Geology, soils and landscape on the Dartmoor Granite around Moretonhampstead and Chagford

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The newly published soil map of northeastern Dartmoor (National Grid 10 km squares SX 68 & 78) covers the granite outcrop from the peat covered high moorland to its eastern limits against the metamorphic aureole, straddling the Sticklepath Fault Zone. The northwest to southeast alignment of that Zone is paralleled by fractures across much of the surveyed area. These, with secondary northeast to southwest lineations, give much of terrain a distinctive trellis-like grain, particularly apparent in the patterns of the groundwater affected soils. However, there are areas where this configuration breaks down, in places replaced by closer, dendritic patterns. In these areas decomposed, *in situ* granite appears commonplace, albeit cheek by jowle with sound rock. Over some of this ground partially underlain by kaolinised granite, there are subsoils with softened, but undisturbed, feldspar megacrysts, usually accompanied by gleying's clear indications of restricted permeability. In these areas physiographic contrasts with the fracture controlled land mirror those of the soil patterns. Here valleys and ridges are smaller and more sinuous, as are steep slopes. Many spur ends have reversed gradients, while dome-like low hills make up some of the area. Critically timed aerial photography, along with LiDAR, reveal further aspects of the distinctive landscape around this section of the Sticklepath Fault Zone.

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Introduction

Over recent years a soil survey was carried out of Ordnance Survey National Grid squares SX 68 and 78, around Moretonhampstead and Chagford. This was chosen to represent the Dartmoor granite along a 20 km long and 10 km wide traverse, from the highest moorland at about 600 m O.D., to the lowest part of the outcrop at below 100 m O.D. It completes the former Soil Survey of England and Wales' programme of sample surveys of Ordnance Survey 1:25,000 Second Series maps in each main natural region.

The main variation in the granite reported (Hawkes, 1982) across the two 10 km squares is a broad westerly decline in the proportion of feldspar megacrysts. A few very small outcrops of finer grained granite are shown on BGS maps. The area is crossed by the Sticklepath Fault running northwest to southeast along the Bovey Valley on the Dartmoor Forest geological map (BGS 1995) and north northwest to south southeast just west of Chagford on sheet 324 (Okehampton)(BGS 1969). Hawkes (1982) indicates that it comprises a zone of complex en-echelon faulting rather than a single fault. Displacement of the granite's contact with the Carboniferous between Hunt's Tor (SX722897) near Castle Drogo and Uppacott (SX734885) suggests the fault zone's easterly expression ends along the scarp running southeast from there passing to the east of Moreton and down the east side of the Wray valley towards Bovey Tracey. Overall lateral displacement is around 1.5 and 2 km. Away from the Sticklepath Fault Zone it is often paralleled by a physiographic grain affecting ridges and valleys, which Waters (1957) interpreted as marking joint and fracture lineations. He identified a secondary alignment from east northeast to west southwest. Waters inferred ridges as occurring at the intersection of wider separations of the joints and fractures on the two lineations, his positive elements, while closer joint spacings were taken to coincide with basins, negative elements.

The nature of any parent material, either as *in situ* rock or as its modification into superficial deposits, such as solifluction head, has a strong influence on soil properties. At the onset of this soil survey it was anticipated that the effects of climate's changes with altitude, culminating in the formation of peat on the higher land, would be the principal influences on pedological development passing from east to west across the survey area. Although that was indeed so, decomposed granite proved to be extensive (particularly in the Sticklepath Fault Zone) in several places having demonstrable effects on the soils and terrain. This paper will explore how the soils' form and distribution, along with the terrain, are influenced by altered granite and how their mapping helps demonstrate its occurrence.

Decomposition and kaolinisation of the Dartmoor Granite is known elsewhere, most obviously being the china clay of Lee Moor. Horsham (2015) quotes Sandemane (1901) as describing over 50 m of altered granite in places in the excavations for Burrator Reservoir. There are occasional references to it on unpublished local field slips in the BGS archives. Linton (1955) recognised it while postulating on tor evolution from the Two Bridges exposure, while Clayden (1971, p.111) described *"in situ weathered granite with distinct soft feldspar crystals up to 5 cm long"* extending down from 58 cm depth in a soil profile between Bovey Tracey and Lustleigh. Over parts of the district covered by this soil survey, exposures in road cuttings, excavations and in small, often casual quarries reveal soft, *in situ* rock, with megacrysts soft enough to cut with the finger nail, as in Figure 1. In places this rotten granite is alongside sound, hard material, only separated by a few cm. The potential of the decayed rockis recognised and commonly exploited with an excavator and tractor and trailer for roadstone on farm or forest roads, even for drives and paths. While this paper concentrates on observations from the lower, enclosed land of the in-bye, much of it in the Sticklepath Fault Zone, kaolinised granite is exposed in various places on the moorland, as at Knack Mine ford, (SX615885), in tin workings at SX616817 south of Broad Marsh and near the confluence of the Lade Hill streamand the East Dart at SX637814.

Kaolinisation of the granite's feldspars is likely to have taken place as the emplacing magma cooled, with both hydrothermal action and pneumatolysis involved. In view of the observation of Tierney *et al*. (2015) that faulting and fracturing facilitated alteration of the St Austell granite, it is worth referring back to the complexity of faulting in the Sticklepath Fault zone. Subaerial deep weathering under tropical or sub-tropical climates can also bring about kaolinisation of the granite. That such conditions prevailed widely over the southwest region, after the retreat of the Cretaceous sea, until the climatic decline heralding the Pleistocene, is indicated by Oligocene kaolinitic deposits at Petrockstowe, 25 km north-west of Chagford, where the kaolinite is from a non-granitic source.

Soils

Before considering the effects of alteration of the granite on soils, it is useful to outline 'normal' soil forming processes over the rock. Comminution of the granite into a porous, gritty, usually sandy head has already taken place near to the surface, thanks to weathering in several forms, although in some sites, particularly with wetter soils, pockets and lenses of more clayey head are encountered. Given this preliminary weathering, soil development is a response to various influences. Among these hydrology is a major consideration, both on the moorland and on the enclosed lowlands of the in-bye. Classed by Palmer *et al*. (1995) as a "minor aquifer (variably permeable)", the granite itself is not effectively permeable, yet its numerous joints, fissures and fractures readily conduct water.

Distribution of soils (Figure 2) in the district (Harrod 2015) clearly demonstrates the rock's aquiferous nature, with groundwater affectedsoils (shown as the Laployd and Sulham/Eversley map units, coloured blue) occupying the lower slopes of valleys. The presence of organic-rich, in places peaty, surface horizons on these soils signifies waterlogging which endures through most of the year. Soil patterns also illustrate the variable permeability of the rock. In places they indicate that the watertable is uniform over some distance, as over the 3.5 km between Watching Place (SX713842) and Heatree Cross (SX729810). Elsewhere, as near Uppacott Cottages (SX733883), it appears confined and discontinuous, sometimes away from well-formed valleys, reflecting variations in fissuring, fracturing etc. and probably the development of less permeable kaolinised bodies. The land around Mardon Down (SX772879) demonstrates the irregularities of water movement in the granite. Most of the discharge of groundwater from beneath Mardon is on its western and northern sides, with extensive Laployd gley soils and several patches of peat. On the Down's eastern side wet soils are confined to the narrow valley floor northwest of Doccombe (SX776868).

Soil forming processes, active around Chagford and Moreton, are:

Figure 1. *Decomposed,* in-situ *granite.The feldspars have been converted to kaolinite, softening the rock so that the knife could be stuck into it. About 3 cm above the blade, the slot in the white psuedomorph of a megacryst was cut with a finger nail.*

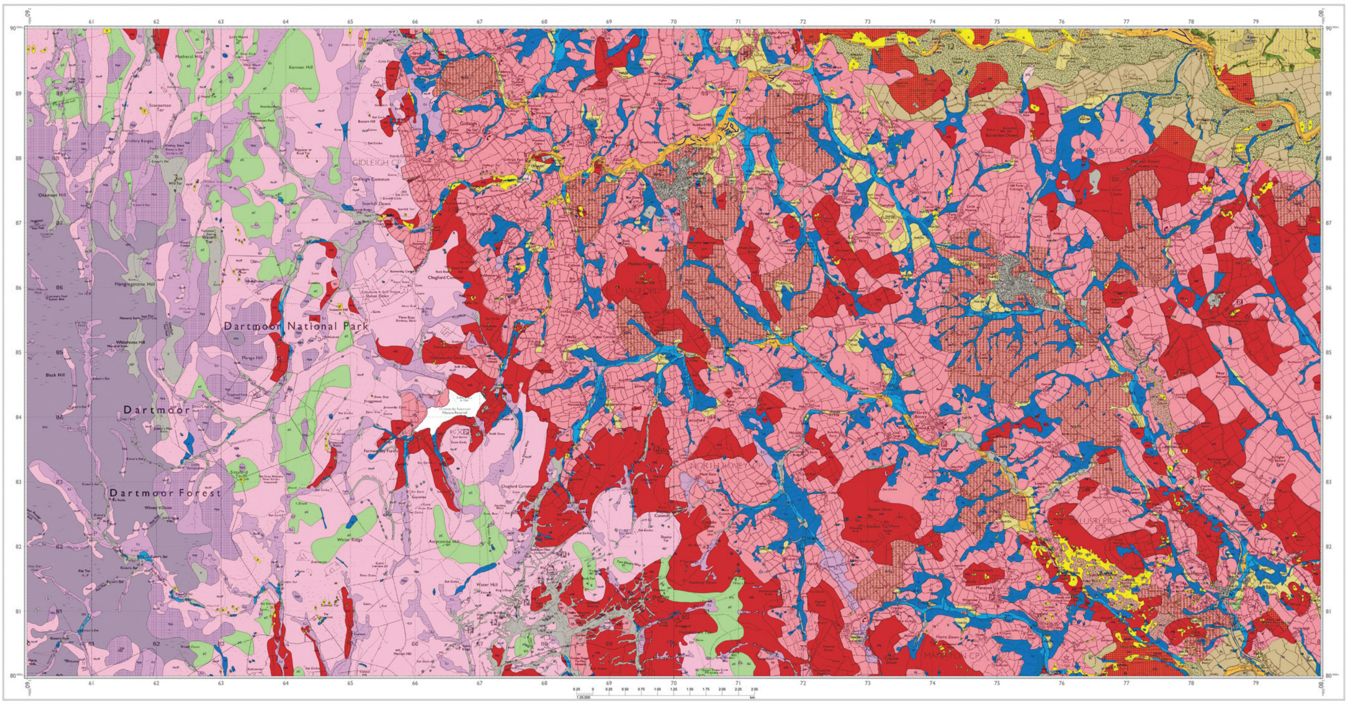

Figure 2. *Soil map of SX 68 / 78; © T.R. Harrod, originally published at 1:25,000 scale. The base map is © Ordnance Survey, licence 100024842. In the eastern two thirds pinks and red represent freely draining Moretonhampstead and Moor Gate soils, blue those affected by high groundwater, principally in the Laployd soil map unit. The reddish brown polygons denote the occurrence of Furlong soils with their thick topsoils. In the west peat is indicated in purple; in the northeast and southeast brown colours show soils over Carboniferous rocks.*

- oxidative weathering in freely draining, well aerated sites; this produces uniform brownish soil colours;
- gleying, the formation of grey and mottled soil colours marking reduced iron, developed where air is excluded below a watertable, as in *ground-water gley soils*, or by dense soil impeding drainage of water and aeration through the profile (*surface-water gley soils*, and soils with *stagnogleyic* features). The latter form of gleying is evident with gleyed soils high in the landscape in occasional places in the in-bye; it also happens in wetter parts on relatively porous soils unable to transmit rapidly the heavier rainfall. In places both hydrological conditions can operate simultaneously;
- podzolisation, the differentiation of distinctive soil horizons by leaching in very acid conditions, particularly on the moorland, often with very grey subsurface layers depleted of iron over bright brown horizons marking iron re-deposition;
- The accumulation of humus and peat due to acidity, excessive surface wetness or high groundwater, or combinations of the three.

Parts of the survey district have soil patterns which can be explained in terms of the controlling influences of the joint alignments recognised by Waters (1957). An example is in the southeast, between the Kennick and Trenchford reservoirs (SX804844 and SX805825) and the B3212, the Moreton to Exeter road. There the pattern of freely drained soils, the Moretonhampstead and Moor Gate map units, shown in pink or red, high in the landscape is complemented by strips of Laployd groundwater gley soils (in blue) along the lower valley sides and floors.These are largely oriented north-northwest to south-southeast. In other places, particularly in the Sticklepath Fault Zone around Moreton itself, that pattern breaks downand the configuration of ground-water gley soils becomes dendritic, lacking any preferred orientation.

There are some locations where the Laployd soils are mapped higher in the landscape. Examples are east of North Bovey at SX745843 and SX757837, also around Little Wooston (SX763886). In places within such delineations there are soil profiles with relatively high clay content, suggesting the presence of kaolinised granite. In some of these polygons the presence of small pockets of thick peat points to perennial springs and further indicates complex hydrology.

Around Moreton, particularly within the large delineation of the stippled Moretonhampstead/Furlong soil map unit, (described more fully three paragraphs below), there are numerous very small springs and wet patches with gleyed soils, high above the valley floors within the otherwise freely draining ground. Examples of this were encountered as far south as SX753836 on the ridge between Dickford Bridge and Barnecourt. Often they are apparent from clumps of hydrophilous vegetation, particularly *Juncus* spp. Their size, often only a few tens of square metres, precluded their separation on the soil map. Again this suggests frequent bodies of altered granite.

Other soils having *in-situ* kaolinised rock, but with less severe gleying, yet still associated with surface wetness (on the soil map as the Halfway House/Drewston map unit) occur sporadically around Moreton and Chagford, within the Sticklepath Fault Zone. This gleying similarly appears to reflect the reduced permeability within the altered granite. A proportion of subsoils on this map unit contain soft feldspar crystals, much as noted by Clayden (1971).

On the low ridge south of Wreyland at SX786811 a small delineation of the organic topped, surface-water gley soils, the Princetown map unit, marks land with impermeable subsoils, much of it with increased clay content, and a proportion with *in situ* rotten granite at depth. Some of this soil material resembles that found over the Oligocene Bovey Beds. Apart from this Wreyland site, Princetown soils are confined to the moorland peripheral to the blanket peat.

A different aspect of soils in the Sticklepath Fault Zone, is the presence of unusually thick topsoils and fewer podzolic subsoils. Areas of such soil are delineated on the soil map in reddish brown, marking the Moretonhampstead/Furlong map unit. Some of these profiles occur beyond the Fault Zone. The distribution of the thick topsoils precludes explanation as colluvial re-deposition of eroded topsoil, some being on abrupt convexities, some extending hundreds of metres. They are well developed around both Chagford and Moretonhampstead, which might suggest an anthropic origin, but they appear devoid of artefacts. The limited amount of chemical analyses shows their reaction (pH) to rise, approaching neutral, with depth, with one profile having abnormally large plant available phosphorus content at depth. As they occur in at least loose geographic association with physiographically distinct terrain that is interpreted as indicating enhanced kaolinisation, the high pH might reflect release of base cations following the breakdown of feldspars.

If the Furlong soils do indicate a geological anomaly, it is interesting to speculate that this soil difference may have been recognised, through favourable indicators in the wildwood vegetation, by the early colonisers of the land and encouraged the development of the settlements of Moreton and Chagford.

Terrain

The contrasts in patterns of ground-water gley soils already described is largely mirrored in Figure 3, not only by the patterns of water courses (shown in black), but by the distribution of dry valleys and channels, marked in red. The lattice-like network in the eastern 10 percent of the survey area, attributable to structural control by joints and fissures, contrasts sharply with the dendritic configuration around Moreton and North Bovey and in other parts of the Sticklepath Fault Zone. Density of drainage channels is also greater there, and noticeably declines to the west, despite the greater climatic wetness of the moorland.

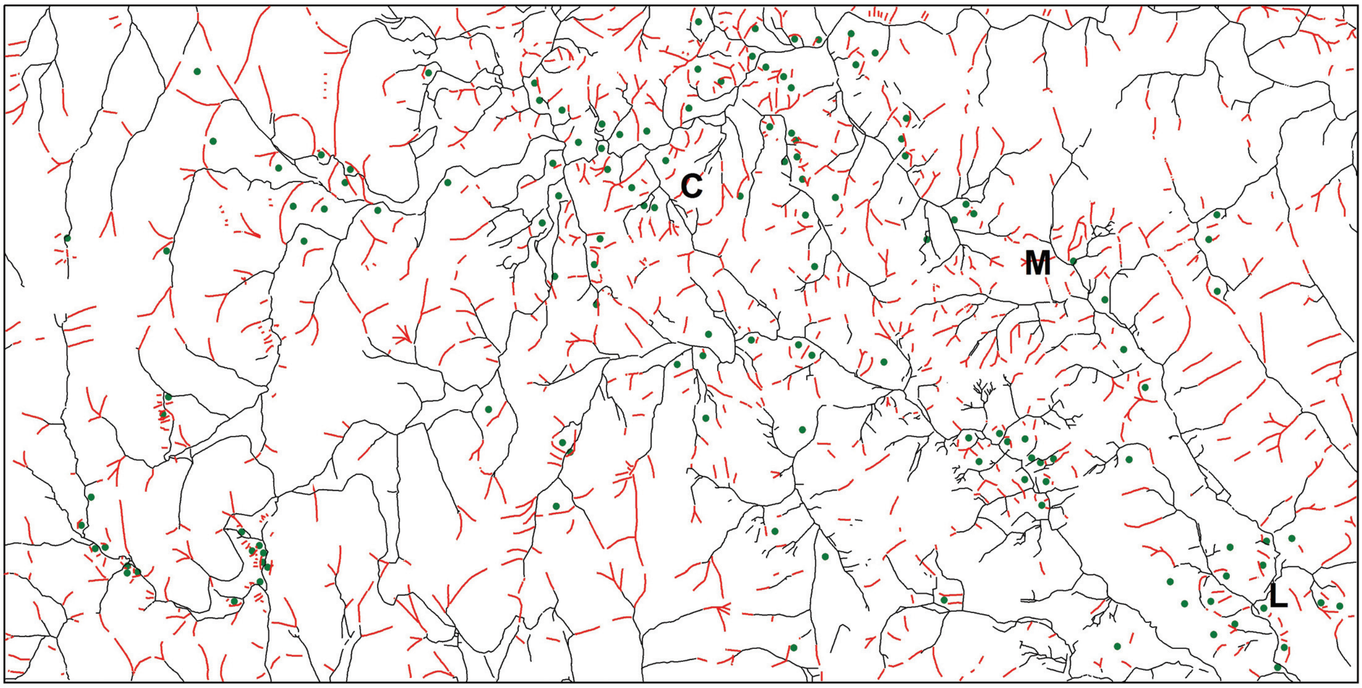

Figure 3. *The drainage network, both watercourses and dry channels. The dots indicate reversed gradients near to spur ends.* ***C*** *= Chagford,* ***L*** *= Lustleigh,* ***M*** *= Moretonhampstead. In the Sticklepath Fault Zone around Moretonhampstead and Chagford drainage density is greatest and structural control least evident, contrasting with areas such as that north of Lustleigh.*

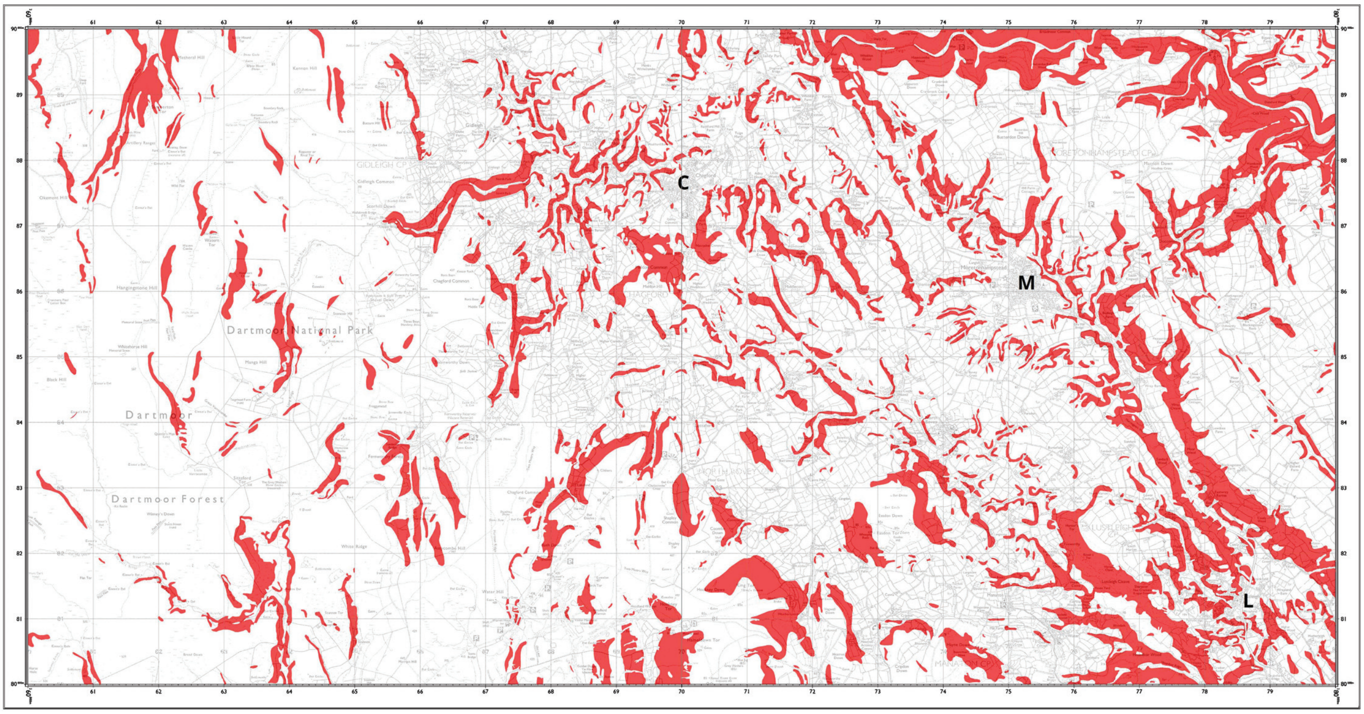

Figure 4. *Slopes steeper than 11° are shown in red. The base map is © Ordnance Survey, licence 100024842.* ***C*** *= Chagford,* ***L*** *= Lustleigh,* ***M*** *= Moretonhampstead. Many steep slopes on the granite are broad and rarely broken by re-entrants. However, around Chagford and Moretonhampstead they are narrower and more sinuous.*

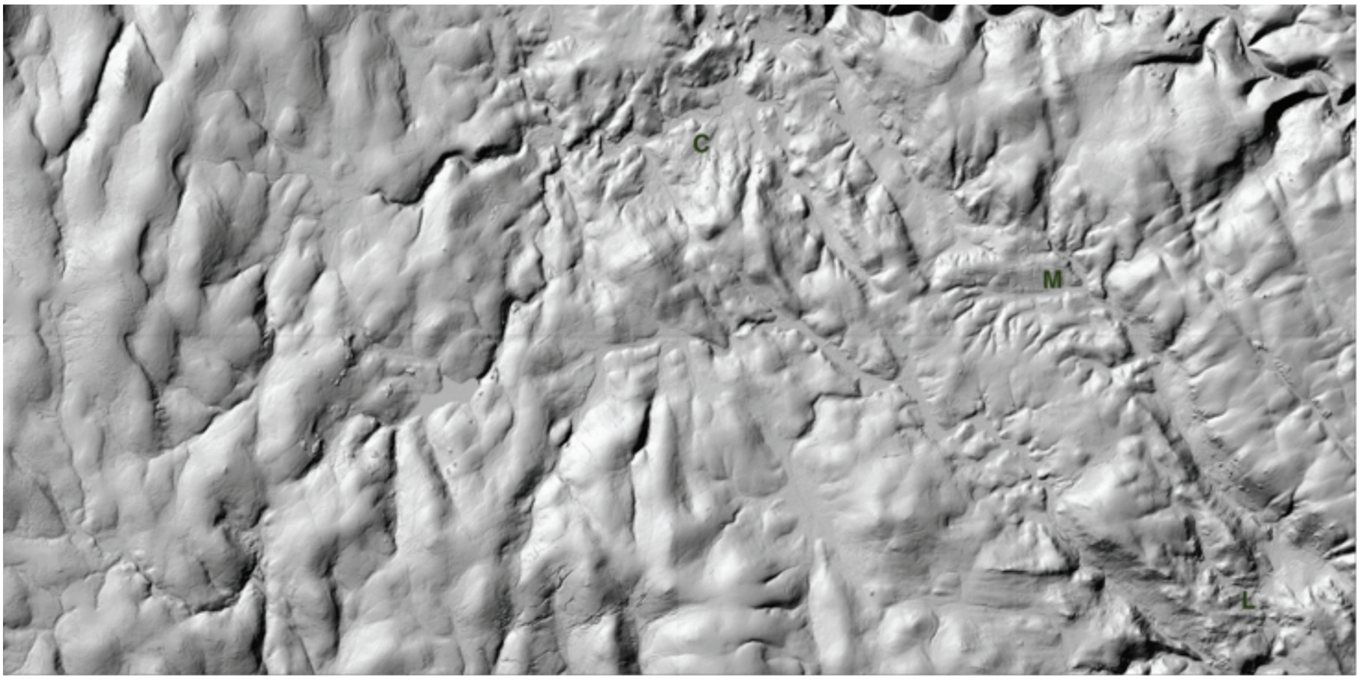

Figure 5. *LiDAR DTM of SX 68 & 78 after NERC Tellus Southwest, (Ferraccioli* et al.*, 2014).* ***C*** *= Chagford,* ***L*** *= Lustleigh,* ***M*** *= Moretonhampstead. Much of the terrain shows strong structurally controlled grains, as for example southeast of Moretonhampstead. These break down within the Sticklepath Fault Zone around Moretonhampstead and Chagford where the landforms are more akin to those on less resistant, unstructured rocks, such as clays or shales. The LiDAR imagery contains freely available data supplied by Natural Environment Research Council (Centre for Ecology & Hydrology; British Antarctic Survey; British Geological Survey). ©NERC (Centre for Ecology & Hydrology; British Antarctic Survey; British Geological Survey).*

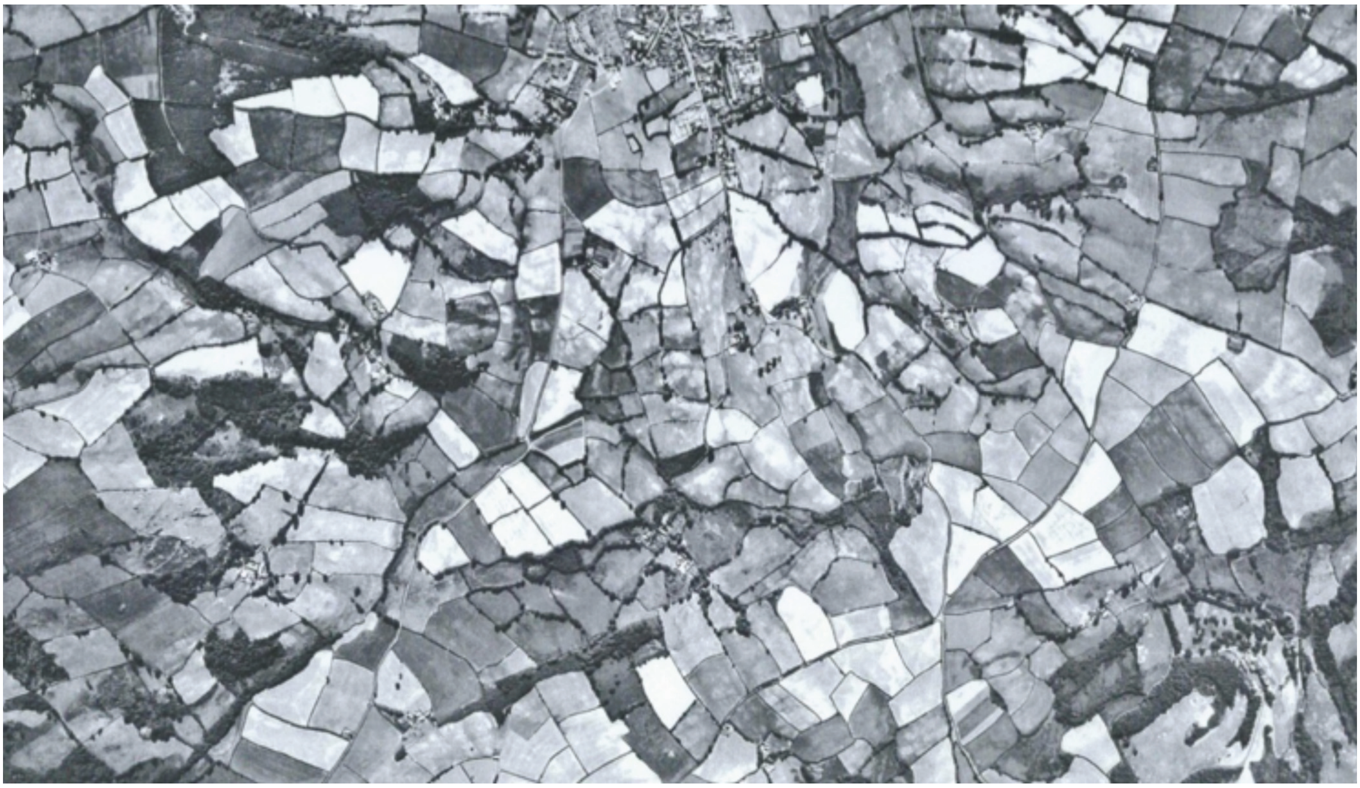

Figure 6. *Vertical aerial photograph of the land immediately west of Moretonhampstead [top centre]. North is to the left. This black and white image was taken in July 1975, following the second driest spring and early summer of the period 1927–2013. The widespread mottling reflects varying drought stress in the grass crops, pale tones indicating sound granite subsoils, darker colours being over softer bedrock. On photographs from this sortie showing areas away from the decayed granite, the crop tones are largely uniform. Air photo 75 298 049, © Ordnance Survey, licence 100024842.*

Associated with the dissimilar drainage and soil patterns are physiographic contrasts. Where the drainage is denser and dendritic the intervening ridges are narrower and lower, with their slopes more sinuous with frequent re-entrants. Figure 4, showing land steeper than 11°, illustrates this well. Also many of the ridges apparently underlain,at least partially, by decayed granite, have reversals of gradient, particularly noticeable towards their ends, some topped by rocks and boulders. Picked outon Figure 3 by green dots, these are interpreted as marking localised residual pinnacles of more resistant, sound granite.

Overall, as Figures 4 and 5 illustrate, this is a distinctive terrain contrasting with the longer, straighter and higher valley sides, with relatively few re-entrants, characteristic of sound granite country. In places its landforms, as northwest of Sandy Park (SX712896), resemble basket of eggs topography. Or it might be likened to a physiographic analogy of reniform mineral morphology, as south and west of Moretonhampstead. Dissection in places produces ridges transverse to the mainvalley line, as at SX711881 and SX713883 east of Chagford and SX786821 and SX786816 north of Lustleigh. A similar feature on the moorland at SX637814, where the Lade Hill stream enters the East Dart, has been explained as a terminal moraine by Evans *et al.* (2012). Other features in the Lade Hill valley and further northwest at SX623840 near Great Varracombe, interpreted by them asbeing glacial in origin, can equally be seen as nothing more controversial than the product of subaerial erosion of softened, kaolinised granite.

Aerial photographs taken in July 1975, fortuitously an extremely dry time, show grass growth variations, which are best explained as reflections of intermixing of sound granite withdecayed rock. Figure 6, around Moreton is an example. Fields away from the area of altered granite have much more uniform visual textures on the photographs.

Conclusions

Considered together there are several indicators of concentrations of rotten Dartmoor granite around Chagford and Moretonhampstead. The patterns of soils, the drainage networks and the configurations of slopes and landforms, all supplement and expand the evidence from exposures. In the earmarked areas, the broad distribution of ground-water gley soils closely compliments the dendritic drainage patterns and the more sinuous slope forms. Further to this, small occurrences of hydromorphic soils in anomalous positions in the landscape are pointers to altered rock, as are patterns revealed by appropriately timed imagery. The anomalous and distinctive Furlong soils may add a further, unexpected link with kaolinisation of the granite.

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