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Comparison of surface water chemistry and weathering effects of two lake basins in the Changtang Nature Reserve, China

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ABSTRACT

The geochemistry of natural waters in the Changtang Nature Reserve, northern Tibet, can help us understand the geology of catchments, and provide additional insight in surface processes that influence water chemistry such as rock weathering on the Qinghai–Tibet Plateau. However, severe natural conditions are responsible for a lack of scientific data for this area. This study represents the first investigation of the chemical composition of surface waters and weathering effects in two lake basins in the reserve (Lake Dogaicoring Qiangco and Lake Longwei Co). The results indicate that total dissolved solids (TDS) in the two lakes are significantly higher than in other gauged lakes on the Qinghai–Tibet Plateau, reaching 20–40 g/L, and that TDS of the tectonic lake (Lake Dogaicoring Qiangco) is significantly higher than that of the barrier lake (Lake Longwei Co). Na^+ and Cl^- are the dominant ions in the lake waters as well as in the glacier-fed lake inflows, with chemical compositions mainly affected by halite weathering. In contrast, ion contents of inflowing rivers fed by nearby runoff are lower and concentrations of dominant ions are not significant. Evaporite, silicate, and carbonate weathering has relatively equal effects on these rivers. Due to their limited scope, small streams near the lakes are less affected by carbonate than by silicate weathering.

Introduction

Ion contents and chemical compositions of surface waters are affected by a number factors, including climate, geology, and human activities. The study of water geochemistry reveals the pattern and linkage between climate, weathering, and tectonic impacts (Brennan and Lowenstein, 2002). The Qinghai–Tibet Plateau, often called the "Third Pole", is extremely sensitive to global climate change. In particular, the water chemistry of many of the plateau's lakes is affected by changes in the surrounding basin hydrology (Mitamura et al., 2003). In recent decades, research on the surface water chemistry of the Qinghai–Tibet Plateau has mostly focused on areas with convenient access and significant impacts of human activities, such as the Qaidam Basin (Tan et al., 2011), Qinghai Lake (Xiao et al., 2012; Xu et al., 2010), and river source regions (Noh et al., 2009; Qin et al., 2006; Wu et al., 2005, 2008) in the Qinghai Province, China. Investigations and analyses of large lakes and rivers located in central and southern Tibet are equally abundant, such as studies of Lake Nam Co (Wang et al., 2009; Zhang et al., 2008), Lake Yamzhog Yumco (Sun et al., 2013; Zhang et al., 2012), Lake Mapam

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Yumco (Wang et al., 2013), and the Yarlung Tsangpo River Basin (Guilmette et al., 2009; Hren et al., 2007). These studies have greatly enhanced the knowledge about the chemical characteristics and evolution of lake and river waters on the Qinghai–Tibet Plateau. For example, Ju et al. (2010) showed that Ca^{2+}, Mg^{2+}, and HCO_3^- were the dominant ions in Lake Pumayum Co and its inflows, which are located in southern Tibet. Spatial variation in the chemical composition of the lake water was shown to depend on the characteristics of its inflows. Wang et al. (2010a) analyzed 76 samples of lake water and 69 samples of river water flowing into Lake Nam Co on the central Tibetan Plateau, and found that Na^+, Ca^{2+}, and HCO_3^- were the main ions, accounting for 60.6%–93.4% of total dissolved solids (TDS). Evaporative crystallization was shown to control the chemical composition of Lake Nam Co, and rock weathering, especially of carbonates and silicates, appeared to be the primary source of ions for its inflows. However, basic scientific understanding of lake basins and their water chemistry in the higher altitude regions of northern Tibet is still limited owing to geographical conditions.

The Changtang Nature Reserve in northern Tibet is the second largest natural reserve in China and provides protection for the local alpine ecosystem and many types of rare animals. This region is centered in the world's second largest inland lake area (Changtang Plateau), which includes 441 closed lakes with surface areas over 1 km^2. The total lake area in this region is 9652 km^2 (Li et al., 2013), comprising 40% of the total lake area in Tibet. In contrast to the low latitude areas in Tibet, the reserve is characterized by extreme natural conditions and difficulty of access, which has resulted in a lack of information on its water chemistry. A comparative study of the chemical composition of two lake basins in this region and associated controlling mechanisms can not only reveal differences and linkages among different types of surface water, but also provide additional insight into the chemical effects of natural processes such as rock weathering. In addition, this research can provide important background information for global change studies of extreme environments.

Rock composition and weathering are the primary factors determining river water composition (Drever, 1994). In this study, end-member and ion comparison analyses were applied to determine the effects of rock weathering on surface water chemistry. Subsequently, a forward model was used to calculate the contribution of ions from weathering of three typical rock types. From this, the spatial variations of surface water chemistry in two lake basins as well as the correlation between the chemical characteristics of waters and the geologic setting were determined.

1. Materials and methods

1.1. Study area

The Changtang Plateau covers an area of over 700,000 km^2 and includes the raised plateau as well as surrounding mountains, including the Tanggula, Kunlun, and Hoh Xil Mountains. The Changtang Natural Reserve is located at the junction of Ngari and Nagqu Prefectures, has an average altitude of more than 5000 m, and covers an area of 298,000 km^2. The average annual precipitation is 100–200 mm, with an average annual temperature of −6 to −4°C. The area is dominated by a network of small seasonal rivers (Chen and Guan, 1989). Both Lake Dogaicoring Qiangco (DQ) and Lake Longwei Co (LW) are located in the region, with a distance of about 182 km between them (Fig. 1).

Lake DQ is a lake in the southern piedmont of Kangzhagri Mountain, which is the highest peak in the Hoh Xil mountain range. The lake is located at 35°19′N and 89°15′E at an elevation of 4787 m. The surface area of Lake DQ has been expanding over the past two decades, and reached about 300 km^2 in 2010. The maximum depth of the lake is about 28 m. The lake water is mainly recharged by runoff from snow and glacier melt from Glacier Kangzhagri (elevation 6305 m) and Glacier Rola Kangri (elevation 6036 m), the latter being the highest peak in the Rola Kangri mountains, located southwest of the lake. In addition, the lake is fed by a number of small streams formed by springs surrounding the lake.

Lake LW is located in a volcanic area, and given its physical setting, is a barrier lake. The lake is located at 33°52′N and 88°18′E at an elevation of 4942 m. The surface area of Lake LW is about 44 km^2, with a maximum depth of about 10 m. The largest river flowing into the lake is the Heishi River, which originates from the Glacier Nadi Kangri (elevation 6004 m). The glacier forms the highest peak in the Nadi Kangri volcanic cluster, which is located about 40 km southwest of the lake. Small streams formed by springs surrounding the lake provide some additional inflow.

In the study area, sparse grassland and barren land are the two dominant land use types, and alpine steppe soil comprises 92.3% of the total area (Bureau of Land Management of Tibet Autonomous Region, 1994). Rocks are primarily Pleistocene and Pliocene in age (Tian and Ding, 2006; Yang et al., 2000), with widely distributed shale, limestone, and siltstone (Bureau of Geology and Mineral Resources of Tibet Autonomous Region, 1993). In addition, silicates and coal-bearing clastics exist around Lake DQ and frost weathering occurs in the slope sediments at the bottom of the stratum. In contrast, the Lake LW basin is composed of volcanics, such as trachyandesite, as well as some sedimentary rocks, such as gypsum, with clastics forming the base of the stratum.

1.2. Sampling and analytical methods

With access limited by road and environmental conditions, the study area could be reached only in winter when a large number of small seasonal rivers were frozen. Therefore, the sampling period for Lakes DQ and LW ranged from 24 October to 7 November 2012. Wang et al. (2010a) have shown that spatial and vertical variations in ion composition in one lake are relatively small between depths of 0–30 m. Therefore, surface water samples from the two lakes were collected at a depth of 30–40 cm. Owing to terrain limitations, samples from Lake DQ basin were collected from the southern end of the lake, while those from Lake LW basin were collected from the eastern and western sides of the lake (Fig. 1). In total, 38 samples were collected, including three types of surface water samples (lake, river, and small stream). Two rivers were sampled in each lake basin. In the Lake DQ basin, the Wuquan River (DA) is fed by runoff from Rola Kangri peak, and an unnamed river (DB) also originates in the Rola Kangri