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Luminescence dating of late Pleistocene proximal glacial sediments in the Olympic Mountains, Washington

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ABSTRACT

Late Pleistocene glacial sediments from the South Fork Hoh River valley in the Olympic Mountains, Washington, USA, were dated using optically stimulated luminescence (OSL) on quartz sand. High sediment supply typical of glacial environments, short transport distances, and sediment newly eroded from bedrock sources were expected to pose problems for luminescence dating. Samples were collected from five distinct sedimentary facies, using approximated distances from the ice-front, to assess how luminescence results varied due to these factors and to determine which samples produced the most reliable age estimates. Results from the South Fork Hoh highlight the importance of transport environment and sedimentary facies on solar resetting. Sediments from better-sorted, ice-distal environments were determined to be more completely bleached and more reliable for OSL dating. Samples were collected as part of larger research goals to improve understanding of the glacial history of the South Fork Hoh River valley.

1. Introduction

Establishing chronologic constraint for ice advance and retreat cycles is important for understanding the influence of climate on glaciation, ice dynamics, bedrock erosion, and sediment transport by glacial ice. However, organic material for radiocarbon (^{14}C) dating is not commonly preserved in glacial deposits and appropriate boulders and target minerals for cosmogenic nuclide dating may not be present on landforms. Optically stimulated luminescence (OSL) dating (Huntley et al., 1985) provides an age estimate of the last time sediment was exposed to sunlight and is therefore a potentially useful tool in dating glacial deposits. This research seeks to refine age control on glacial sediments from the South Fork Hoh River, Olympic Mountains, Washington, USA (Fig. 1) and assess the viability of using OSL in various proglacial depositional environments. The primary goal is to investigate the influence of depositional environments, facies, sediments, and relative distance from the ice front on OSL characteristics and equivalent dose (De) distributions in late Pleistocene proglacial settings.

This research is part of a larger project that seeks to provide and refine age control on packages of outwash and glaciolacustrine sediment in the study area. Broader goals include investigating glacial dynamics and responses of these glacial systems to climate forcings. This facies-based research approach aids investigations of glacial dynamics and sediment transport and depositional architecture in hyper-humid settings.

OSL dating has been used in glacial settings with variable success. Proglacial environments are commonly turbid and have high sediment loads, which may not allow sufficient sunlight exposure to completely bleach (zero) the luminescence signal prior to deposition. Many studies discuss incomplete bleaching prior to deposition as the primary complication with OSL dating (e.g. Duller et al., 1995; in Scotland; Gemmel, 1999; in the European Alps; Berger and Doran, 2001; in Antarctica; Gemmell et al., 2007; in Scotland; Klasen et al., 2007; in the Eastern Alps; Alexanderson and Murray, 2012; in Svalbard). Additional complications include high levels of thermal transfer of quartz signals in samples from the Himalaya (Spencer and Owen, 2004) and Greenland (Alexanderson, 2007), changes in luminescence sensitivity of feldspar in samples in the Hindu Kush (Owen et al., 2002), feldspar contamination of

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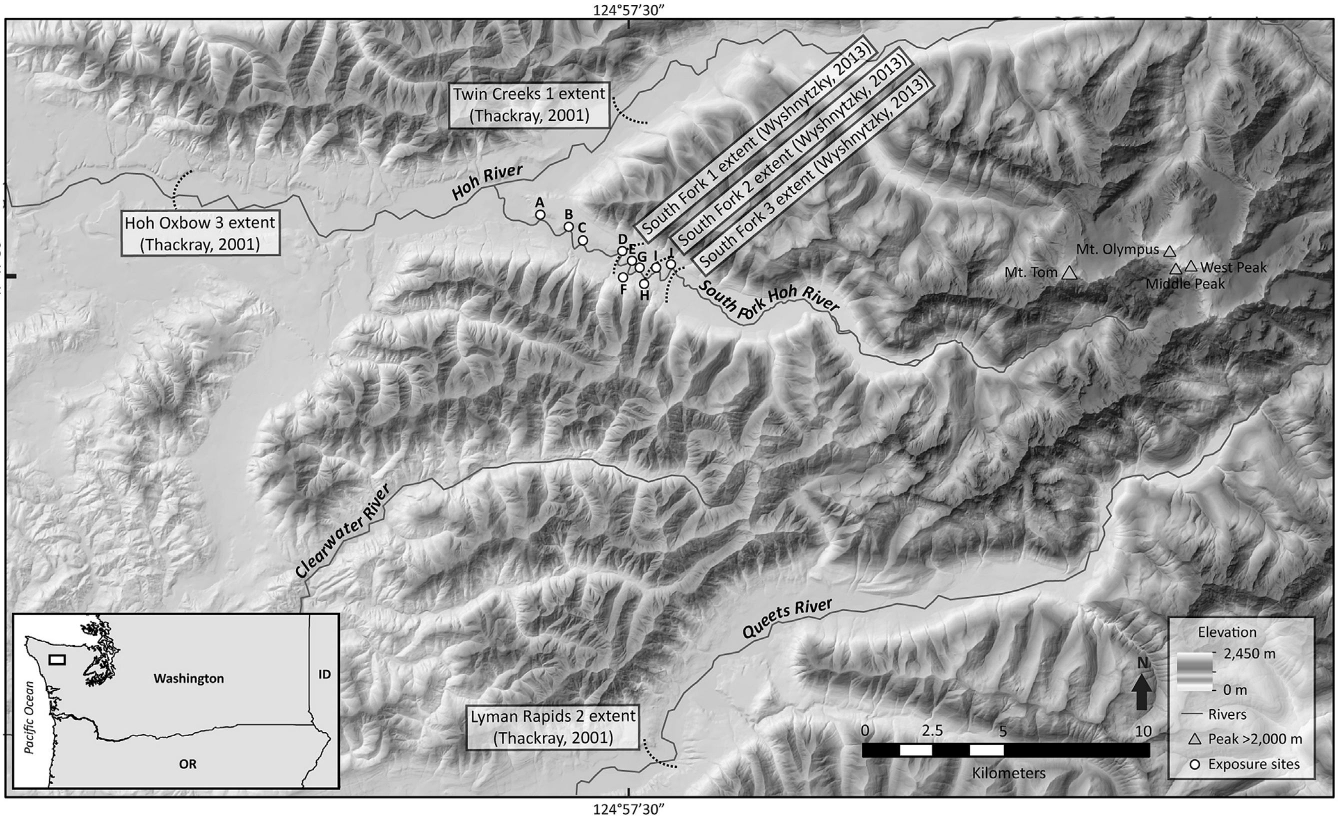

Fig. 1. The location of the South Fork Hoh River, Washington, USA and exposures studied. Inset map shows the location of the SF Hoh River in Washington, USA. Exposures studied are labeled as Sites A–J, with Site A being the farthest down-valley and Site J the farthest up-valley. Dashed lines indicate ice as mapped by Thackray (2001) and Wyshnytzky (2013). Elevations derived from 30 m NED DEM data.

quartz samples due to the immature nature of the sediment (e.g. Lukas et al., 2007 in Scotland), and generally poor luminescence properties (e.g. Preusser et al., 2006 in the Southern Alps; Lukas et al., 2007). Additionally, many glacial sediments may be derived directly from bedrock due to glacial erosion and may have experienced short transport and deposition histories, which may produce weakly luminescence quartz with poor luminescence properties and sensitivity (e.g. Moska and Murray, 2006 in Poland; Lukas et al., 2007; Pietsch et al., 2008 in New South Wales; Sawakuchi et al., 2011; various locations in South America; Jeong and Choi, 2012 in Korea).

Few previous studies have applied OSL dating to deposits on the Olympic Peninsula of Washington. Applications include quartz OSL and infrared stimulated luminescence (IRSL) dating of feldspar in the Puget Lowland (Polenz et al., 2010, 2012) and a northwestern coastal dune (Feathers, 2013, personal communication). Feldspar IRSL dating methods were preferentially used in the dune study due to complications with the quartz signals and age underestimations. Resent research in the Olympic Peninsula of Washington along the South Fork Hoh River (Wyshnytzky, 2013) and the western coastal cliffs (Marshall, 2013) used quartz OSL and feldspar IRSL dating to enhance and revise chronologic constraints of Pleistocene glaciation.

2. Study area

The Olympic Mountains of Washington lie on the northwesternmost edge of the contiguous United States (Fig. 1). The Olympic Peninsula is bounded by the Puget Sound to the east, the Pacific Ocean to the west, the Strait of Juan de Fuca to the north, and the Chehalis River lowland to the south. Pleistocene valley glaciers flowed from the high peaks of the Olympic Mountains to the coastal lowlands and beyond the modern shoreline (Thackray, 2008). Thackray (2001) provides the most comprehensive summary of the major valley glacier advances on the western Olympic Peninsula. Named advances consist of the Lyman Rapids (MIS 4), Hoh Oxbow 1-3 (MIS 3–2), and Twin Creeks 1-2 (MIS 2) advances. The Twin Creeks 1 advance most closely corresponds in age to the global last glacial maximum (LGM) (26–19 ka; Clark et al., 2009). Landforms marking this ice-marginal position include terminal moraines in the Hoh and Queets River valleys and broad outwash deposits extending to coastal bluffs.

Today, the remnants of these glaciers and their meltwater feed the South Fork Hoh River (SF Hoh), which flows west out of the Olympic Mountains (Fig. 1). The SF Hoh (~30 km long, ~140 km^2 catchment area) joins the main Hoh River, which flows roughly west-southwest before entering the Pacific Ocean. The elevation of the SF Hoh ranges from ~125 to 2427 m, with Mount Olympus representing the highest point in the watershed. Cut banks of meander bends along the SF Hoh expose glacial sediment (Wyshnytzky, 2013). Diamicton, glacial outwash, and lacustrine sediments were deposited in association with four late Pleistocene ice positions, the oldest of which (Hoh Oxbow 3) extended beyond the SF Hoh into the mainstem Hoh River valley (>23 ka) (Thackray, 2001; Wyshnytzky, 2013). Three younger ice positions mapped as the South Fork 1-3 (SF 1-3) are preserved stratigraphically in cutbank exposures and geomorphically by moraines. Eleven OSL and ten radiocarbon samples (Table 1) were collected from nine exposures to provide age control for proglacial deposits and ice-marginal positions within the SF Hoh (Thackray, 2001; Wyshnytzky, 2013).