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Holocene environmental change resets lichen surface dates on Recess Peak glacial deposits in the Sierra Nevada, California

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ABSTRACT

Development of an accurate chronology for glacial deposits in the Sierra Nevada has long been problematic given the lack of suitable organic material for radiocarbon dating. Lichenometry initially appeared promising as ages showed an increase from cirque headwalls to down-canyon moraines. However, while Recess Peak lichen age estimates range from 2 to 3 ka, recent work shows these deposits to be at least 10 ka older. Here, we present evidence for a late Holocene reset of Recess Peak lichen ages by significant post-depositional climate change. Following late-Pleistocene deposition of Recess Peak moraines, warming through the mid-Holocene allowed forests to advance into shallow basins eliminating local inverted tree lines. This produced a partial canopy where shading killed the original post-Pleistocene crustose lichen colonies. Late-Holocene cooling resulted in forest retreat from these basins as alpine tree line fell. Lichens then recolonized the re-exposed Recess Peak deposits. We conclude that while Recess Peak lichen ages are accurate to within the dating uncertainty of the technique, existing lichen ages actually date the timing of post-mid-Holocene cooling and recolonization, and not the original emplacement of these deposits. Thus, applications of Lichenometry should consider post-depositional environmental change when interpreting the meaning of these dates.

Introduction

Reconstructions of middle-to-late Holocene glacial/environmental change in the Sierra Nevada, until recently, were limited by a pronounced lack of radiocarbon datable macrofossils (Pohl et al., 1996; Clark and Gillespie, 1997). In the absence of direct radiocarbon dating, the relatively unweathered Recess Peak advance found between 3000 and 3400 m from Yosemite National Park on the north to Cottonwood Basin on the south (Burbank, 1991; Clark and Gillespie, 1997), was first interpreted as post-mid-Holocene climatic optimum using boulder weathering relative dating approaches (Birman, 1964; Burke and Birkeland, 1983; Scuderi, 1984). However, recent dating of organic debris from lakes (Clark and Gillespie, 1997; Bowerman and Clark, 2004), moraines and pro-glacial lake deposits (Konrad and Clark, 1998), chironomids (Potito et al., 2006) and macroscopic charcoal (Hallett and Anderson, 2010) allowed the development of a more comprehensive chronology of environmental variation where the Recess Peak advance is now recognized as being late Pleistocene (~13,500–12,500 cal yr BP) in age. Subsequent work (Clark and Gillespie, 1997) suggested that there was a single post 700 cal yr BP late-neoglacial Matthes advance, an interpretation that implies a relatively ice-free Holocene Sierra Nevada, with possibly only minor advances, between 11,000 and 700 yr ago.

This Sierran Holocene chronology was refined in recent years (Konrad and Clark, 1998; Bowerman and Clark, 2004, 2011) to include multiple neoglacial advances with the earliest occurring at ~3200 ^{14}C yr BP (3400 cal yr BP) and the latest and most extensive equivalent to the Matthes Little Ice Age advance at ~250 to 170 cal yr BP. This latest advance overrode earlier neoglacial advances, eliminating most evidence of these earlier cold intervals. This newest revision places Sierran neoglacial history in line with chronologies worldwide with multiple and distinct glacial maxima that show glacial advance and significant climate change following early to mid-Holocene climatic warmth (Gillespie and Clark, 2010).

Lichenometry was initially used in the Sierra Nevada by Curry (1969) and Scuderi (1984, 1987a) as a means to establish the age of moraine stabilization on Recess Peak and Matthes age moraines but has since proved to be problematic. Used successfully in similar environments worldwide (Denton and Karlen, 1973; Benedict, 1993; Beget, 1994; Benedict, 2009), its application in the Sierra Nevada provides ages that are far too young for Recess Peak deposits in light of the most recent dating. While possible circular reasoning in Curry's (1968, 1969) dating control points (discussed in Clark and Gillespie, 1997) may explain a portion of the discrepancy, we note that the environmental setting in which the Sierran Recess Peak moraines were emplaced may complicate the interpretation of lichen ages.

In Cottonwood Basin (Fig. 1) cirque glaciers heading along the main crest of the Sierra Nevada 2.5 km west of our study site produced a complex of blocky moraines covering a low-lying depression ~1 km^2. Similar to Recess Peak deposits found throughout the Sierra

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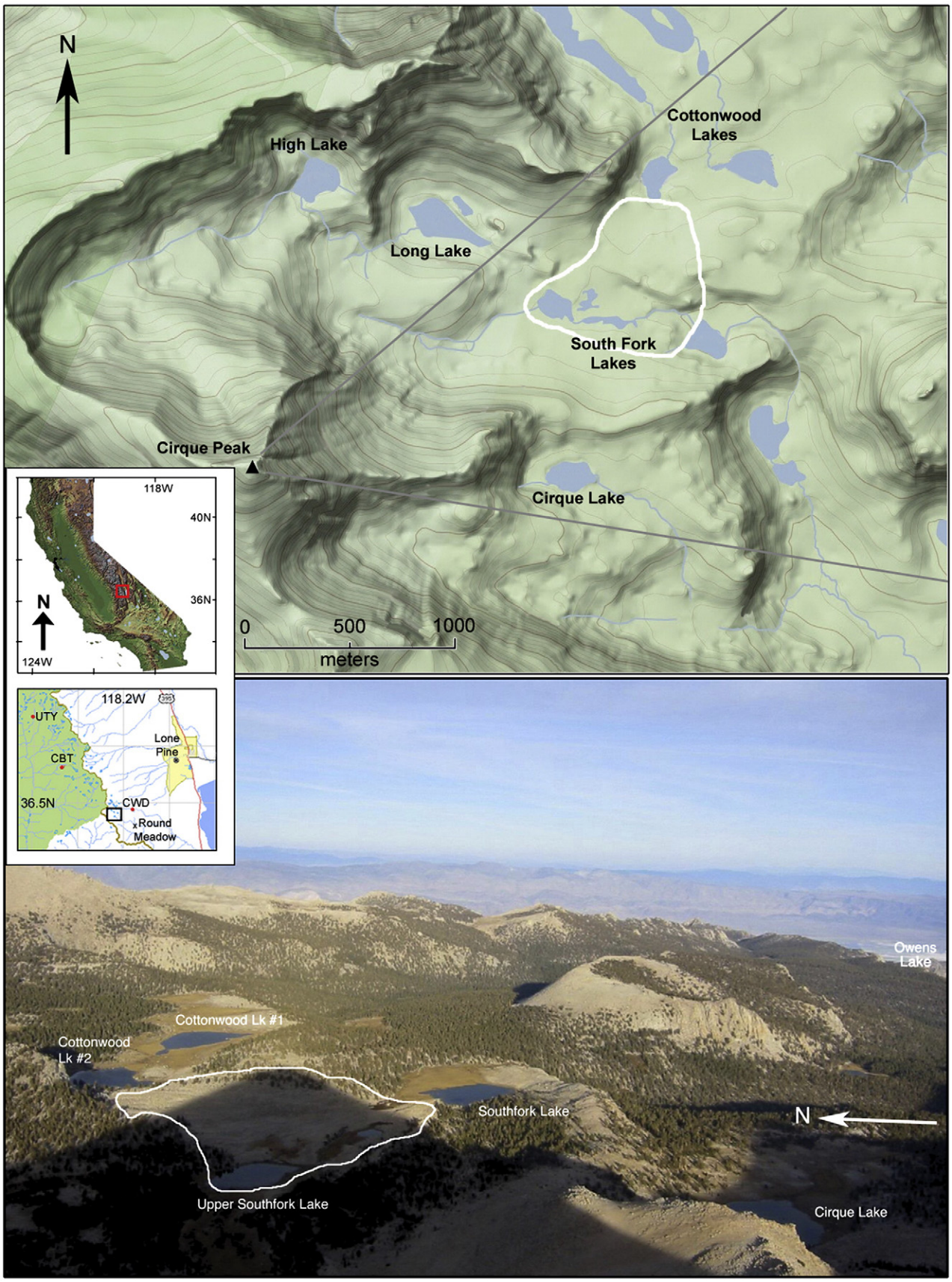

Figure 1. Top: Southern portion of Cottonwood Basin with area of Recess Peak glacial deposits indicated with white border. Gray lines indicate sight lines of lower image. Bottom: Cottonwood Basin looking northeast from the summit of Cirque Peak. The study area inverted treeline is outlined in white and contains Recess Peak moraines. The tree line examined in this study is at the apex of the shadow of Cirque Peak. Other areas of cold-air collection and inverted treelines can be seen around Cottonwood Lakes 1 and 2 and at Southfork Lake. Scale varies across image. Boxes on inset maps show location of study site. Red dots indicate weather station locations (UTY — Upper Tyndall Creek, CBT — Crabtree, CWD — Cottonwood). Black X indicates location of the Round Meadows/Horseshoe Meadow inverted tree line sensors.