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The granite tors of Dartmoor, Southwest England: rapid and recent emergence revealed by Late Pleistocene cosmogenic apparent exposure ages

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A B S T R A C T

Dartmoor, in SW England, is a classic periglaciated granite upland adorned with a population of over 150 tors. The origin of the tors has been controversial, but their emergence by differentiation after stripping of regolith during Pleistocene cold phases is accepted. However, their actual age has been unknown, with possible scenarios ranging from preservation since the early Middle Pleistocene to relatively short-lived landforms in a maritime climate with high denudation rates. The latter is now supported by 32 cosmogenic surface exposure dates from 28 tors across the whole upland. The distribution of apparent ^{10}Be ages peaks strongly in the Middle Devensian (36–50 ka), which with corrections for weathering and limited ice shielding could be interpreted as Early Devensian. These ages are much younger than those found for three glacially unmodified Cairngorms tors, and somewhat younger even than glacially modified Cairngorms tors. The dates show little spatial variation. Although an ice cap has now been modelled in the heart of northern Dartmoor, tors here are of median age, suggesting that ice cover sufficient to shield tors from incoming radiation was of short duration. The few younger tor ages support the idea of continuing landform instability across the landscape, with weathering flakes redeveloping soon after inferred loss of top pillows by gelifraction or gravitational toppling. The few older tor ages have no systematic explanation, and may indicate inheritance from an earlier cycle of bedrock near-exposure. Since most tors are modest in height (typically 2–5 m), volumetrically insignificant, and often in advanced stages of disintegration, the general impression is that they are evanescent features, which emerge and quickly disappear during every Pleistocene climatic downturn. Tor populations may thus flicker across the landscape rather randomly over the Quaternary. The remarkably consistent age of the present tor population could be associated with a stripping event at the start of the Devensian, but fuller analysis must await closer controls on tor denudation rates in different climatic phases, and on ice cover extent and duration. These results only date extant tor surfaces, not the landscape, but as the best available erosion pins they have evident value in exploring theories of the evolution of Dartmoor during the Quaternary.

1. Introduction – Dartmoor as a tor-studded periglacial landscape

Dartmoor is the largest exposure of the Cornubian granite batholith, which dominates the landscape of SW England. It extends over 625 km^2 at elevations of 300–621 m as a subdued moorland with local 100–200 m-deep fluvial incision of its fringing scarps (Fig. 1). It lies well beyond the maximum limits of the British-Irish Ice Sheet (BIIS) (Fretwell et al., 2008; Clark et al., 2010; McCarroll et al., 2010; Rolfe et al., 2012). It has long been regarded as "probably the purest relict periglacial landscape in Britain" (Waters, 1960, p. 174): thus "during the Pleistocene the landscape was severely affected by periglacial processes" (Brunsden, 2007, p. 67), with extensive evidence including patterned ground, frost regolith, gelifracted outcrops and gelifluction deposits (notably 'clitter' block streams), and gentle convexo-concave slope profiles (see Campbell et al., 1998, and relevant review sections therein). Such evidence is widespread across Dartmoor, including at sites on

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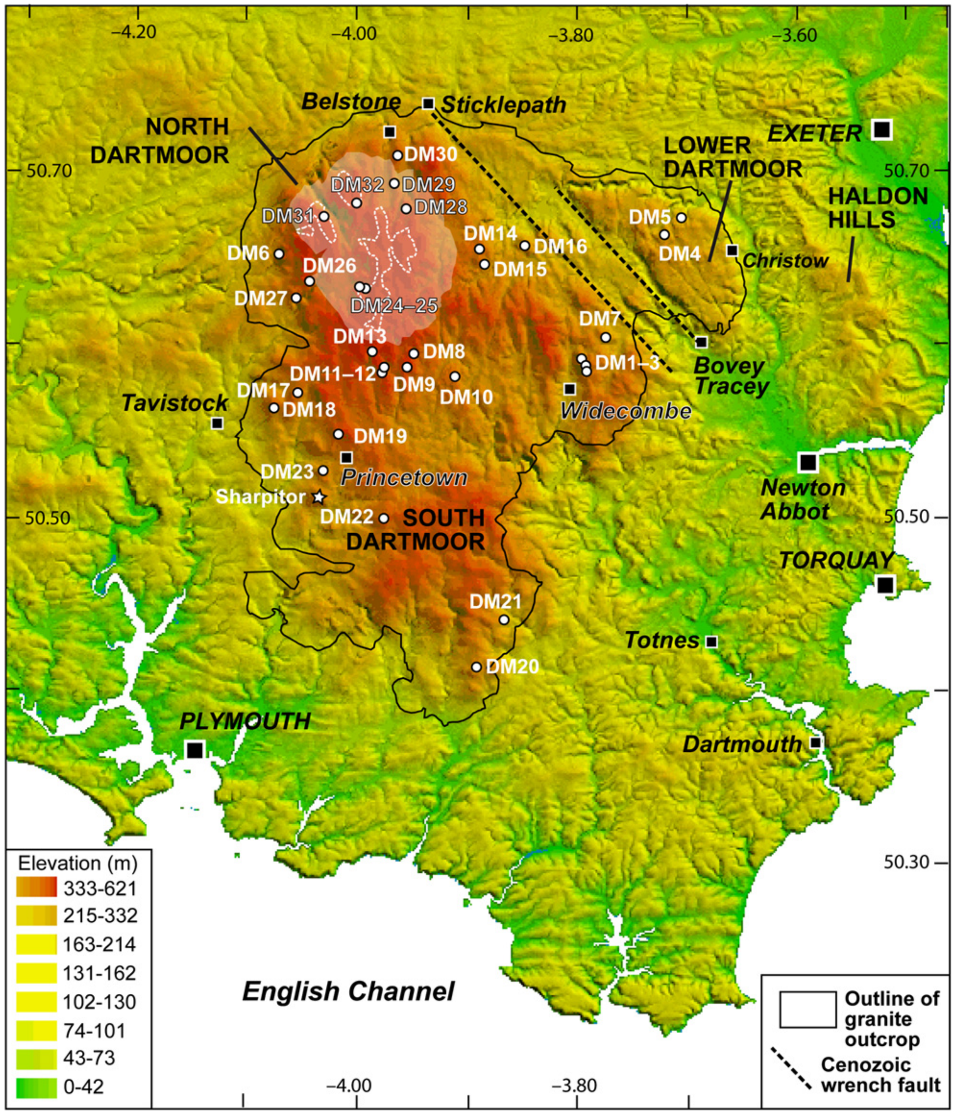

Fig. 1. Location of sampled tors with place names mentioned in the text. Dashed white lines in NW Dartmoor represent the 550 m elevation contour. Pleistocene ice cap nucleation began here and corresponds to the ELA postulated by Evans et al. (2012) in their numerical model. Translucent shaded area delineates maximum ice extent on Dartmoor according to Evans et al. (2012).

North Dartmoor where inferences of an ice cap by Evans et al. (2012) have been made (see Section 6.5): clearly, there must have been sufficient ice-free periods for periglacial processes to operate, including permafrost formation unshielded by even thin ice cover.

Dartmoor is particularly celebrated for the "finest set of periglacial tors in Britain" (Palmer and Neilson, 1962, p. 336), and is now considered a global type-location for tor theory (Ehlen, 2004). There are at least 150 tors, typically 2–5 m high, with a number barely emergent or atypically located on steep valley sides or on other lithologies, and only a few classic 10–20 m edifices, with Vixen Tor and Haytor exceptionally attaining ~35 m on one side. Tors may be monolithic, but usually comprise several stacks on a plinth (platform), sometimes separated by a central avenue, with the upper joint blocks often detached as 'pillows' (Fig. 2). Tors tend to cluster in groups and in certain areas of the upland, with other parts devoid of tors for no established reasons.

Although the origin of the tors has provoked much debate and speculation, the consensus for some time has been that both the 2-stage 'deep weathering corestones within saprolite' model of Linton (1955) and the 1-stage 'periglacial differentiation within shallow regolith' model of Palmer and Neilson (1962) have their merits, illustrating equifinality. Tors of both modes may thus co-exist on Dartmoor (French, 1976; Cullingford, 1982; Campbell et al., 1998). Ballantyne and Harris (1994, p. 181) favour the 1-stage scenario on Pennine gritstone edges but the 2-stage on Dartmoor granite, with emergence of resistant residuals from beneath pre-existing sandy grus. Hall and Sugden (2007) suggest they are two extremes of a continuum, with tors developing in a wide range of climatic environments.

Crucially, advocates of both models have always recognised periglacial stripping of the weathering layer as the means of exposing summit and spur tors. Following Gerrard (1974), 'summit tors' ornament low-gradient interfluve skylines; 'spur tors' occur at lower relative elevations, typically near the break of slope with a steeper valley side.

Under either model, tors emerge when the rate of regolith stripping exceeds the rate of bedrock denudation. They will persist while these rates diverge or remain similar, and are likely to disappear when regolith stripping slows to a lesser rate. In the pure 2-stage Linton model, the summit surfaces of any intact tor are