Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2017-647-AC3, 2018

Hydrology and Earth System Sciences
Discussions
Open Access
EGU

Interactive comment on "Groundwater origin, flow regime and geochemical evolution in arid endorheic watersheds: a case study from the Qaidam Basin, Northwest China" *by* Yong Xiao et al.

Yong Xiao et al.

jshao@cugb.edu.cn

Received and published: 2 May 2018

Dear Referee #1, Thank you very much for the insightful comments concerning our manuscript entitled "Groundwater origin, flow regime and geochemical evolution in arid endorheic watersheds: a case study from the Qaidam Basin, Northwest China" (Manuscript NO.: hess-2017-647). Your comments to manuscript are very valuable and helpful. We have carefully studied and incorporated them into our revised manuscript. Please see the point-to-point response to your comments as following. The revised manuscript is attached in the supplement.

Printer-friendly version

Discussion paper

Comment a. Agree with the argument that there may be three different groundwater flow systems as evidenced by the numerical model and the increased age and the lighter isotopic values downdip in the flow system.

Comment b. Authors should have run their chemical analyses through a geochemical equilibrium program to determine degree of mineral saturation. They comment on the fact that there are significant rock water reactions, which is correct, but they should have provided some further documentation as to what minerals are important and whether the water are at saturation. This would give further credence to their geochemical argument.

Reply: We quite agree with this comment. The truth is that we have done this work in the initial submission version, and the results are presented in Table 4. You can find relative discussions in Page 12 lines 21-22, Page 13 lines 13-16, 23-25 as follows. Page 12 lines 21-22: "The calculated results of halite saturation index (SIhalite<0) (Table 4) confirm that halite minerals of the aquifer matrix could be readily available to the groundwater." Page 13 lines 13-16: "The saturation index values of aragonite, calcite and dolomite are all almost greater than 0 in all samples (Table 4), suggesting the dissolution of these three minerals must be minimal. While the saturation index values of gypsum and anhydrite for groundwater in these areas are all below zero (Table 4), corroborating the contribution of gypsum and anhydrite dissolution for groundwater mineralization." Page 13 lines 23-25: "Groundwater in the low-lying depression (Zone 5) has extremely high TDS values (>300,000 mg/L) (Table 1) and almost all minerals are over-saturation (SI>0) (Table 4), therefore, precipitation (crystallization) of minerals is the primary geochemical process in this part of the aquifers (Li et al., 2010)." We are very sorry for that the Table 4 is missing in the Discussion Paper due to some unexpected mis-operation. Now it has been added in the revised manuscript.

Comment c. The authors did not mention anything about the redox system, which may be important. Are there any organics in the sediments? Is sulfate reduction occurring down the flow paths, especially when you get to the salt lakes and playasïij§

Reply: We have added the redox potential info of groundwater in Page 7 lines 7-9 as following. “The redox potential (Eh) of SGW are in the range of 123-162 mV from alluvial fan to middle lower stream area (Zone 2, Zone 3 and Zone 4), suggesting an oxidation condition. The Eh values of DGW vary from 153 mV to 40 mV along the flow path (Zone 3 to Zone 4), indicating the redox condition gradually evolves from oxidation to reduction (Fig. 3e).” It can be known that shallow phreatic groundwater from alluvial fan (Zone 2) to middle lower stream area (Zone 4) is in oxidation condition. While the redox condition of deep confined groundwater from overflow area (Zone 3) to middle lower stream area (Zone 4) evolves from oxidation to reduction. Although we do not have the redox potential data of the basin center (Zone 5), it can be assumed that the redox condition of deep confined aquifers is reduction according to the Eh values of deep confined groundwater in Zone 4. As the sediments in the downstream area have very low organic carbon content, which was reported in the literature (Bowler et al., 1986; Chen and Bowler, 1986), sulfate reduction has very limited influence on groundwater chemical evolution. This discussion has been added on Page 13 lines 18-22 as following: Page 13 lines 18-22: “As mentioned earlier, the redox conditions of the deep confined aquifers in Zone 4 has evolved to a reducted environment, but due to the extremely low organic carbon content in the sediments (Bowler et al., 1986; Chen and Bowler, 1986), sulfate reduction has a very limited influence on groundwater chemical evolution. This is also the reason that groundwater in the downstream area (Zone 4 and Zone 5) has an abundant content of SO42- in contrast to Ca2+.”

Comment d. The authors do not provide much documentation that the brines in Zone 5 have migrated into downdip section of the flow system from some other location during an earlier time period. Presumable evaporates have been accumulated at this location since the Pleistocene, and the chemistry observed results from in situ rock/water interactions, and not the migration in from other location.

Reply: As seen in figure 5, the stable hydrogen and oxygen isotopes of brines in Zone 5 is quite different from the upper stream. Specifically, all groundwaters in Zone 5

are with relative enriched δD and δ18O values in contrast with modern water and deep confined groundwater in the middle lower stream area (Zone 4), and deviate away from the LEL and towards the left. This may imply their quite different recharge sources or recharge environment. Previous researches reported that the depocenter of Qaidam basin gradually migrated from the northwest to the Dabusun lake area since Late Oligocene (Chen and Bowler 1980; Zhang 1987; Huang 2007). In this depocenter migration process, the paleo lake water and groundwater, both of which were brines, also migrated to the Dabusun lake area. After this, the basin experienced several arid climate cycle, as a result, evaporates precipitated from these paleo migration waters and also the newly recharged waters of this watershed. Briefly, the evidence of brines migration is the tectonic activity and paleo lake migration in the geological history reported in previous literatures. This was briefly stated in Page 11 line 26-27. To provide more evidence, we add two more literatures (Zhang (1987) and Huang (2007)), in the Page 11 lines 26-27. [1] Chen, K., Bowler, J. M., 1986. Late Pleistocene evolution of salt lakes in the Qaidam basin, Qinghai province, China. Palaeogeography Palaeoclimatology Palaeoecology, 54 (1-4):87-104. [2] Zhang, P. X., 1987. Salt lakes in Qaidam Basin. Science Press, Beijing. [3] Huang, L., Han, F. Q., 2007. Evolution of salt lakes and palaeoclimate fluctuation in Qaidam Basin. Science Press, Beijing.

Comment e. Figure 6 and 7 may be too complicated. Data for different flow systems might be better represented as individual graphs.

Reply: We agree that it might be much more clear to present the data for different flow systems in individual graphs. In the current presentation, the data has been separated according to the physiographic zones and phreatic/confined aquifers and represented as different legend, which is enough to illustrate the hydrogeochemiscal evolution. But if we separate the data for different flow systems in individual graphs, there will 4 more pictures (two's size like Figure 6 and two's size like Figure 7) in the manuscript, which will greatly increase the manuscript length. Therefore, we suggest present the data as different legend according to the sampling physiographic zones and phreatic/confined

aquifers like the current presentation.

Comment f. How does intense evaporation occur at the water table (i.e. a few meters below land surface)? It may well well be out of an evaporation zone. Are caliches developing?

Reply: Generally, the evaporation is very intense in the basin due to the hyper-arid climate. But its influence is very limited and can be ignored in the alluvial fan where the groundwater table is tens of meters below the ground surface. For Zone 3∼5, the depth of phreatic groundwater is very small, all within 3 meters, as a result, intense evaporation has a significant influence on groundwater chemistry, which can be shown by the stable isotopes presented in Figure 5c and hydrochemistry in Figure 6, as well as the change of minerals saturation states presented in Table 4. Caliches are widely found developing on the ground in the downdip section (including the north part of Zone 4 and the whole Zone 5, see the Picture A.

Comment g. Paper should be considered as a reconnaissance level paper, opening the door for the authors to look at their conclusions in greater detail and greater analysis.

Reply: In this revised manuscript, some analysis (e.g. groundwater age dating) and conclusions have been further expanded and discussed. All of this can make the conclusions and analysis more clear and credible. In addition, some extra sentences are also added on Page 15 lines 9-14 to further illustrate the purpose and importance of this study as follows. Page 15 lines 9-14: “Previous studies on arid closed basins such as the Great Artesian Basin, Murray Basin, Death Valley and Minqin Basin have established a lot of typical groundwater circulation and evolution regimes. While the Qaidam basin, a typical arid sedimentary closed basin formed with the uplift of the Tibetan plateau, has groundwater circulation patterns characterized by the complex tectonic activities, paleo climate variation, arid climate characteristics, sedimentary lithology, and systematic evolution from fresh to salt water. Studies of this basin can enhance the understanding of groundwater origin, flow regime and hydrogeochemical evolution

in such complex tectonic influenced arid sedimentary closed basins worldwide." This can let the readers clearly know what have done in this study and the general points which can provide references for similar basins worldwide. Generally speaking, this study integrates hydrogeochemistry, environmental isotopes and numerical modelling approach based on the current material and data to get reconnaissance insights into the origin, flow pattern and geochemical evolution of regional groundwater from mountain pass to terminal lake in a typical endorheic watershed of Qaidam Basin. The origin and its recharge characteristics of groundwater, especially the brines in the terminal lake area, have been firstly identified in Qaidam Basin based on multiple evidences (e.g. isotopic evidences, tectonic activities in the geological past). Additionally, the regional groundwater flow and geochemical evolution are systematically established in this study. All above can provide a reconnaissance understanding of hydrogeological regimes in the study area and also provide references for similar basins worldwide.

Please also note the supplement to this comment:
https://www.hydrol-earth-syst-sci-discuss.net/hess-2017-647/hess-2017-647-AC3-supplement.zip

---

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2017-647, 2017.

Printer-friendly version

Discussion paper

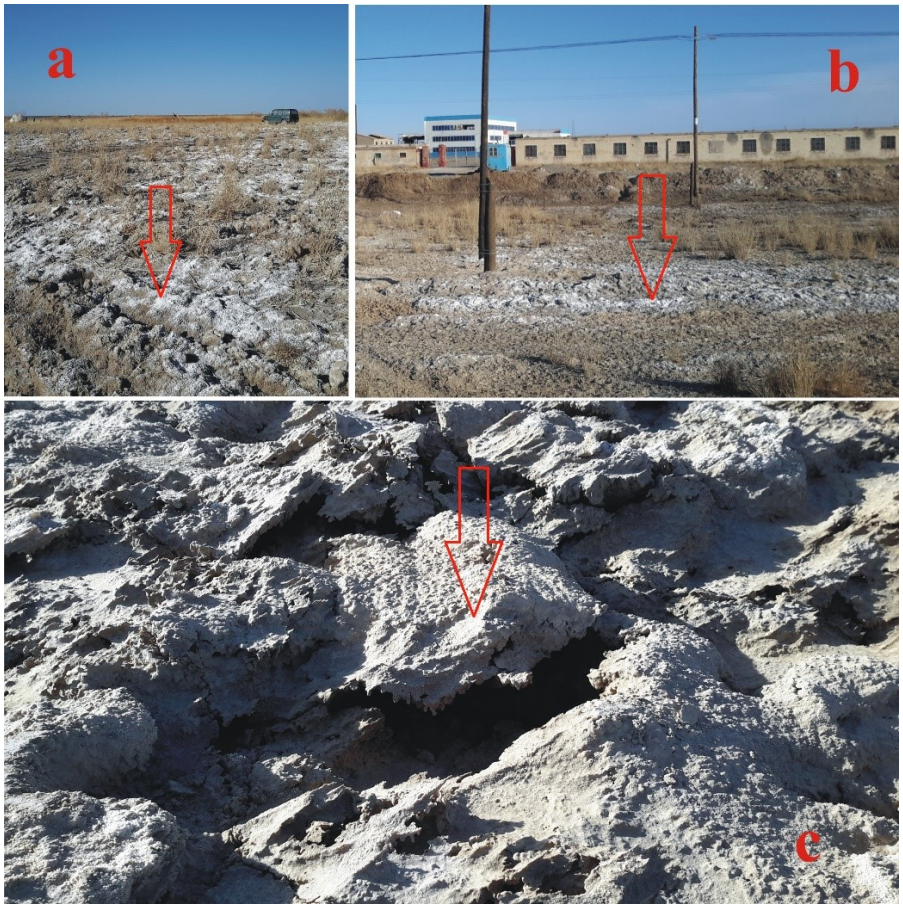

Fig. 1. Picture A: The developed caliches in the Zone 4 and 5.