Sedimentary Geology 339 (2016) 134–150

Contents lists available at ScienceDirect

Sedimentary Geology

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

Historical seismicity of the Mont Dore volcanic province (Auvergne, France) unraveled by a regional lacustrine investigation: New insights about lake sensitivity to earthquakes

Léo Chassiot [a,*], Emmanuel Chapron [a,b], Christian Di Giovanni [a], Patrick Lajeunesse [c], Kazuyo Tachikawa [d], Marta Garcia [d], Edouard Bard [d]

[a] Institut des Sciences de la Terre d'Orléans (ISTO), UMR 7327, CNRS, Université d'Orléans, BRGM, 1A rue de la Férollerie, 45071 Orléans Cedex 2, France
[b] Géographie de l'Environnement (GEODE), UMR 5602, CNRS, Université Toulouse 2 Jean Jaurès, Allée A. Machado, 31058 Toulouse Cedex, France
[c] Centre d'Etudes Nordiques (CEN), Département de Géographie, Université Laval, Pavillon Abitibi-Price, 2405, rue de la Terrasse, Québec G1V 0A6, Canada
[d] Centre Européen de Recherche et d'Enseignement en Géosciences (CEREGE), UM 34, CNRS, Université Aix-Marseille, IRD, Collège de France, 13545 Aix-en-Provence, France

ARTICLE INFO

Article history:
Received 5 February 2016
Received in revised form 11 April 2016
Accepted 12 April 2016
Available online 20 April 2016

Editor: Dr. J. Knight

Keywords:
Volcanic lakes
Mass-wasting deposits
Earthquakes
Lake sensitivity
Paleoseismology
French Massif Central

ABSTRACT

Lake sediments are relevant natural seismographs over long time scale. However, because tectonic events are not systematically recorded in lake sediments, one forthcoming challenge for paleoseismology is to better assess lake sensitivity to earthquakes. To this end, a limnogeological investigation, including hydroacoustic mapping techniques, core sampling and multi-proxy sediment analyses, has been conducted within four small volcanic lakes located in the Mont Dore province (Auvergne, France), an area with a moderate seismo-tectonic activity. Results show the existence of several gravity reworking processes in the lakes over the last millennium. Around AD 1300, the occurrence of synchronous events in lakes Pavin, Chauvet, Montcineyre and Guéry (100 km^2 area) highlights an undocumented earthquake as a common trigger for slope failures in disconnected basins. At regional scale, the record of this tectonic event may have been favored by human-induced increase in sediment load (Chauvet and Montcineyre) and/or after an abrupt lake-level drop (Pavin) affecting the sediment stability. In addition, synchronous turbidites and mass-wasting deposits (MWD) recorded in lakes Pavin and Guéry provide evidence for a seismic activity during the XIXth century. Potential triggers are historical earthquakes that occurred either in the Mont Dore area or in the southern part of the Limagne fault at this time. Despite moderate seismic activity in this intraplate volcanic domain, these results highlight the role of tectonics as a major trigger in the sedimentary processes dominating these lacustrine infills. Within the diversity of studied sites, it appears that lake sensitivity to earthquakes was not constant over time. This sensitivity can be expressed as a combination of external factors, namely earthquake magnitude and lake-epicenter distance and internal factors such as lake morphology, nature of sediment, lake-level fluctuations and human-induced changes in catchment sedimentary load.

1. Introduction

Metropolitan France is a country of low seismotectonic activity (Baize et al., 2013). The seismotectonic zonation established from both geological background and evidence of Neogene tectonic activity leads to a regional-scale seismic hazard assessment, which is highly variable within the country (Terrier et al., 2000; Baize et al., 2013). According to SISFRANCE and AHEAD databases (Lambert et al., 1997; Baumont and Scotti, 2011; Stucchi et al., 2013), compressing stress zones like the Alps and the Pyrenees host active faults favoring the generation of recurrent and in some cases large earthquakes (magnitude ≥6). Major tectonic features located near Hercynian chains are also responsible for smaller tectonic events (magnitude ≤6), as in the Armorican Massif or the French Massif Central (Lambert et al., 1997). In both settings, the instrumental records span the last century, which remains problematic to assess the seismic hazard for events of long return periods. Hence, extending earthquake records beyond this time window is a key issue for understanding regional seismicity and hazard risk.

Over the last decades, lake sediments have been analyzed for their relevance to record seismic events and have been successfully used as natural seismographs for long-term record of earthquake-induced sedimentary disturbances (Strasser et al., 2013). Today, many studies use various forms of instantaneously formed sedimentary deposits or structures for qualitative and quantitative earthquake reconstructions in lacustrine systems during the Holocene, as long as the seismic origin of these deposits is clear. Most of these studies are concentrated in tectonically active regions such as the Alps (Beck et al., 1996; Schnellmann et al., 2002; Monecke et al., 2004; Nomade et al., 2005; Strasser et al.,

* Corresponding author.
E-mail address: leo.chassiot@hotmail.fr (L. Chassiot).

http://dx.doi.org/10.1016/j.sedgeo.2016.04.007
0037-0738/

2006, 2013; Wilhelm et al., 2015; Chapron et al., 2016), the Anatolian fault (Schwab et al., 2009; Avşar et al., 2014, 2015) and around the Pacific where recurrent and large earthquakes have been recently experienced such as in Chile (Chapron et al., 2006; Bertrand et al., 2008; Moernaut et al., 2007, 2014), US western coast (Karlin et al., 2004; Maloney et al., 2013; Morey et al., 2013; Smith et al., 2013), Japan (Inouchi et al., 1996) or New Zealand (Howarth et al., 2014; Gomez et al., 2015). Moreover, recent limnogeological investigations in glacial lakes of the mid-continental North America underline the ability of sediment to archive earthquakes throughout the Holocene, despite the low to moderate magnitude of earthquakes that occurred in this intraplate domain (St-Onge et al., 2004; Doughty et al., 2014; Lajeunesse et al., in press; Locat et al., 2016). However, because earthquakes do not systematically trigger mass-movement deposits in lake basins, one forthcoming challenge for paleoseismology is the characterization of lake sensitivity to earthquakes, which can vary from one lake to another (Wilhelm et al., 2015).

In order to contribute to the growing interest of earthquake records in lacustrine environments, the present study focuses on the volcanic province of the Mont Dore area (French Massif Central) where a limited but existent tectonic activity has been reported for the last half-millennium (Lambert et al., 1997; Stucchi et al., 2013). This region hosts various types of small volcanogenic lakes which are, with rare exceptions, barely known in limnogeological terms. Supporting pioneer works published by Chapron et al. (2012), the present study provides an up-to-date dataset of high-resolution seismic profiles coupled to radiocarbon-dated sediment cores from four nearby lakes (100 km^2 area), including maar Lake Pavin (Schettler et al., 2007; Chapron et al., 2010, 2012; Chassiot et al., 2016), maar Lake Chauvet (Juvigné, 1992), volcanic-dam Lake Montcineyre (Chapron et al., 2012) and the poorly documented glacial Lake Guéry (Fig. 1). This regional dataset also improve the scope of earthquakes that triggered turbidites recently described in Lake Pavin sedimentary archives (Chassiot et al., 2016).

2. Regional setting

2.1. Geological background

The French Massif Central hosts a succession of volcanic edifices along a North–South transect. Among them, the Puy-de-Dôme culminates at 1465 m a.s.l. above the Chaîne-des-Puys, a volcanic province separated from the Limagne graben by a normal fault (Boivin et al., 2009). The Limagne fault is a major tectonic structure of an Oligocene rifting episode (Merle et al., 1998) (Fig. 1B). The Sancy stratovolcano

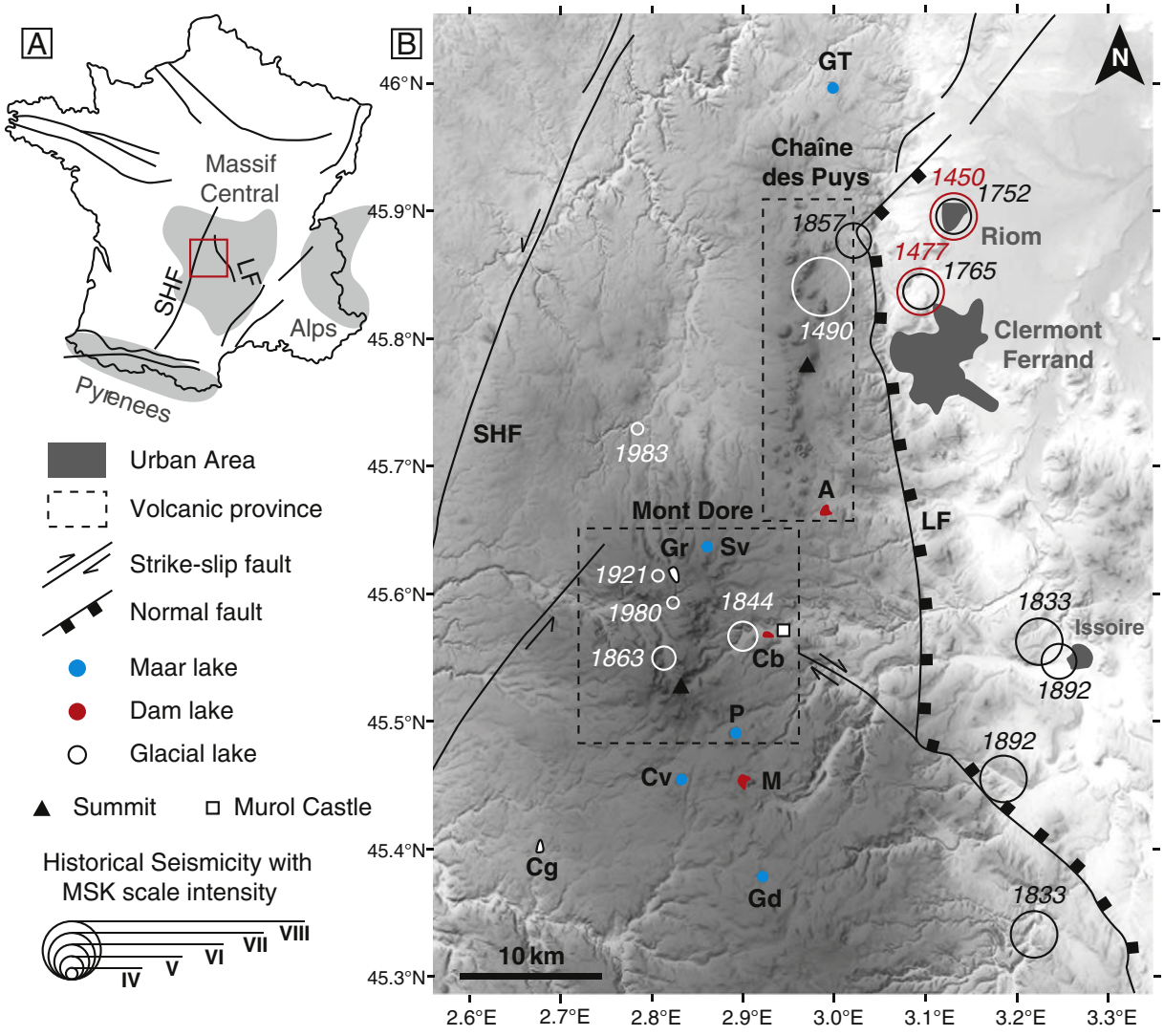

Fig. 1. (A) Simplified seismo-tectonic map of France with major faults (redrawn after Baize et al., 2013). (B) Historical seismicity of the study area from Sisfrance database (Lambert et al., 1997) displaying main volcanic provinces, faults (LF: Limagne Fault and SHF: Sillon Houiller Fault) and lakes (A: Aydat; Cb: Chambon; Cv: Chauvet; Cg: Crégut; Gd: Godivelle-d'en-Haut; GT: Gour de Tazenat; Gr: Guéry and P: Pavin).