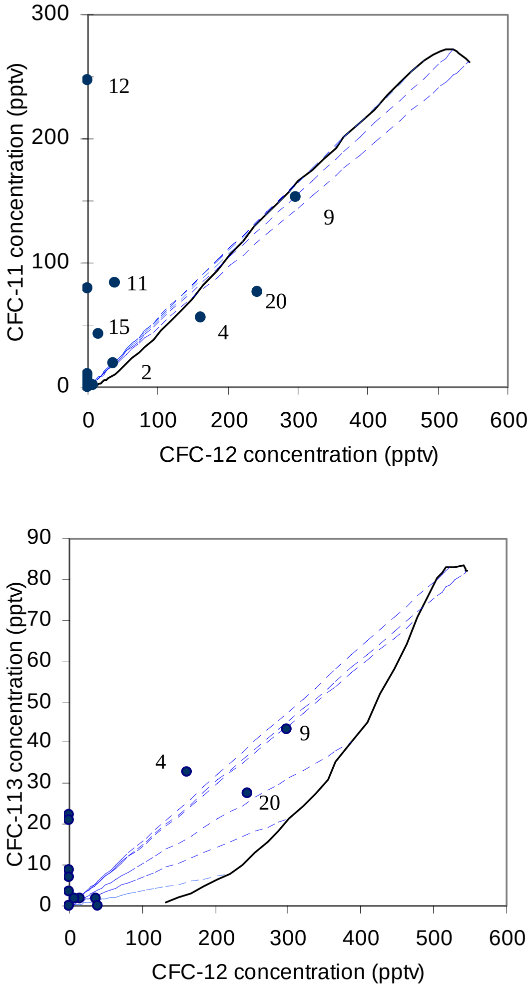

Figure 4 Diagram showing relationship of CFC-11, CFC-12 concentration versus CFC-113 concentration (converted to atmospheric concentrations in pptv) for water samples collected in 2001. The solid line indicates the CFCs concentrations the atmosphere. The dash curves represent the binary mixture of young water with pre-CFC water. Solid points represent samples. Sample number in the right plot can refer to the left plot.

Sample GZH-2 was taken from a well at depth of 2100 m, lies close to the south side of Wei River. CFC-12 excesses concentration in equilibrium solubility with air and possibly has occurred contamination. CFC-113 and CFC-11 concentration are approximately in equilibrium with air. The inconsistence of CFC-11, CFC-12, and CFC-113 concentration-based ages suggests that the sample is a mixture of young and old water. Using binary mixing model and CFC mixing ratios, the fraction of young water was determined to be 16% with an age of 24 years. The mixing may occur by infiltration of water from the Wei River, or shallow groundwater.

Sample GZH-18 from a well of 1600 m deep contain minor CFCs. Sample GZH-18 contains CFC-11 and CFC-12, without detectable CFC-113, this implies that a recharge before 1970s had occurred.

Sample GZH-15 from a well of 2518 m deep is close to the Wei River at its each side. They have minor young fraction water, 4 % of water with an age of 13 years.

Sample GZH-11 from a well of 2588 m deep lies near the north bank of the Wei River. The apparent ages of CFC-11 based on piston flow are 26 years. The apparent ages of CFC-12 based on piston flow are 38 years. CFC-113 is undetectable. The apparent age of CFC-11 is younger than that of CFC-12, at this situation, the apparent age obtained by CFC-12 is possible.

Sample GZH-4 was taken from a well of 3001 meter deep. The well was drilled in Quaternary and Tertiary sediments and has two water-bearing aquifers near the total depth of the well. The inconsistent CFC apparent ages (piston flow ages) indicate that the well likely produces a mixture of young and old water. Using binary mixing model and CFC mixing ratios, the fraction of young water was determined to be 31% with apparent ages of 8 years.

5. ENVIRONMENTAL ISOTOPES

The stable isotope compositions in the Xi'an geothermal waters are shown in Figure 6, along with the Global and Local Meteoric Water Lines (GMWL and LMWL). The δ^2H values range from approximately –87‰ to -80‰, and δ^{18}O values range from approximately –12‰ to -3‰ for the deep geothermal groundwater, where shows an apparent ^{18}O shift. The ^{18}O shift is related to the well temperature, and depth (Fig. 5).

The δ^{18}O values for present-day precipitation, cold groundwater, shallow geothermal groundwater and Beishan katstic groundwater are –5.2 to –6.1‰, –13 to –8.8‰ and –12 to –10.7‰ and –10.48 to –8.53‰, and δ2H values are –36.4 to –33.4‰, -64 to -71‰, –89 to -81‰ and –75.75 to –57.23‰ respectively (Qin and Tao, 2001). The stable isotopic data for the cold and shallow geothermal groundwater does not show an ^{18}O shift, in contrast to that in deep geothermal groundwater (from greater than 1500 m depth). Due to aquitards that act as an isolating layer for deep geothermal aquifer (Tao, 1995; Tian and Zheng 1995), the ^{18}O shift may reflect the hydraulic isolation between the shallow and deep geothermal aquifers. Water in deeper aquifers could have a longer residence time, higher temperatures and lower flow rates than shallow groundwaters.

In addition, the stable isotope values for deep geothermal groundwater is different from that of the Beishan karstic groundwater, indicating possibly no recharge from the Beishan karstic groundwater system into the deep geothermal groundwater system.

The stable isotopic data indicate that the Xi'an geothermal waters are of meteoric origin. The other waters, especially those at depth and distance from the Qinling foreland, have increasing δ^{18}O with constant δ^2H, situated on a line with a slope of approximately zero below the global and local meteoric line in the δ^2H vs δ^{18}O diagram (Figure 5).

Tritium (^{3}H) and ^{14}C activities of the dissolved inorganic carbon in the waters were used to constrain the age estimates of the thermal waters. The thermal waters have consistently low tritium concentrations of less than 0.32 TU and are consequently considered to be effectively tritium-free and recharged prior to the 1960's. Radiocarbon activities of the thermal water are in the range from 50.49 to 1.33 pmC. Most samples have low ^{14}C activity of less than 20 pmC, except sample GZH-9, GZH-16, GZH-19 and GZH-20, which have relatively high ^{14}C activity. Uncorrected carbon-14 activities suggest that the geothermal waters have residence time of 10.2 to 34.7 ka.

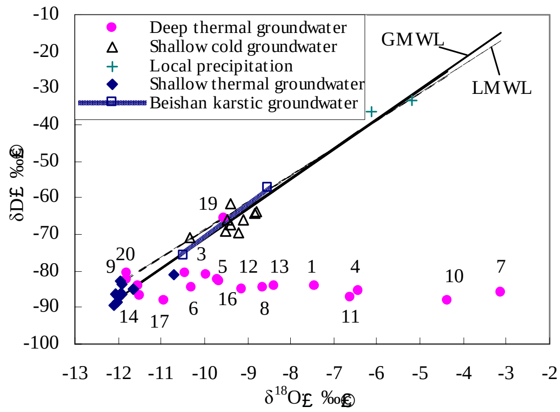

Figure 5. δ^2H -δ^{18}O plot showing the stable isotope composition of thermal water and evidence for interaction between surrounding rock and thermal water away from the Qinling Mountain. The solid line is the Global Meteoric Water Line (GMWL), $\delta D=8\delta^{18}O+10$. The dashed line is the Local Meteoric Water Line based on the data from the GNIP network, at Xi'an station, $\delta^2H = 7.49\delta^{18}O+6.1$. Solid circles are the data from this study and the other data indicated by open triangle, solid diamonds and crosses are from Qin and Tao, 2001. Beishan karstic groundwater data are from Li Jianning et al. (2003). ("GZH" has been omitted in sample numbers)

6. DISCUSSION

6.1 CFCs and isotopes

Comparison of the geothermal groundwater data with the cold groundwater δ^2H data (Qin and Tao, 2001), shows it is i) depleted compared to the cold groundwater and ii) since the δ^2H is not shifted by mineral-water exchange, indicates that the geothermal waters were probably recharged from higher elevation sources in the Qinling range. In addition, the (deep) geothermal groundwater shows similar δ^2H values to those of shallow geothermal groundwater (Qin and Tao, 2001), indicating a similar origin.

Groundwater samples that depart from the GMWL and lie approximately parallel to the δ^{18}O axis have been affected by several processes including δ^{18}O exchange between water and calcite or silicate minerals, or could be derived from the cooling down of much deeper thermal water that has already undergone strong δ^{18}O exchange at higher temperature.

CFC-12 concentrations for CFC-bearing geothermal water samples decrease with depth, which is consistent with increasing groundwater age. Figure 6 depicts CFC-12 concentrations plotted against well depth. The vertical bars on this figure indicate the vertical extents of well screens. The horizontal bars indicate variation of CFC concentrations among duplicate samples at the same sites. Faults in the Qinling Mountain front could be responsible for the infiltration of young water into geothermal aquifers. These are consistent with relationship between ^{14}C and depth except sample GZH-16 and GZH-19 (Fig. 7). CFCs and ^{14}C for samples from the Qinling Mountain front indicate a recent recharge in geothermal water, whereas infiltration from shallow aquifer may be introduced into deep geothermal water wells by over pumping activity. The apparent $\delta^{18}O$ shift excluded the large scale recent recharge into the deep geothermal water aquifers, therefore the CFCs data are possibly a good indicating an increasing hydraulic connection with shallow aquifers and a sign of over-pumping geothermal water.

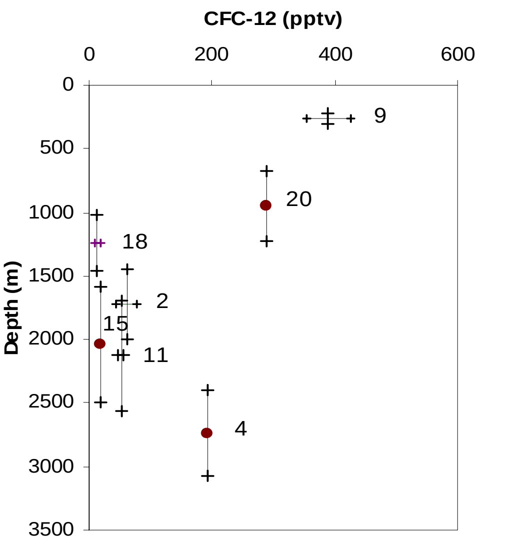

Figure 6 CFC-12 concentrations versus well depth CFC-12 concentrations, converted to atmospheric concentrations by using a recharge temperature of 13.6, versus well depth below the ground surface. Horizontal bars indicate the range of values measured at different duplicate samples at the same site. Vertical bars indicate the vertical extent of the well screen.

6.2. Geothermal water mixing and sources

CFCs are found in post 1940s water and thus their occurrence in groundwater is an indication of some fraction of relatively recent recharge and the recent recharge area. Because of the low detection limit for CFCs and stability of CFCs, CFC-12 can be used to as a tracer of young water (post-1940s).

The fact that geothermal waters are from depth over 1500 m and about 3000 meters in maximum suggests that geothermal waters with older ages (10-30 ka of C-14 age) should be CFC-free waters and not have modern recharge. The mountain-front and river-side geothermal water samples contained significant concentrations of CFC-12. These were apparently inconsistent with tritium concentration of less than 0.32 TU. The presence of CFCs in the Eastern Snake River Plain aquifer beneath more than 300 m of unsaturated zone indicates active recharge, while tritium concentrations of 0.02 to 0.08 TU may suggest that no recharge was occurring (Plummer et al., 2000). This implies that tritium and CFCs behave differently under control by such as thickness of unsaturated zone. The case study in the Xi'an geothermal field may reflect a control by thick unsaturated zone (over 100 meter loess) and overlain shallow cold water aquifer on CFCs and tritium. Three possibilities can be considered: (1) Dilution may cause low tritium water up to detection limit much faster than CFCs; (2) The inconsistence of CFC-bearing and tritium-free geothermal water may be due to different flow rate between gaseous CFCs and liquid water with tritium.

The presence of CFCs in the geothermal waters suggests that modern sources of waters could be infiltration of the geothermal water systems since CFCs are anthropogenic organic materials. It is feasible that the assumption of binary mixing model was used to interpret the CFC data. CFC-bearing waters are in consistence with a basic requirement for a binary mixing model that both CFC-11 and CFC-12 ages are greater than the age of CFC-113. To determine the fraction of a mixture of young and old water, the following two cases are considered: (1) when an old water enters into a shallow aquifer, CFC concentrations in the aquifer will decrease; and (2) when a young water (e.g. leakage of river, or lake etc.) enters into an aquifer of old groundwater, CFC concentrations in the aquifer will increase.

Some geothermal groundwater samples from wells close to the Qinling Mountain and adjacent to the Wei River could be CFC-bearing, and indicate recharge of the last 50 years. Infiltration through preferential channels, such as faults and fissures, followed by mixing with old water may have occurred.

6.3. Model of geothermal water formation

Sample GZH-9 and GZH-20 have large amount of young fraction and are quite different from all other samples. These two geothermal water samples lie close to the Qinling Mountain. It is possible that young recharge went through foreland faults came to geothermal water reservoirs. The main recharge of geothermal water could be mainly derived from the Qinling Mountain area, which went down through factures, faults etc. Waters have gone circulation with different depth that affects the temperature of geothermal water, and discharge toward the inner basin. The more deep water circulated, the longer water was resident in high heat flow rocks, and the higher temperature of geothermal water was. Deep rocks of the Qinling Mountain provides main heat source.

Some young water with small fraction found in waters from wells over 1500 m deep far away the Qinling Mountain appears not to be formed by a natural recharge process, because it is hard to understand how these water go through at least 1500 m vertical distance in tens of years. Although well developed faults in the area could have potential as channel of young water infiltrating through them relatively at high rate, the young fraction and stable isotope data suggest that the young water did not change features of geothermal water very much. Hence the water samples demonstrate that the young water could be introduced through channels, such as (active) faults, fissures, and by pumping activities to lead to infiltration of shallow water. Based on this point, we can use the CFC method to monitor variation of water quality during production and predict possible overexploitation and other effects.

According to the likely component dominating the water-rock interaction process, the$\delta^{18}O$-$\delta^{2}H$ diagram in the Xi'an geothermal field may be split into two groups:

1). Essentially stagnant, rock-dominated systems with large $\delta^{18}O$ shift, indicating adjustment of the isotopic composition of water to those of sedimentary rock at relatively low temperature (<120□).

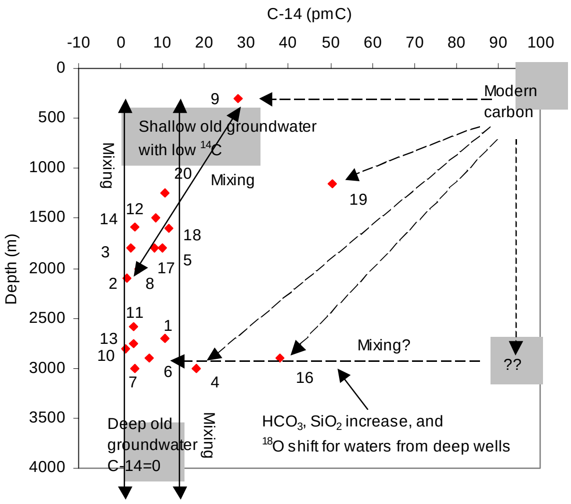

Figure 7 **^{14}C (pmC) versus well depth (m) Shadow: source of carbon and potential source of water; dashed arrow line: evolution line of groundwater; double arrow solid line: potential evolution and/or mixing between each ends ("GZH" has been omitted in sample numbers**

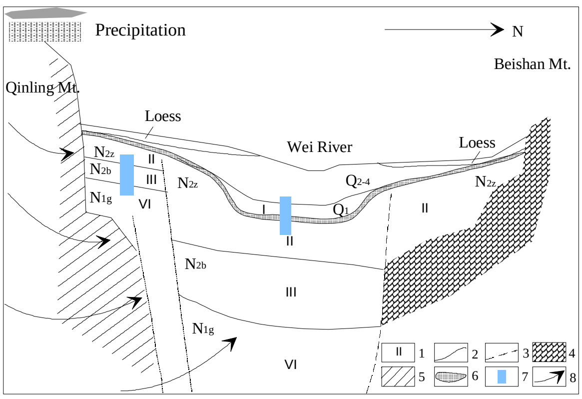

Figure 8 Generalized genetic model for thermal water from the Guanzhong Basin based on CFCs and stable isotope data 1:Number of geothermal reservoir; 2: Stratigraphic boundary; 3: Predicted fault; 4: Ordovician-Cambrian carbonate; 5: Achaean metamorphic rocks (schist, gneiss); 6: Clay layer as aquitard between quaternary and tertiary aquifer; 7: Infiltration of young groundwater into deep aquifers; 8: Predicted flow line of recharge for geothermal water aquifer; Q2-4: Late Quaternary alluvial sediment; Q1: Early Quaternary alluvial sediment; N2z: Zhangjiapuo Formation, Late Pliocene, clay interbedded with fine grained sand; N2l : Lantian Formation, Late Pliocene,clay interbedded with middle grained sand; N1g: Guoling Group, Early Pliocene, clay interbedded with fine to middle sand.

2). Young groundwater from shallow aquifers and local precipitation.

Recharge areas are assumed to be the Qinling Mt. in the south of Guanzhong basin, infiltration of precipitation occurred rapidly through fractures and foreland alluvium (Figure 8). The $\delta^{2}H$ and $\delta^{18}O$ of waters close the recharge area would remain unaltered during infiltrating and there were no obvious evaporation and isotope exchange. With the increasing deep circulation and long residence time, water-rock and water-gases interaction may have occurred to form $\delta^{18}O$ shift.

7. CONCLUSIONS

This study applies the CFC dating and tracing method to identify the presence of modern recharge and infiltration of shallow and surface water. The depth of most geothermal wells is not limited the use of CFCs as a dating and tracing method, although the aquifers are deep to over 1500 m. CFC concentrations in combination with stable isotope data can provide very useful for determination of the recharge, residence time, flow path of geothermal water, and connection with shallow, surface water.

CFCs are sensitive to identify young recharge from a groundwater system. This is in advantage of solving many problems in assessment of water resources in some area when it is ambiguous to determine local recharge proportion. The measurement of CFC concnetrations can be used in estimating the fraction of river water into groundwater aquifers, domestic and municipal supply wells. This helps define the susceptibility to contamination of the groundwater resources, determine the deduced surface water into a well as pumping, assess the degree of over-exploitation of groundwater and provide diagnostic tools for detection and early warning of overexploitation of a water supply system. It can also provide important information on the management and protection of water resources. CFC data can be used to monitor some boreholes to determine the change of water quality, consequently, can be used to predict overexploitation in wells or boreholes.

Infiltration of young water may have been occurring and mixing with geothermal water in the foreland of the Qinling Mountain in relatively significant amount. Young water in the geothermal water near the Wei River could be introduced through stress decrease by pumping of geothermal water, it may indicate potential of mixing, continuity with surface water. Some of the wells need to continue to monitor variation in CFC concentration and stable isotopic composition.

The obvious $\delta^{18}O$-shift suggests that many geothermal waters, particularly at distance (3-5 km) from the Qinling Mountain, have less continuity with shallow and surface waters. A deep groundwater circulation model starting from the Qinling Mountain catchment is recommended though this study.

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