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Isotopic and geochemical evidence of palaeoclimate changes in Salton Basin, California, during the past 20 kyr: 2. $^{87}Sr/^{86}Sr$ ratio in lake tufa as an indicator of connection between Colorado River and Salton Basin

Hong-Chun Li [a,b,c,*], Chen-Feng You [a], Teh-Lung Ku [b], Xiao-Mei Xu [d], H. Paul Buchheim [e], Nai-Jung Wan [a], Ruo-Mei Wang [a], Min-Lin Shen [a]

[a] *Department of Earth Sciences, National Cheng-Kung University, Tainan, Taiwan*
[b] *Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089, USA*
[c] *College of Geography Science, Southwest University, Chongqing 400715, China*
[d] *Department of Earth System Science, University of California, Irvine, CA 92697, USA*
[e] *Department of Natural Sciences, Loma Linda University, Loma Linda, CA 92350, USA*

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Abstract

As a part of the Colorado River drainage system, Southern California's Salton Basin has two major tributaries: Colorado River and Whitewater River. Interpretations on palaeoclimatic records from the basin strongly depend on the Colorado River inflow to the basin. In this study, we have used the $^{87}Sr/^{86}Sr$ ratio in lacustrine deposits to identify the time and duration of the Colorado River input. Our measurements of $^{87}Sr/^{86}Sr$ ratios made on water samples collected from Salton Basin indicate that the $^{87}Sr/^{86}Sr$ ratio (0.710169) of the Colorado River input is identical to that of Salton Sea (0.710105), implying little change in the lake water ratio since 1905 when Salton Sea formed and began receiving water mostly from Colorado River; and the $^{87}Sr/^{86}Sr$ ratio of Colorado River is much lower than that of Whitewater River (0.715960). These results enable us to trace past changes in the Colorado River input using $^{87}Sr/^{86}Sr$ in lake carbonates. Using a two-end-member mixing model, we discuss the major factors that control the $^{87}Sr/^{86}Sr$ variation of Lake Cahuilla, which was an ancient lake in the Salton Basin between 400 and 20,500 yr BP. Thirty measurements of $^{87}Sr/^{86}Sr$ were made on AMS–^{14}C-dated tufa carbonates in two slabs from Lake Cahuilla. The results show relatively constant $^{87}Sr/^{86}Sr$ ratios throughout the past 20 kyr, ranging from 0.709944 to 0.710140. The average of these $^{87}Sr/^{86}Sr$ ratios, 0.710060 ± 0.000049 ($n=30$), is very close to that of the Colorado River input. Our results indicate that (1) the Colorado River input was the dominant water source for Lake Cahuilla at least during 800–20,500 yr BP when the tufa grew in the basin, and (2) the provenance of run-off to the Colorado River did not change significantly during 800–20,500 yr BP. Hence, the palaeoclimatic proxies retrieved from the Lake Cahuilla tufas in the Salton Basin can decipher the discharge and flood history of the Colorado River under the influence of climate variability in the Colorado River drainage basin.

Keywords: Strontium isotopes; Trace elements; Lake tufa; Salton Basin; Lake Cahuilla; Colorado River

* Corresponding author. Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089, USA. Fax: +1 213 740 8801.
E-mail address: hli@earth.usc.edu (H.-C. Li).

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1. Introduction

Deposited in fresh or brackish water, tufa is the product of calcium carbonate precipitation under ambient temperatures, and is often associated with the remains of micro-and macrophytes, invertebrates and bacteria (Ford and Pedley, 1996; Smith et al., 2004). Although "tufa" is used as a general name, it covers a wide variety of carbonates, and has also been used for the evaporative travertine deposits on the shorelines of ephemeral or dried-up lakes in the Great Basin of Western USA (Newton and Grossman, 1988; Rieger, 1992; Benson et al., 1995). These tufas are normally considered as carbonates precipitated from saline and alkaline lakes through microbial and physico-chemical processes (Scholl and Taft, 1964; Osboume et al., 1982; Benson, 1994). In the Salton Basin of Southern California (Fig. 1), such carbonates formed in ancient lakes during the past 20 kyr BP (Li et al., 2008-this issue). The palaeohydrological and palaeoclimatic potential of the tufa deposits at this site has drawn little attention compared to other sites in the Great Basin due to changes in the connection between the Salton Basin and Colorado River (e.g., Water, 1983). Geographically speaking, Salton Basin is located in the southwest corner of the Colorado River drainage basin. When the Colorado River is connected with Salton Basin, one should consider that the river discharge is tied to climatic changes in the entire Colorado River drainage basin, which includes the upstream states of Colorado, Utah, and Wyoming, and downstream states of California, Nevada and Arizona.

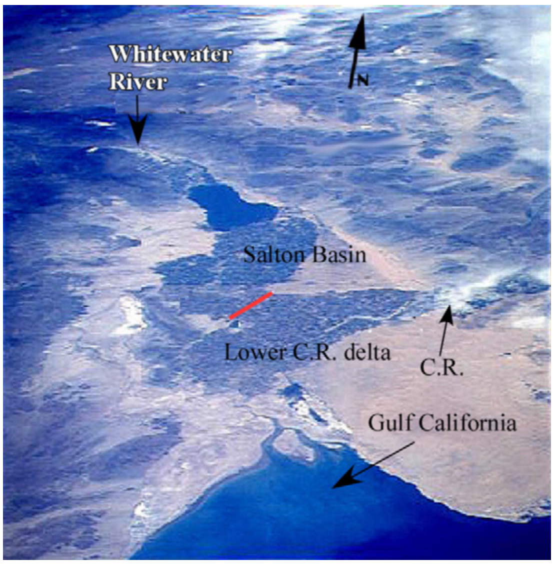

Fig. 1. Satellite image of Salton Trough, with Salton Basin in the north and Lower Colorado River delta in the south (http://www.sci.sdsu.edu/salton/SaltonBasinHomePage.html).

When the Colorado River is not connected with the Salton Basin, surface run-off to the lakes in Salton Basin is limited to the catchment area of the basin in southeastern California. Thus, the climatic information recorded in the tufa then mainly reflects climate changes of southeastern California rather than the Colorado River drainage basin (Fig. 1). Therefore, understanding how the Colorado River–Salton Basin connection evolved is a key for deciphering the hydrological changes, hence the palaeoclimatic history, of Salton Basin.

Our recent study on the $\delta^{18}O$ and $\delta^{13}C$ time series in a 60-cm-thick tufa slab (LC-1) from the Salton Basin shows that the tufa appears to record changes in relative humidity and in discharge or flood frequencies of the Colorado River, which are related to climate variations in the Colorado River drainage basin (Li et al., 2008-this issue). The climate variations could be strongly affected by the summer monsoon strength and by position and strength of the Westerlies. However, the detailed hydrological history and interpretation of the stable-isotope records rely on how the Colorado River was connected to the Salton Basin during the past, as mentioned earlier.

In this study, we use the strontium isotopic composition of tufa deposits for tracing water source and hydrologic state of the Salton Basin. We have measured $^{87}Sr/^{86}Sr$ ratios of surface waters in the Salton Basin, and found a means for assessing past changes in the Colorado River input using $^{87}Sr/^{86}Sr$ in lake carbonates. Using a Sr isotope mass-balance model we discuss the controlling factors of $^{87}Sr/^{86}Sr$ ratio in the lake with two major water sources from Colorado River and Whitewater River. Finally, we have obtained information on past shifts of Colorado River input to the basin between 800 and 20,500 yr BP, by measuring $^{87}Sr/^{86}Sr$ time-series in tufas LC-1 and SST-1.

2. Background and previous work

Strontium isotopes have been used in studies of Sr mixing processes from different sources in Earth systems (Condie, 1993; Quade et al., 1995; Capo et al., 1998; Capo and Chadwick, 1999; Kurtz et al., 2001; Stewart et al., 2001; Dalai et al., 2003; Banner, 2004; Li et al., 2005). For example, Van der Hoven and Quade (2002) conducted a study of strontium isotopes in soil as a tracer for identifying Ca in pedogenic carbonates from two different sources. Flecker et al. (2002) reconstructed palaeosalinity in marginal marine systems of the Mediterranean based on a simple two-end-member mixing model of Sr isotopes in river and ocean water. Dogramaci and Herczeg (2002) developed a mixing model of Sr isotopes to study carbonate-solution interactions and inter-aquifer