15 Land's End: Landscapes and Mining at the Tip of England

Jasper Knight and Stephan Harrison

Abstract

The region around Land's End, Cornwall, forms the southwesternmost tip of England and shows a range of distinctive upland and coastal landscapes that reflect the effects of physical and chemical weathering of granite over long geological time periods. Hydrothermal weathering of the Land's End granite resulted in the concentration of metal-rich ores in surrounding country rocks, and provided the conditions under which the tin mining industry developed during the seventeenth century. During the Pleistocene, the region was strongly affected by periglacial processes, and these helped shape the weathered granite summits (tors) found in upland areas. Unconsolidated weathered products have accumulated over bedrock surfaces, in particular in coastal lowlands. Stratigraphic evidence from key coastal sites provides a record of late Pleistocene environmental change, in which enhanced slope sediment supply by solifluction took place during more humid periods. In combination, late Pleistocene geomorphic processes and human exploitation of mineral deposits have shaped both the physical and human environments of the Land's End region, giving west Cornwall its distinctive character and identity.

Keywords

Archaeology • Cornwall • Heritage • Mining • Periglacial • Solifluction • West Penwith

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15.1 Introduction

The Land's End peninsula refers to the area located west of St Ives and Penzance in west Cornwall, the southwesternmost extremity of England (Fig. 15.1). The county of Cornwall is bounded by the Bristol Channel coast to the north, English Channel to the south, and Celtic Sea and open Atlantic to the west, and these provide a strong marine influence on landscape-scale geomorphology as well as on settlement patterns and cultural imprints of human activity in the landscape. Inland, the geology and landscapes of Land's End peninsula, more commonly known as West Penwith, are dominated by granite bedrock with weathered tor summits reaching a maximum elevation of 252 m asl at Watch Croft near the north coast of West Penwith. The landscape comprises a number of erosional surfaces between ~75 and 131 m asl and these probably range in age from late Cretaceous to Neogene (Coque-Delhuille 1991; Walsh et al. 1999). However, these surfaces have also been affected by differential uplift throughout the Cenozoic, meaning their elevations may reflect diachronous phases of erosion (Westaway 2010). Morphologically these erosion surfaces are generally laterally extensive and parallel to the present coast, can be several kilometres in width, and are backed by a steep fossil cliffline (Fig. 15.2). Into these flat surfaces are incised narrow but steep-sided river valleys (Everard 1977).

The geology of the West Penwith region is dominated by the Land's End biotite granite pluton. This pluton was emplaced around 268–274 Ma during the Variscan orogeny (Manning 1998), and was associated with hydrothermal alteration of the metamorphosed country rocks and enrichment within these rocks of metal ores, in particular tin but also copper, lead, zinc, iron, silver and arsenic (Jackson et al. 1989; Müller et al. 2006). The orientation of fractures within the country rocks has focused the location of ore mineralization and influenced, in turn, the location of tin mine development during the seventeenth–nineteenth centuries,

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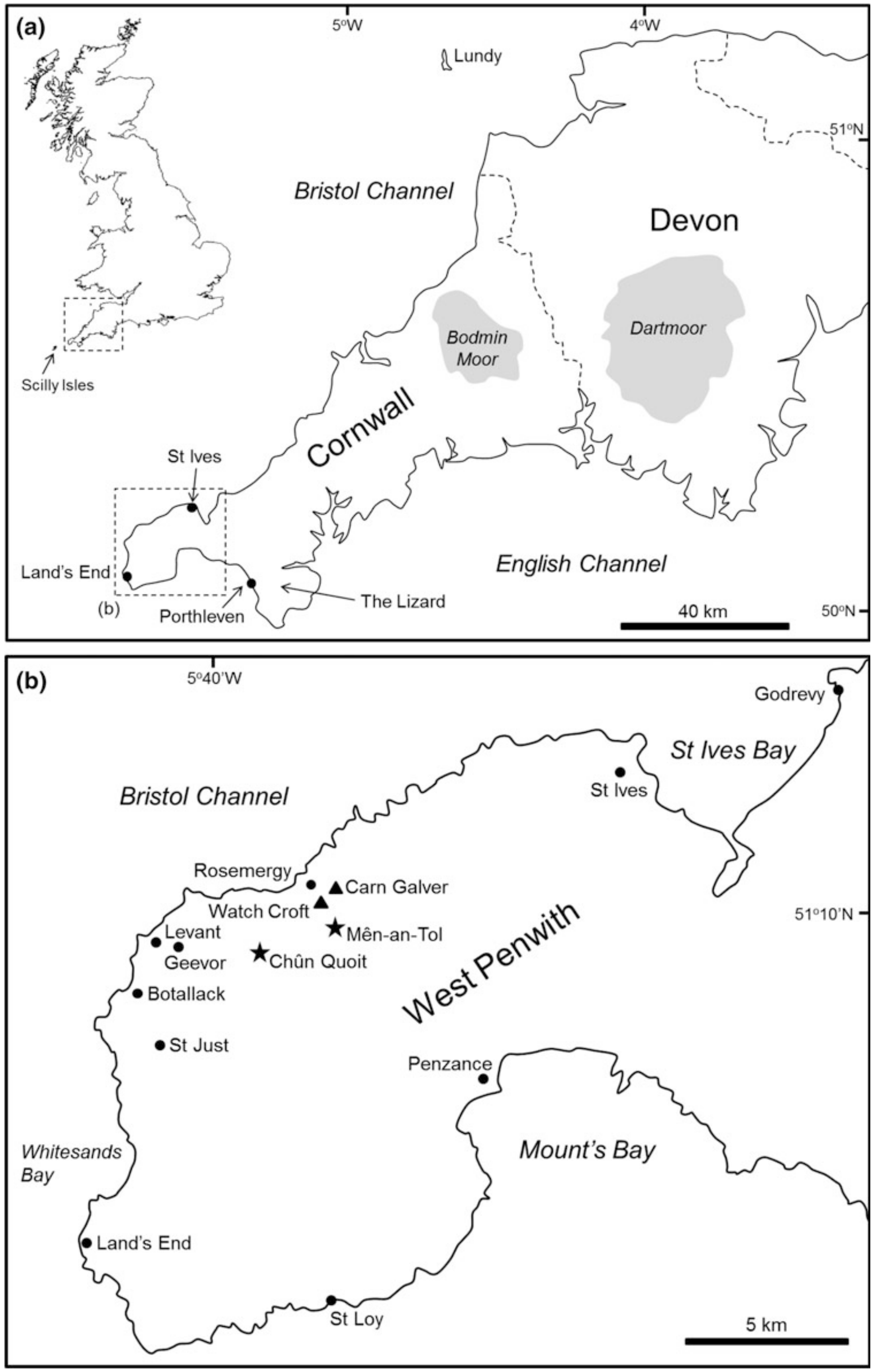

Fig. 15.1 Location of the West Penwith study area in Cornwall, southwest England, and place names mentioned in the text

and miners' villages and estates (Cocks 2010). A description of key geological sites in this area is given by Hall (2005).

In combination, underlying geology and Quaternary history have given rise to the distinctive physical landscape of West Penwith. The Quaternary history of the region is discussed by Scourse and Furze (1999). The current consensus is that Cornwall was not glaciated during the Quaternary but was instead affected by periglacial processes dominated by frost shattering of bedrock and mass movement of weathered debris downslope (Ealey 2012). This

Fig. 15.2 Some landscapes of West Penwith. **a**–**c** Upland, tor and mining landscapes on the north coast of the region, **d** bedrock-dominated coastal landscape on the south coast of the region, **e**, **f** stacks, arches and caves on the granite coast at Land's End (photos a–d: Jasper Knight, **e**, **f**: Piotr Migoń, reproduced with permission)

resulted in brecciation of exposed bedrock and formation of distinctive tors, in particular on the higher elevation areas of Dartmoor and Bodmin Moor (Linton 1955). Although the formation of tors has also been linked to deep Cenozoic weathering (Gerrard 1989), the morphology of tor summits in Cornwall and the presence of large angular debris (clitter) on surrounding hillslopes suggests that their development occurred mainly by periglacial processes over multiple cold phases (Gunnell et al. 2013) and was affected by pre-existing bedrock structures (Gerrard 1978). Deposition of weathered material contributed to the formation of boulder lobes and blockfields with the coarsest debris, and transport of smaller fractured and weathered products downslope by solifluction processes, giving rise to rectilinear sediment aprons and contributing to sediment fills within valleys and on coastal lowlands (Scourse 1987). There is limited geochronometric control on these sediment fills, but radiocarbon dating suggests that solifluction took place episodically in the period 35–12 ^{14}C kyr BP (Scourse 1996).

In addition, there are close relationships between the physical landscape and development of human activity in West Penwith, including ancient field boundaries, archaeological features, exploitation of mineral resources through mining, and non-material ways in which people relate to the landscape through myth/legend, art, literature and regional identity (Knight and Harrison 2013). As a result, the West Penwith region offers an excellent example of the way in which a multidimensional landscape produces a palimpsest with varied physical and human landscape elements that reflect its evolution over the late Pleistocene and Holocene. In detail, this chapter describes the development and characteristics of (1) upland and (2) coastal landscapes in West Penwith, and then (3) the distinctive landscapes associated with mining activities.

15.2 Upland Landscapes

Over the central interior of West Penwith, upland moorland areas have developed with isolated bedrock summits over 220 m asl, many of which exhibit the development of tors (Fig. 15.2a–c). Intervening valleys are broad and subdued in relief and characterized by relatively thin, acid soils (Williams et al. 1986). These soils reflect past hydrothermal weathering of the underlying granite bedrock, leading to a loose, friable material (growan) that is susceptible to slope movement. In turn, these soils support nutrient-poor grassland and heath (Brookes 1995) and, in combination with the high winds common in the region, produce an absence of trees across the higher parts of the landscape.

Tors are the most common and distinctive upland landform seen in the region. The term tor refers to an upstanding bedrock protrusion displaying enhanced weathering along structural weaknesses that results in rounded profiles and stacks of partly detached bedrock up to 10 m high (Evans et al. 2017). An absence of weathered products around the tors is attributed to slope processes that distribute this debris downslope (Linton 1955; Ealey 2012). In Cornwall, most research on tors has focused on Bodmin Moor (Linton 1955; Gerrard 1978) but they also exist throughout the West Penwith region and elsewhere in west Cornwall, including the Lizard peninsula (Ealey 2012) and the adjacent Isles of Scilly (Scourse 1987). The degree to which tor surfaces have been weathered has been used as a proxy for their relative age (Hall and Phillips 2006), and the presence of tors on Lundy Island (Bristol Channel) has been used as evidence that it was not glaciated during the late Devensian (Carr et al. 2017). There is considerable debate about this, however (see also Rolfe et al. 2012). On the Isles of Scilly, contrasting levels of tor development types have been used to distinguish between those areas on the northern fringes of the archipelago that were glaciated during the late Devensian, and those areas to the south that escaped Devensian glaciation (Scourse 1987).

Despite decades of research the Pleistocene glacial history of the Land's End region is not fully known. It is generally thought that mainland Cornwall was not glaciated during the late Devensian and thus its upland tors can be considered to reflect a long late Pleistocene period of subaerial weathering and slow exhumation by slope processes (Linton 1955; Harrison and Keen 2004). Despite this, however, a number of intriguing issues concerning past glaciations are yet to be resolved. For instance, there is still uncertainty about the extent to which the Isles of Scilly were glaciated during the Pleistocene. While there is good evidence that late Devensian ice impinged upon the northern edge of the Isles of Scilly group (e.g. Scourse 1991), recent work suggests that the islands were completely overrun by a glacial advance at least once during the Pleistocene (John 2018). Such an event may also have impacted on the Land's End region on the mainland.

Recent research also suggests that small glaciers might have existed in favourable topoclimatic locations in the region. A possible niche glacier of Last Glacial Maximum age has been described at Rosemergy on the north coast of West Penwith, bounded by summit tors at Watch Croft and Carn Galver (Harrison et al. 2015). Here, a bedrock hollow 650 m long and 430 m wide faces to the northwest and has asymmetric lateral margins. Carn Galver is the tor summit to the northeast of the hollow and shows a blocky granite bedrock exposure reflecting fracture orientation, and is a 'vertical tor' according to the typology of Scourse (1987) (Fig. 15.3a, b). Downslope, the largest detached boulders <5 m diameter form discontinuous scatters (Fig. 15.3c), with smaller boulders (<1.6 m diameter) organized into openwork lobes. Downslope of the rock lip that defines the frontal edge of the hollow, <7 m thickness of slope deposits are present. These deposits comprise stratified diamicton, interpreted as glacially-influenced (Harrison et al. 2015). Within these deposits, striated and glacially-abraded clasts are present. These were either deposited by this small glacier or possibly may have been deposited by Irish Sea ice from a position just offshore in the Bristol Channel. Adjacent to Rosemergy, steep bedrock cliffs over 40 m in height have been strongly affected by periglacial frost shattering (Fig. 15.3d).

Postglacial records of landscape change from Land's End are rare. However, analysis of pollen records shows that heathland has dominated upland summit areas of Cornwall since the lateglacial period, with variations between moss/lichen and grass heaths determined mainly by moisture availability (Caseldine 1980). In detail, the palynological record from Bodmin Moor indicates disturbance of upland ecosystems that took place during the Neolithic (from around 4000 years BP) and accelerated during the Bronze Age when deforestation helped clear the land and field systems became established (Gearey et al. 2000). Further, the tor summits are often associated with Bronze Age archaeological features including standing stones, stone circles and stone-walled settlement enclosures (Tilley 1996; Hamilton et al. 2008). The likely reasons for this association include clear visibility of bedrock summits, and availability of large tabular bedrock-derived clasts as construction materials (Tilley 1996; Tilley et al. 2000; Eve and Crema 2014). In West Penwith, many archaeological features are widely distributed in upland landscapes. For example, Chûn Quoit is a Neolithic portal dolmen located in the middle of a round barrow and has a capstone 3.6 m in diameter

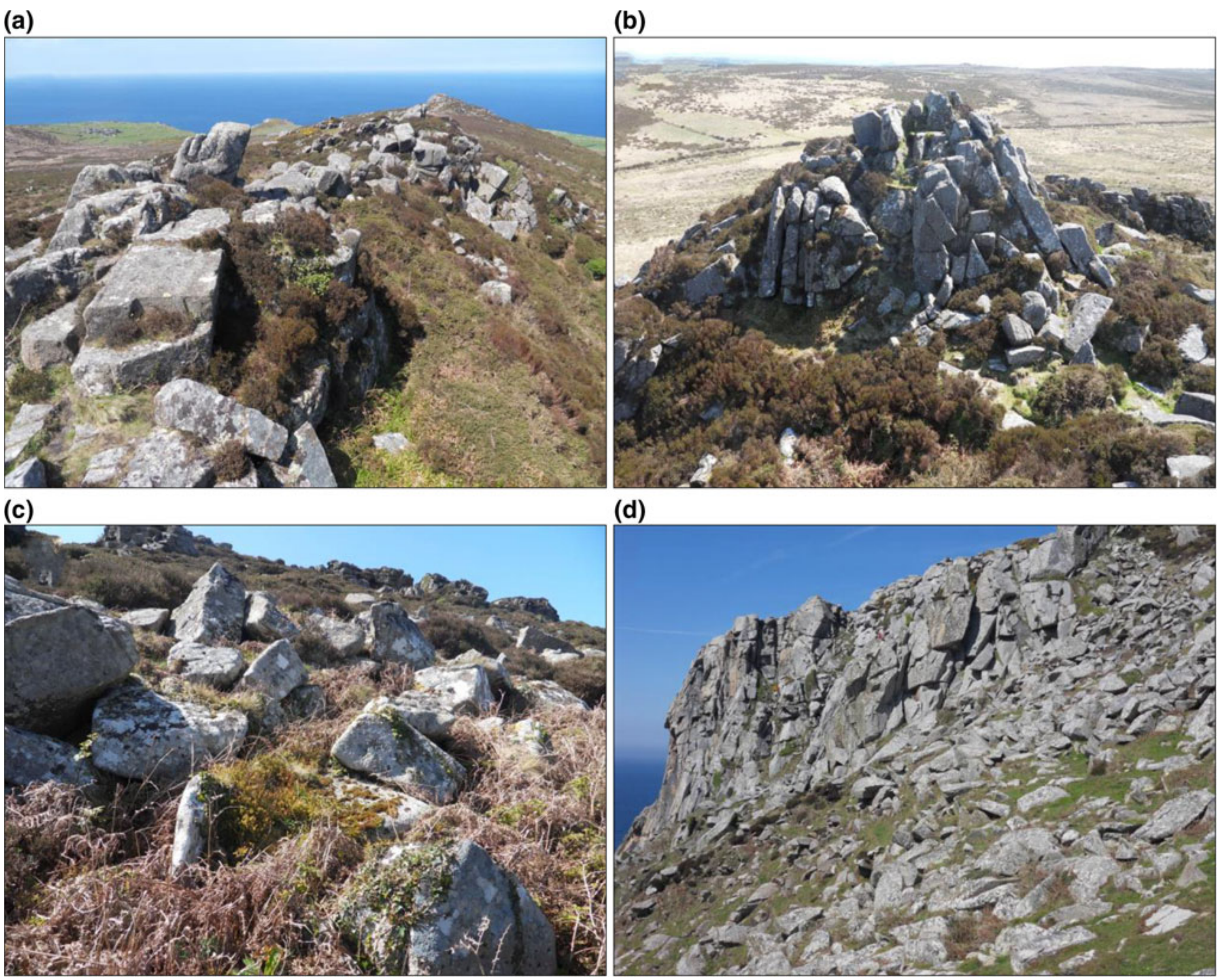

Fig. 15.3 The geomorphology of upland landscapes in West Penwith. **a–c** Tor geomorphology at Carn Galver, showing intact (**a**, **b**) and detached (**c**) bedrock blocks; **d** strongly frost-shattered cliff and debris at the adjacent seacliff, immediately outside of the limits of the proposed niche glacier (photos Jasper Knight)

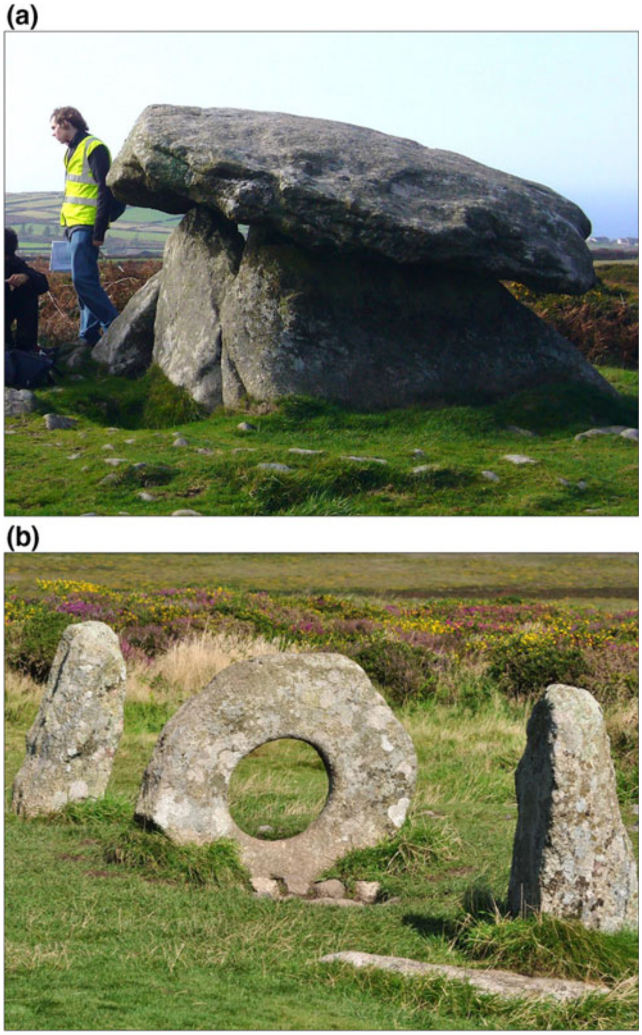

Fig. 15.4 Archaeological features of upland landscapes in West Penwith. **a** Chûn Quoit (photo Jasper Knight); **b** Mên-an-Tol (photo Wikimedia Commons)

(Fig. 15.4a). It is located adjacent to Chûn Castle, a circular Iron Age hillfort 85 m in diameter with two sets of ramparts faced by granite blocks. This was a significant defensive site with clear views over the surrounding landscape, and pottery and smelting evidence suggests it was occupied for at least 900 years. The Mên-an-Tol holed stone (Fig. 15.4b) is likely a Bronze Age structure, but has been repositioned several times, and is associated with superstitions of healing powers (Hunt 1908).

15.3 Coastal Landscapes

Research on the granite coastline of west Cornwall has a long history (e.g. Arber 1940, 1949). The coastline of west Cornwall most commonly comprises steep cliffs with isolated sea stacks, arches and caves (Fig. 15.2d–f). Many caves, however, are not natural features but are in fact mine adits. Whitesands Bay just north of Land's End is a 2 km long sandy beach, but mostly only small, pebbly pocket beaches are present, commonly situated at the mouths of narrow but steep-sided valleys. Several such valleys have been mapped in west Cornwall and largely have their origins during past glaciations when sea levels were lower than present, leading to offshore extension of river systems in Mounts Bay and St Ives Bay. Slope processes, likely over several glacial–interglacial cycles, have contributed to infilling of accommodation space within these narrow feeder valleys (Camm 1999), and sediment accumulation on coastal fringes of Cornwall by the formation of solifluction aprons that overlie bedrock surfaces (James 1995). The stratigraphy of these deposits can be used to reconstruct Quaternary processes and climate in the West Penwith region (Scourse 1996). A critical stratigraphic marker along this coastline is the presence of raised beaches and rock platforms, and three clusters of late Pleistocene-age platforms have been recognized at 4.4 m asl, 12–13 m asl and 20 m asl, with the lowest one being the most extensive (James 1995). The precise ages of these platforms and the sediments immediately overlying them are uncertain, mainly through lack of dating evidence but also because platforms may have been reoccupied at different times and thus are composite features. For example, different interpretations of amino acid ratios from marine shells within raised beach gravels at Godrevy, described below, have significant implications for the age and duration of overlying sediments. Several key sites on the north and south coasts provide good evidence for late Quaternary events in west Cornwall, included within the Penwith Formation, which extends from marine isotope stages 7–2 inclusively ($\sim$200–11 ka BP; Campbell et al. 1999).

On the east side of St Ives Bay at Godrevy, cliff exposures up to 8 m high provide a record of up to 300,000 years of Quaternary climate and environmental change, and have been discussed in several studies (Whitley 1906; Rogers 1910; James 1995, 2008; Scourse 1996). The cliff stratigraphy (Fig. 15.5) comprises several different elements. An eroded and planar bedrock surface of the Devonian-age Mylor Slate Formation is present at the base of the exposure and rises from 4 to 10 m asl in the cliff profile. The bedrock is overlain discontinuously by 1.5 m of raised beach gravels with well-rounded, openwork cobbles (unit i). Several layers of beach gravels are present, interbedded with beach sands. The gravel and sand beds vary in thickness laterally. Basal layers of beach gravels have a manganese cement whereas overlying layers are not cemented. This unit is overlain by unit (ii) comprising 2.0–3.5 m thickness of fine sand, termed 'raised beach sands' by Scourse (1996). However, in detail this unit comprises poorly sorted fine to medium laminated sands, and undulating mud drapes are present.

The uppermost part of the exposure is unit (iii) and contains <5 m of massive diamicton comprising a solifluction deposit with a high proportion of equant pegmatite cobbles. The pegmatite is likely derived from the outer margins of the granite pluton, and mixed with angular local slates that have been affected by frost weathering. The diamicton grades laterally to a local slate-dominated breccia is containing cryoturbation features indicative of frost heave (Fig. 15.5d, e). This diamicton is overlain by <1 m of sandy soil (unit iv). Age control on the stratigraphy at Godrevy is based on amino acid racemization of marine *Patella* shells contained within the basal conglomerate, which suggest formation during oxygen isotope substage 5e (Ipswichian; ~122–128 ka), or stage 9 (Hoxnian; ~186–245 ka) (Bowen et al. 1985). In addition, Scourse (1996) correlates the uppermost sandy soil with the Lizard Loess Member (now termed the Lizard Formation) which has been dated by the luminescence method to 15.9 ka, on a sample from the Lizard, but 18.6 ka from both of two samples from the Isles of Scilly (Wintle 1981).

At St Loy on the south coast of West Penwith, sediments within a solifluction apron are exposed in coastal cliffs (Scourse 1996; Knight 2005) (Fig. 15.6). Bedrock is the Land's End granite. The stratigraphy comprises an eroded granite bedrock surface that is intermittently exposed at the base of the section, overlain by unit (i) which is 1 m thick concentrations of granite cobbles on the surface and set within a massive, amalgamated diamicton with sandy interbeds. This facies is overlain by unit (ii) which is a coarse diamicton containing large, well-rounded granite clasts up to 1 m in diameter with coarse sand and granule matrix. This unit is highly variable in thickness and overlain by stratified granule to fine gravel beds 2–3 m thick in total (unit iii). This unit contains deformed wisps of organic-rich granules within a zone 40–50 cm thick (Fig. 15.6a). These organic-rich layers are termed the St Loy Bed (Campbell et al. 1999), and pollen analysis show taxa consistent with an open temperate or Arctic tundra grassland (Scourse 1996). A radiocarbon date of 29,120 +1690/−1400 ^{14}C yr BP (Scourse, 1996) suggests deposition during oxygen isotope stage 3, and thus prior to the last glacial maximum. This unit is transitional to unit (iv), a diamictic breccia 2–4 m thick that varies from massive to planar stratified, and contains subrounded local granite pebbles, and occasionally much bigger tabular granite slabs indicative of episodic rockfall (Fig. 15.6b, c).

An interesting phenomenon along the west Cornwall coast is a large boulder known as the Giant's Rock, located within the present intertidal zone to the west of Porthleven (Fig. 15.7). This is a 50-ton garnetiferous microcline gneiss block (Flett and Hill 1912). Whilst its location suggests a drift ice origin, the size of this erratic seems to rule out emplacement by floe ice (van Vliet-Lanoë et al. 2000). An alternative explanation is deposition by icebergs from a calving margin to the west in the Western Approaches, possibly in the vicinity of the Isles of Scilly, but this may have been unlikely given significant sea-level depression during glacial periods. The most likely hypothesis, therefore, is that deposition of the Giant's Rock erratic occurred under conditions of glacioisostatic depression, although the full details of this hypothesis remain to be determined. The origin of the Giant's Rock is unclear; its petrology does not fit with any known Scottish metamorphic terrain and it has been speculated (Bowen 1994) that it could be from Greenland and brought into the western English Channel by icebergs from a collapsing Laurentide ice sheet. A similar origin might also have allowed the passage of Icelandic basalt erratics to reach Brittany in northwest France (van Vliet-Lanoë et al. 2000; Harrison and Keen 2004).

15.4 Climate and Geologic Controls on the Geomorphology and Landscape in West Cornwall

Granite dominates the landscapes of west Cornwall, but physical (mainly frost shattering and pressure release) and chemical (hydrothermal alteration and hydrolysis) weathering processes have modified the landscape over long time periods (Butler 1953), have substantially shaped surface bedrock exposures, and provided suitable loose sediment supply to build aprons and fans of slope sediments that now —at least partly—infill coastal lowlands and river valleys. Thus, aggradational phases of slope sediments correspond to periods of climatic deterioration and land surface instability. This is evidenced by the limited dating control from sites such as Godrevy and St Loy where warmer interglacial sediments are overlain by cooler glacial-age sediments. In more recent times, dated periods of aggradation within river valleys (Thorndycraft et al. 2004) and geochemical enrichment within river and estuary sediments (Pirrie et al. 2003) match archaeological and palynological evidence for landscape disturbance through deforestation and mining in the last 2000 years. Infilling of river valleys and coastal lowlands by such sediments (Camm 1999) reduces contemporary accommodation space and limits capacity for contemporary morphological adjustment. In turn, this means that Cornwall's palaeo-landscapes have high preservation potential, resulting in a landscape palimpsest that reflects its long history of development (Knight and Harrison 2013).

Fig. 15.5 Quaternary coastal stratigraphy at Godrevy, north Cornwall coast. **a** Composite stratigraphy of raised beach elements (unit i) overlain by sand (unit ii) and periglacial solifluction deposits (unit iii); **b** planar bedrock surface overlain by beach gravels (unit i). Surveying staff is 2 m high; **c** laminated sands within unit ii; **d**, **e** cryoturbated solifluction deposits (unit iii) and the deformed basal contact with underlying sands (unit ii). Trowel is 15 cm long (photos Jasper Knight)

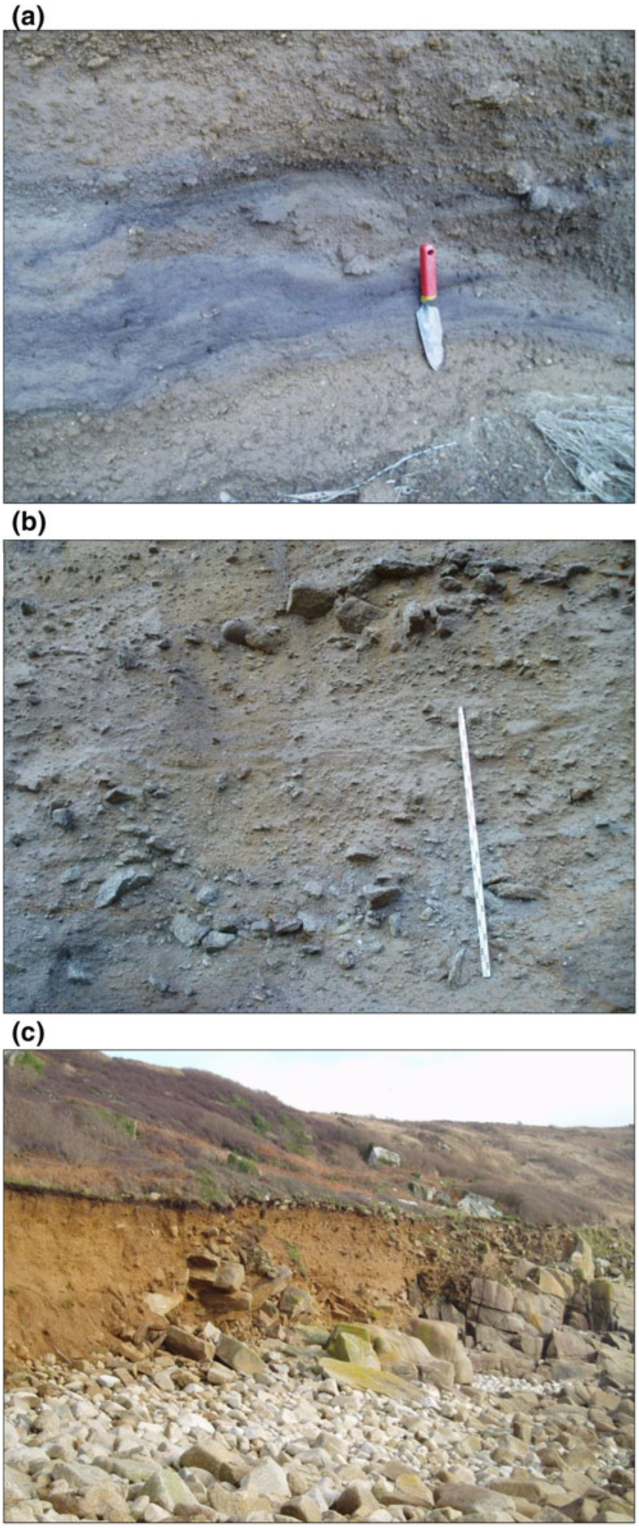

Fig. 15.6 Sediments affected by solifluction processes at St Loy, south Cornwall coast. **a** Organic-rich layers (unit iii); **b** laminated to massive diamicton formed by solifluction; **c** rockfall blocks embedded within the upper solifluction diamicton (unit iv) (photos Jasper Knight)

Fig. 15.7 The Giant’s Rock erratic boulder, Porthleven (photo Pat Sargeant, reproduced with permission)

15.5 Anthropogenic Imprints: Mining Landscapes of West Penwith

A wide variety of metalliferous minerals have been mined in west Cornwall over a long period. The most common ore extracted from the West Penwith region has been tin from the mineral cassiterite (SnO_2), with copper and lead deposits becoming more prevalent farther east (Meharg et al. 2012). Rapid industrialization of the mining industry, especially during the nineteenth century, made west Cornwall a world-leading centre of innovation and economic power. Underground mining not only shaped the land surface through deposition of slag and gangue, but metal extraction from rock ores produced chemical contaminants that can leach into groundwater and river systems (Pirrie et al. 2003). In addition, expansion of the mining industry in west Cornwall during the eighteenth and nineteenth centuries also led to the development of new settlement patterns including miners’ villages and owners’ estates; new educational institutions; and the spread of religious nonconformism, in particular, shown by the building of large Methodist halls. This led to new spatial expressions of human activity in the landscape, reflecting not only an anthropogenic imprint but also how different modes of human activity were mediated by the physical environment, such as its geology (Knight and Harrison 2013).

The region around Levant, Botallack and Geevor in West Penwith was an important area of tin production from at least the seventeenth century onwards, and by the nineteenth century the Levant mine workings extended over 1.5 km from the pithead and up to 600 m depth below the sea floor.

The last tin mine (Geevor) stopped production in 1986, and the region now falls within the Cornwall and West Devon Mining Landscape UNESCO World Heritage Site (inscribed 2006) (Cocks 2010). This includes the nineteenth century engine house at Botallack (Fig. 15.8a) and more recent workings at Geevor (Fig. 15.8b). The mining heritage of the region in combination with extensive preserved archaeological evidence gives West Penwith a distinctive character, and several studies have examined the relationship of the physical landscape to the generation of regional identity, myth, legend and art (Tilley and Bennett 2001; Laviolette 2003; Causey 2008; Shepherd 2013).

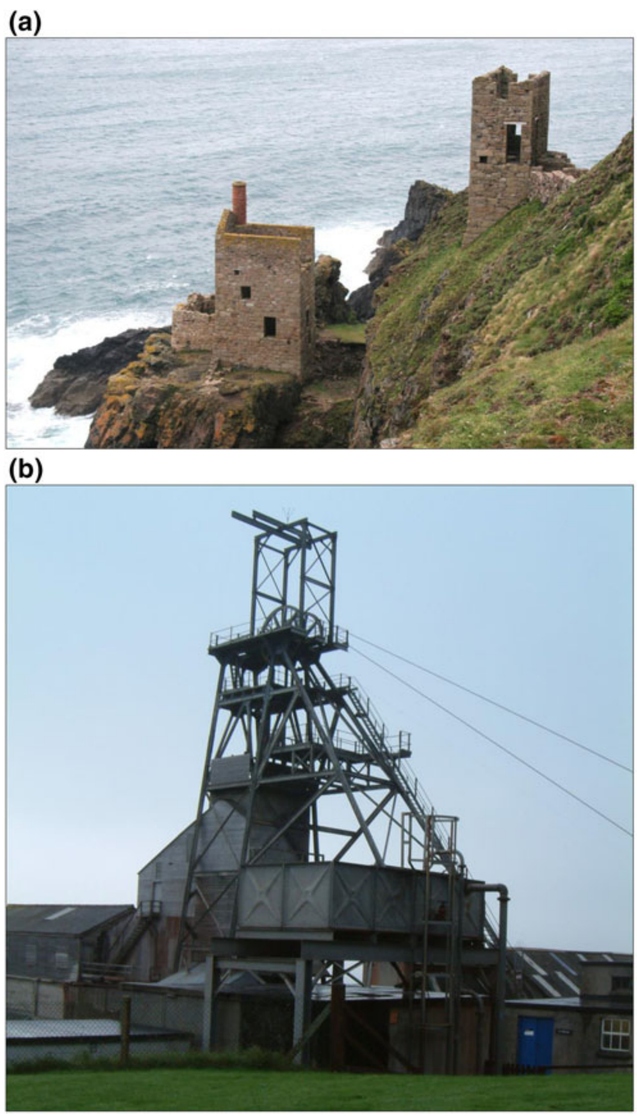

Fig. 15.8 **a** The engine house at Botallack mine (photo Wikimedia Commons); **b** engine head at Geevor mine (photo Jasper Knight)

15.6 Conclusions

The Land's End region of West Penwith, west Cornwall, has a distinctive identity related to both its physical and human landscapes, and the common themes of geological and climatic/geomorphic processes that have influenced their development. The presence of granite and its associated ore mineralization allowed for the development of the mining industry which not only provided the basis for economic development in the seventeenth–nineteenth centuries, but also influenced all aspects of human activity in the landscape. Mining heritage is a strong element of the Cornish identity and economy even today.

Periglaciation was the dominant environmental regime during late Pleistocene cold periods, and resulted in physical weathering on granite upland areas, forming tors and associated boulder litter (clitter). In places, this large debris has been modified into boulder lobes. Periglacially-enhanced slope sediment transport (solifluction) was the main mechanism by which smaller weathered debris was moved into surrounding valleys and coastal lowlands, and the stratigraphic and dating record from sites including Godrevy and St Loy can help constrain the timing and nature of landscape response during late Pleistocene climate phases.

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