Sedimentary Geology 308 (2014) 32–43

Contents lists available at ScienceDirect

Sedimentary Geology

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

Origin and palaeo-environmental significance of the Berrazales carbonate spring deposit, North of Gran Canaria Island, Spain

Jon Camuera [a,*], Ana M. Alonso-Zarza [a,b], Álvaro Rodríguez-Berriguete [a,b], Alejandro Rodriguez-Gonzalez [c]

[a] Dpto. Petrología y Geoquímica, Facultad de Ciencias Geológicas, Universidad Complutense de Madrid, José Antonio Novais 12, 28040 Madrid, Spain
[b] Instituto de Geociencas (CSIC, UCM), José Antonio Nováis 12, 28040 Madrid, Spain
[c] Dpto. Física GEOVOL, Campus de Tafira, Universidad de Las Palmas de Gran Canaria, 35017 Las Palmas de Gran Canaria, Spain

ARTICLE INFO

Article history:
Received 20 February 2014
Received in revised form 25 April 2014
Accepted 28 April 2014
Available online 9 May 2014

Editor: B. Jones

Keywords:
Carbonate spring deposit
Travertine facies
Canary Islands
Microbes
Stable isotopes
Volcanic setting

ABSTRACT

The Berrazales carbonate spring deposit is a small outcrop constituted mainly by cascade-like geometries. Four main facies have been identified: *fibrous dense macrocrystalline* formed by rapid degassing under high-flow conditions; *framestones* of coated plant moulds formed in moderate energy flow favoured by the presence of biogenic support; *micrite/microsparite* are primary precipitates in which crystalline aggregates nucleated on organic filaments and/or EPS; *banded micrite-coarse crystalline* were the result of alternating physically, chemically and biologically induced precipitation in areas of varying flow-velocities. Most facies underwent different degrees of micritization processes. Micrite is distributed as thin lines penetrating the crystals, as irregular patches or as micrite layers. In the first case organic filaments penetrate crystals, suggesting that micritization is mainly biogenically driven. In the latter cases micritization is caused mostly by partial dissolution. Microbe participation in micrite formation increased micrite $MgCO_3$ content in comparison with coarse crystalline facies.
Isotopic analyses show positive $\delta^{13}C$ values (+2.63 and +4.29‰ VPDB) and negative $\delta^{18}O$ (−5.65 and −4.48‰ VPDB) values. Positive $\delta^{13}C$ values clearly indicate "deep-sourced" fluids.
The Berrazales spring deposit studied here very probably is a small part of a larger carbonate building that was largely eroded by fluvial incision. Calculations of spring water temperature give a range from 20 °C to 35 °C, characteristic of a cold to warm spring favouring precipitation of calcite and important biogenic activity (*framestones*). Although the study deposit has textural characteristics of tufas, proving that the CO_2 sourced from deep fluids, it should be considered as thermogene travertine, being one more example of the difficulty of using those terms for ancient sedimentary deposits. Carbonate spring deposits, very rare in the Canary Islands, are good archives of recent volcanic activity, fluvial processes and vegetation regimes prevailing in the islands in recent times.

1. Introduction

Calcareous spring deposits have been reported in various volcanic settings, such as in the hot-spot of Yellowstone (Fouke, 2011), in the Bogoria and Turkana lakes of the African Rift (Jones and Renaut, 1996; Renaut and Jones, 1997) and in arc-islands or compressive systems as in Japan (Nishikawa et al., 2012). Other calcareous spring deposits are located along extensional fractures, such as the well-known Pamukkale-Karahayit travertines in Turkey (Hancock et al., 1999; Özkul, 2005), the Tivoli area (Gandin and Capezzuoli, 2014) or the Euganean geothermal field (Pola et al., 2014) in Italy. The large hydrocarbon reservoir of the South-Atlantic Pre-salt also contains facies similar to carbonate spring deposits (Terra et al., 2010). In spite of increasing interest in the study of these deposits there is not yet a consensus on how to interpret many of their facies, nor on the role of biogenic versus abiogenic processes in their formation or on their classification (Ford and Pedley, 1996; Pentecost, 2005; Gandin and Capezzuoli, 2008; Gandin and Capezzuoli, 2014). Lack of consensus continues regarding calcareous spring deposits and also fluvial carbonates with regard to the use of terms travertine and tufa. Originally, travertine has been applied to compact rocks used for building construction material, whereas tufa usually denotes a softer more friable deposit (Viles and Pentecost, 2008). Even so, recently these terms have been scientifically redefined by some authors such as Capezzuoli et al. (2014). Thus, travertine is defined for non-marine carbonates formed from hydrothermal-sourced waters, associated with tectonically active areas (and high geothermal heat flux) and characterized mainly by high depositional rates, low porosity, regular bedding and fine laminations, and an inorganic crystalline fabric. In contrast, the tufa is generally produced from meteoric water at ambient temperature and characterized by low depositional rates, high porosity and high content of microphytes and macrophytes (Capezzuoli et al., 2014, Table 1). The temperature of water feeding the spring is another classification criteria, although in some cases it is difficult to apply to ancient deposits. Two main types of waters may feed springs: 1) organic CO_2-rich and low temperature waters (generally lower than 20 °C) coming from the soil and

* Corresponding author. Tel.: +34 913944915.
E-mail address: jcamuera@gmail.com (J. Camuera).

http://dx.doi.org/10.1016/j.sedgeo.2014.04.005
0037-0738/

groundwater form meteogene travertines, which have negative $\delta^{13}C$ (-12 to -2‰ PDB) values; 2) $\delta^{13}C$ values of thermogene travertines, sourced from hot to warm waters (generally higher than 30 °C) coming from the interaction between host rock and CO_2 rich fluids at depth, vary between -2 and $+10$‰ PDB (Kele et al., 2011; Capezzuoli et al., 2014). Mineralogy, facies and microfacies of calcareous spring deposits are controlled by a set of environmental parameters such as: water chemical composition and temperature, rate of CO_2 degassing, saturation levels and calcite deposition rate, macro and microbial activity or the presence of some inhibitors (Talbot, 1990; Jones and Renaut, 2010; Guo and Chafetz, 2014; Sun et al., 2014). These make spring deposits good palaeo-environmental archives (Andrews, 2006; Anzalone et al., 2007; Keppel et al., 2012; Gradziński et al., 2013, 2014).

In the Canary Islands carbonate spring deposits are very scarce (Demény et al., 2010; Alonso-Zarza et al., 2012; Rodríguez-Berriguete et al., 2012). In this paper we study the Berrazales spring deposit, located in Gran Canaria Island. Our aims are to unravel: a) the thermal–volcanic influence in the formation of carbonate spring deposits in volcanic settings, b) the role of biogenic versus abiogenic processes and their interrelation during and after crystalline growth and, c) water physicochemical conditions (temperature, pH, chemistry, etc.) controlling the formation of the deposits. Our conclusions can be an aid to the understanding of the processes and the main controls involved in the formation of travertines in volcanic settings and their palaeo-environmental and palaeohydrological significance.

2. Geographical and geological setting

The Canary Islands (Spain) are located off the NW African coast, between 29° 25′ and 27° 37′ N and 18° 10′ and 13° 20′ W, developed over the Jurassic oceanic lithosphere as a result of the eastward movement of the African plate over a mantle hotspot (Holik et al., 1991; Carracedo et al., 1998, 2002). Similar to other intra-plate volcanic islands, the Canarian archipelago displays the hotspot volcanic stages of evolution: juvenile (shield), volcanic quiescence and rejuvenated stage. Gran Canaria, actually in an advanced rejuvenated stage, is a nearly circular island located at the centre of the Canarian archipelago. A dense radial network of deep ravines ("barrancos", the local toponomy) dissects the island, forming a rugged topography. The sub-aerial development of Gran Canaria records a juvenile stage (ca. 14.5–8.0 Ma), a volcanic quiescent stage (ca. 8.0–5.5 Ma) and a rejuvenated stage (ca. 5.5 Ma to present) including the Roque Nublo stratovolcano and the Post-Roque Nublo volcanism (Perez-Torrado et al., 1995; Carracedo et al., 2002; Guillou et al., 2004; Aulinas et al., 2010). The most recent Post-Roque Nublo volcanism, Holocene in age, created a monogenetic volcanic field with at least 24 vents. The eruptive style is mainly strombolian with formation of small scoria cones and lava flows, mostly with aá morphologies (Rodríguez-González et al., 2009, 2012). The Holocene vulcanism has a strong control on the development of the few carbonate spring deposits that have been studied in Gran Canaria. One of these deposits is the Azuaje travertine described by Rodríguez-Berriguete et al. (2012) located 9 km north-east of the study area.

The carbonate deposits studied are located above the stratigraphic contact between the scoria cone and lava flow of the Berrazales eruption (Fig. 1A), in the upper part of Barranco Los Ríos (Fig. 1B). The lava flow is classified as basanite (Rodríguez-González et al., 2009). Holocene lava flows were emplaced at the bottom of the ravines, with little erosive incision and draining towards the coast (Rodríguez-González et al., 2009, 2012). This eruption is stratigraphically related to Jabalobos (dated by ^{14}C at 2760 ± 60 BP) and Fagajesto (dated by ^{14}C at 3030 ± 90 BP) eruptions (Rodríguez-González et al., 2009; Aulinas et al., 2010).

3. Methods

Samples of the Berrazales outcrop were studied using conventional petrological, mineralogical and geochemical analyses. Twenty-six samples were chosen for conventional optical petrographic study in thin sections. Fragile thin sections were impregnated with epoxy resin.

Mineralogical semi-quantitative composition of all samples was determined by X-ray powder diffraction (XRD) using a Philips PW-1710 with CuKα at 40 KV and 30 mA. $MgCO_3$ mole percent is measured from d-spacing of calcite crystal lattice, which was determined by the variation of 2 value of the principal calcite peak of the X-ray diffractograms (Goldsmith et al., 1961; Tucker, 1988; Scholle and Ulmer-Scholle, 2003; Ries et al., 2008).

The texture and components studied in 12 gold-coated samples were determined using a JEOL JSM 6400 scanning electron microscope on the Research Support Centre (CAI) of Geological Techniques of

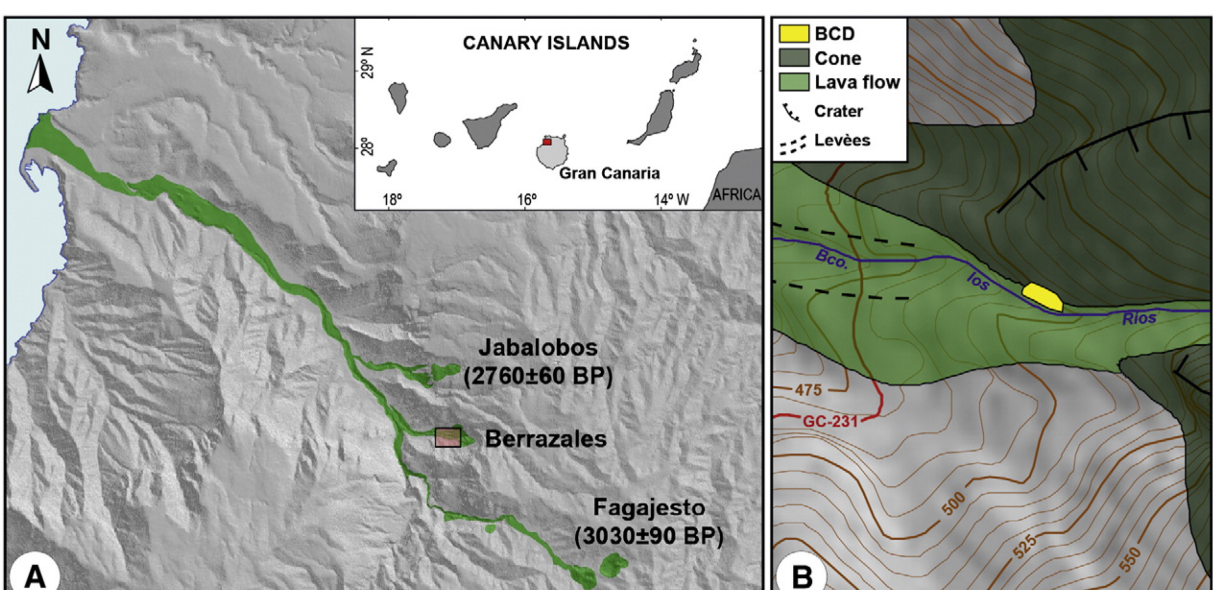

Fig. 1. (A) Location of the Berrazales area, in the north-west of Gran Canaria Island. (B) Situation of the Berrazales Carbonate Deposit (BCD) between volcanic materials in the Barranco Los Ríos.