Quaternary International xxx (2016) 1–9

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Geochemical transect through a travertine mount: A detailed record of CO_2-enriched fluid leakage from Late Pleistocene to present-day — Little Grand Wash fault (Utah, USA)

Emanuelle Frery [a,*], Jean-Pierre Gratier [b,c], Nadine Ellouz-Zimmerman [d], Pierre Deschamps [e], Dominique Blamart [f], Bruno Hamelin [e], Rudy Swennen [g]

[a] CSIRO, Kensington, WA, USA
[b] ISTerre, Université Grenoble Alpes, 38041, Grenoble, France
[c] ISTerre, CNRS, 38041, Grenoble, France
[d] IFPEN, Rueil-Malmaison, France
[e] Aix-Marseille University, CNRS-IRD, CEREGE UM34, Europole Mediterraneen de l Arbois, BP80, 13545, Aix-en-Provence, France
[f] LSCE, Gif sur Yvette, France
[g] KU Leuven, Celestijnenlaan 200E, 3001, Heverlee, Belgium

A R T I C L E I N F O

Article history:
Available online xxx

Keywords:
Travertine
CO_2-enriched fluids
Leakage
U/Th dating
Oxygen and carbon stable isotopes
Vein growth rate

A B S T R A C T

Active and fossil endogenic travertine mounts scattered along the Little Grand Wash fault are studied as records of Quaternary CO_2-enriched fluid leakage. This study focusses on a particular area where a fossil mount formed in a near-surface setting by successive circulation/sealing episodes from Late Pleistocene to Mid-Holocene and where a modern surface travertine is still being formed by a CO_2-enriched fluid source. The fossil mount is composed of horizontal and vertical veins whereby the vertical veins recorded numerous cycles of circulation/sealing/dissolution events and were used as conduits for the CO_2-enriched fluid circulation from the depth to the surface or along sub-horizontal fractures where successive precipitation events are recorded. The modern travertine is being built at the surface by successive eruption of Crystal Geyser, an anthropic geyser active since the 1930's.

$\delta^{13}C$ and $\delta^{18}O$ signatures and U/Th datings, ranging from 11.5 ky till present-day allows calibrating in detail the CO_2 enriched fluid leakage along a single fault segment and in a post glacial context, as last glaciations in the study area took place 15 ky ago. The dataset shows a high decrease of the oxygen stable isotope values till about 6 ky, then the variations reflect a constant range until present-day. This tends to restrain the period of local increase of the meteoric water input in the aquifer that is sourcing the CO_2-enriched water.

The fossil travertine represents a 7 ky-long record of CO_2 leakage above a natural reservoir, from Late Pleistocene to Mid-Holocene. The flux of CO_2 leakage through time and the total escaping volume have been computed and appears to be low in comparison with an anthropogenic leak provoked, for instance, by a non-sealed well.

1. Introduction

Endogenic travertines are records of paleoclimatic and paleotectonic events (Altunel and Hancock, 1993; Hancock et al., 1999; Faccenna et al., 2008; Brogi et al., 2010; Capezzuoli et al., 2010; De Filippis et al., 2011; Gratier et al., 2012; Priewisch et al., 2014; Ricketts et al., 2014; Frery et al., 2015). Travertines are calcium carbonate agglomerates known to be built under near ambient conditions in continental areas (Pentecost, 2005; Capezzuoli et al., 2014). Endogenic is use to define the origin of the CO_2-enriched fluids sourcing the agglomerate formation. Endogenic travertines are usually built along fault systems, where deep CO_2 and/or hot water are escaping from the depth to the surface (Janssen et al., 1999; Glover and Robertson, 2003; Crossey et al., 2006, 2009). Little Grand Wash present-day active travertine called Crystal Geyser is formed by cold water (~17 °C) with a heavy carbon isotope composition (>4‰, Kampman et al., 2009). The $\delta^{13}C$ and $\delta^{18}O$

* Corresponding author.
E-mail address: emanuelle.frery@csiro.au (E. Frery).

http://dx.doi.org/10.1016/j.quaint.2016.09.035
1040-6182/

signature of Green River fossil travertine mounts also demonstrate an endogenic origin of the fluids (Heath, 2004; Dockrill and Shipton, 2010). U/Th dating of these mounts calcium carbonate precipitations range from 400 ky to present-day (Burnside, 2010).

Such endogenic travertines located along Little Grand Wash and Salt Wash faults have been demonstrated to be formed episodically (Shipton et al., 2004; Dockrill, 2005; Burnside, 2010; Dockrill and Shipton, 2010; Kampman et al., 2012; Burnside et al., 2013; Frery et al., 2015). Kampman et al. (2013) showed that the CO_2 pulses can be related to glacial cycles.

In this contribution a detailed study of $\delta^{13}C$- and $\delta^{18}O$-signatures recorded along a travertine mount section is presented. U/Th dating and a part of the stable isotope measurements along this profile have been published in Frery et al. (2015) in order to build a conceptual model of episodic fluid circulation along an active fault. The record lasts from Late Pleistocene to present-day, providing a unique detailed record of this period of time that deserves to be closely analysed regarding i) the structure of the dated travertine veins; ii) the significance of the data regarding the Quaternary glaciation episodes on the Northwest part of the Colorado Plateau as well as iii) the calibration of CO_2 leakage during this period of time.

Results from more than 300 stable isotope analyses of the carbonate veins forming the travertine are analysed through time, based on 14 U/Th datings. Stable isotope measurements are shown for the whole dated period, from the thin section scale to the outcrop scale and on present-day active travertine forming close to the studied outcrop. Vertical and horizontal veins are studied regarding their petrography and their isotopic signature evolution through time. The results are then discussed in the perspective of the Late Holocene post-glacial cycle in the region and as potential proxy to calibrate the CO_2 paleo-leaky volumes along a particular segment of the fault during this period of time.

2. Location and sampling

The study focused on the so-called T1 fossil travertine mount, which is located in the footwall of a normal fault called Little Grand Wash (Fig. 1A and B). The mount is partially eroded. An accurate chronology has been obtained through 14 radiometric datings (U/Th) of 9 travertine veins sampled along a 10 m-thick profile (Fig. 1C). All samples were cleaned using a chemical pre-treatment to remove possible contamination. $^{234}U/^{230}Th$ ages were then measured with a TIMS mass spectrometer (CEREGE-Aix en Provence). The accuracy of the datings (from 11.469 to 4.559 ky) ranges from 27 to 9 years.

362 calcium carbonate powders (~1 mg each) were then collected using a dental drill on polished sections of 5 dated veins and 6 undated veins. These analyses were performed with an optima micromass spectrometer (LSCE, Gif sur Yvette, France). The accuracy on the measurements is ±0.04‰ and ±0.06‰ respectively for $\delta^{13}C$ and $\delta^{18}O$. The results are reported relative to

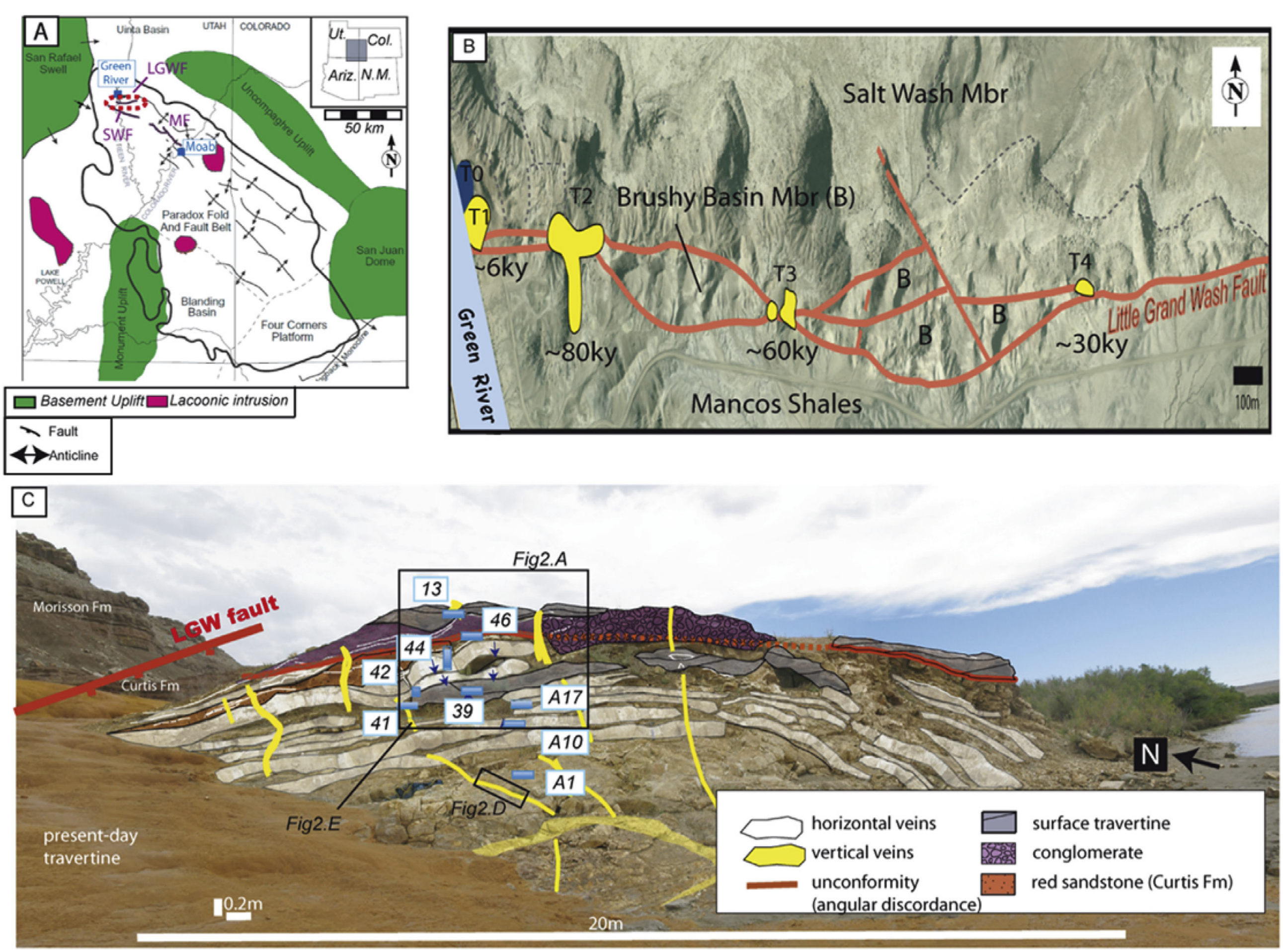

Fig. 1. Geological setting and sampling: (A) Location of the Little Grand Wash and Salt Wash faults within the Colorado Plateau. (B) Simplified geological map of Little Grand Wash fault. (C) Picture of the studied travertine mount and location of the sampling (modified from Condon, 1997; Dockrill, 2005 and Frery et al., 2015).