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ZOLTÁN KERN (*) & SHAWN THOMAS (**)

ICE LEVEL CHANGES FROM SEASONAL TO DECADAL TIME-SCALES OBSERVED IN LAVA TUBES, LAVA BEDS NATIONAL MONUMENT, NE CALIFORNIA, USA

ABSTRACT: KERN Z. & THOMAS S., *Ice level changes from seasonal to decadal time-scales observed in lava tubes, Lava Beds National Monument, NE California, USA.* (IT ISSN 0391-9838, 2014).

Numerous lava tubes host seasonal or perennial ice accumulation in the Lava Beds region. Systematic ice level monitoring has been conducted for eight ice caves since 1990, and four other ice caves were added to the monitoring program during recent years. Cave names are used for publically advertised ice caves, and cave codes are used to help protect ice resources of the other eight monitored ice caves. Monitoring data has revealed that the seasonal cave ice phenology can be characterized by autumnal ice level low-stands of ice floors in the lava tubes. Regarding the multiannual evolution, both positive and negative ice mass balance periods were detected during the past 23 years. Balanced glaciation characterized the lava tubes over the early 1990s. Positive mass balances were reported for many caves from the late 1990s. Ice levels are still stable in Skull Ice Cave and U-200. Severe ice loss, however, has characterized the evolution of ice deposits in the other monitored caves. Major ice loss started in 1999 in Merrill, C-270, and M-470 ice caves, while not until 2003 in L-800. The recent rapid ice melt resulted in total ice loss for some caves. The perennial ice disappeared, for instance from M-470 and M-475 by 2005 and from Merrill Ice Cave by 2006.

KEY WORDS: Lava tube, Cave glaciation, Cave ice phenology, Decadal ice level trends.

(*) *Institute for Geology and Geochemistry, Research Centre for Astronomy and Earth Sciences, MTA, Budaörsi út 42, Budapest, H-1112, Hungary* (kern@geochem.hu, zoltan.kern@gmail.com).

(**) *Bat Conservation International - Subterranean Programs, Flagstaff, Arizona USA.*

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INTRODUCTION

Shrinking glaciers, decreasing sea ice extent, and thawing of permafrost are well known and frequently quoted examples of the recent retreating trend of the global cryosphere (Lemke & *alii*, 2007; UNEP, 2007; Zemp & *alii*, 2008); however, information regarding the status of cave glaciations worldwide is relatively scarce (Kern & Perşoiu, 2013). In this respect, multiannual, systematic volumetric and/or ice level monitoring data are definitely invaluable records for revealing cave glaciation trends. Such monitoring, however, is extremely rare in ice caves (Rajman & *alii*, 1985; Ohata & *alii*, 1994b; Luetscher & *alii*, 2008; Strug & Zelinka, 2008; Kern & *alii*, 2007), and perhaps the Romanian Scărişoara IC (Ice Cave hitherto abbreviated as IC) (Racoviţa, 1994; Perşoiu & Pazdur, 2011) and the German Schellenberg IC (Ringeis & *alii*, 2008) are the best examples so far of published multidecadal ice level monitoring data. Reconstructed ice level histories based on historic or stratigraphic evidence are also available in limited numbers (e.g., Luetscher & *alii*, 2005; Spötl & *alii*, 2014).

It has long been known that numerous lava tubes host seasonal or perennial ice accumulation in the Lava Beds region (Balch, 1900; Swartzlow, 1935; Halliday, 1954; Knox & Gale, 1959). However, the observation records obtained from systematic ice level monitoring conducted for 12 ice caves in the Lava Beds region were practically unknown to the ice cave research community until recently. Fuhrmann (2007) published 16 years of mean ice level changes from Merrill IC, while a recent study showed ice volume change estimates using five additional records in a global overview (Kern & Perşoiu, 2013). In this paper we publish the full ice level monitoring record of the 12 lava tubes covering the period from 1990 to 2012.

Although the dominant role of winter cooling is a consensus view in the community regarding the link between