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Geomorphology 73 (2006) 78–100

GEOMORPHOLOGY

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An environmental model of fluvial tufas in the monsoonal tropics, Barkly karst, northern Australia

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Received 12 October 2004; received in revised form 6 July 2005; accepted 7 July 2005
Available online 13 September 2005

Abstract

Spring-fed streams that deposit tufa (ambient temperature freshwater calcium carbonate deposits) in the tropics of northern Australia are influenced strongly by perennially warm water temperatures, high evaporation rates, and monsoon driven high-magnitude floods. This paper presents an environmental model that will aid interpretation of fossil fluvial tufas throughout monsoonal Australia. In the Barkly karst, northern Australia, tufas form in dam, cascade and pool/waterhole geomorphic environments. Each environment is represented in the morphostratigraphical record by a specific combination of tufa geomorphic units and facies associations. A diverse array of tufa facies is present, including microphytic, larval, calcite raft, macrophytic and allochthonous types.

Preservation of particular Barkly karst tufa facies is thought to reflect the strength of monsoonal floods. A strong monsoon is represented by an abundance of flood indicators such as the allochthonous phytoclastic, lithoclastic and intraclastic tufa facies. Conversely, evidence of weak monsoons or a prolonged absence of floods may include oncoids, calcite rafts and thick accumulations of fine carbonate sediments. The history of the Australian monsoon is not fully understood. However, fossil tufa deposits, which record terrestrial climate information, have been preserved throughout northern Australia and hold great potential for reconstructing the region's climate history. Fossil tufa sequences at two Barkly karst sites have been interpreted using the new model. It can be applied to other Barkly karst fossil tufas as well as those in similar environments elsewhere in the world.

Keywords: Tufa; Travertine; Environmental models; Monsoonal tropical Australia

1. Introduction

Tufas are an important archive of terrestrial palaeoenvironmental information (Andrews et al., 2000; Horvatinčić et al., 2000; Ihlenfeld et al., 2003; Rich et al., 2003). In some parts of the world, they

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doi:10.1016/j.geomorph.2005.07.007

have been used successfully to investigate regional climatic histories (Drysdale and Head, 1998; Pedley et al., 2000; Martín-Algarra et al., 2003; Nyssen et al., 2004). However, field interpretation of fossil tufas can be difficult, especially where weathering or partial burial has masked the critical stratigraphic and geomorphic detail necessary for reconstructing palaeohydrological conditions. Field interpretations can be enhanced significantly if local biological and climatic factors are well understood, as these control the geomorphic and sedimentological architecture of tufa environments. Environmental models are the principal means by which accurate field interpretations can be achieved (Pedley et al., 2003).

Environmental models are conceptual representations of tufa systems based on data from both active and fossil tufa sequences. They summarize the characteristic tufa deposit morphology, facies associations, hydraulic conditions, and flora and fauna that occur in each system (Pedley, 1990). Such models have been developed for a variety of hydrological settings, such as rivers, lakes, springs and swamps (Ford and Pedley, 1996). Models are essential tools for studying tufas for a number of reasons. Firstly, they aid identification of tufas in stratigraphical sequences by providing criteria that distinguish between tufaceous and non-tufaceous material (Ford and Pedley, 1996). Secondly, models allow accurate interpretation of fossil tufas and the palaeoenvironmental information they contain. This is especially important at sites where tufa formation is not actively occurring and so modern analogues are not available to interpret features preserved in the fossil deposits (Evans, 1999). Thirdly, models indicate the likely location of particular facies and geomorphic units within the tufa system, which is necessary when collecting suitable samples for dating or high-resolution geochemical analyses (Matsuoka et al., 2001; Ihlenfeld et al., 2003). Finally, environmental models provide insights into tufa formation and the factors that control tufa growth, which is essential for effective management of tufa sites (Pentecost et al., 2000).

It is vital that an appropriate model is used for the site under investigation. Environmental models have not been previously derived from studies of tropical monsoonal sites and existing models are not adequate for investigating fluvial tufas in northern Australia (Carthew et al., 2003a). Year-round warm water temperatures (min: 19 °C, max: 36 °C), high evaporation rates (~1 cm/day—pan values), strongly seasonal precipitation and regular destructive floods characterize tropical monsoonal tufa sites (Carthew et al., 2003a). These factors have a great influence on the tufa deposits. The perennially warm spring-fed flow ensures abundant populations of aquatic insect larvae and microorganisms in these locations. Such organisms play an important role in tufa formation and the development of numerous distinctive tufa facies (Drysdale, 1999; Drysdale et al., 2003; Carthew et al., 2003b). High evaporation rates contribute to the formation of calcite rafts, which are unusual in more temperate locations (Taylor et al., 2004). The strongly seasonal precipitation and regular destructive floods may result in lamination, abrupt changes in tufa facies, dramatic shifts in stream position, abundant phytoclastic and intraclastic deposits, and a general lack of oncoids and thick sedimentary fills (Carthew et al., 2003a).

In the monsoon-affected climate zone of northern Australia, there are various potential sources of datable Quaternary records (Hesse et al., 2004) but many are not well preserved and subsequently climate histories are poorly understood (Wyrwoll and Miller, 2001). Tufas may provide a useful source of information for resolving the monsoon history of Australia. They are present throughout northern Australia, from Mount Etna (Dunkerley, 1981a,b) and Chillagoe karst (Dunkerley, 1987) in the east, to the Kimberley region in the west (Jennings and Sweeting, 1963; Ellaway et al., 1990; Viles and Goudie, 1990; Goudie et al., 1990; Wright, 2000; Wallis, 2002). Within this zone there is extensive active deposition as well as fossil tufas from the Quaternary (Drysdale and Head, 1998) and Tertiary (Megirian, 1992) that are located in the Barkly karst (Fig. 1). These tufas provide an excellent opportunity to examine the history of the Australian monsoon. The aim of this study is to develop an appropriate model that will aid interpretation of the tufa deposits. The model proposed here is based on general features of existing schemes, especially those reported by Pedley (1990), Violante et al. (1994) and Pedley et al. (2003), but it has been adapted to suit tropical