# A NEW INTERPRETATION OF THE EARTH HUMMOCKS ON COX TOR, DARTMOOR, DEVONSHIRE

C.R. MOREY

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A re-investigation of the field evidence suggests that turf-covered mounds forming micro-relief on the slopes around Cox Tor are the work of the yellow meadow ant *(Lasius flavus)*. This contrasts with previous interpretations that have attributed them to frost-heaving and other largely physical processes.

*14 High Street, Flitton, Bedfordshire, MK45 5DU, U.K.*
*(E-mail: colin.morey@virgin.net).*

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## INTRODUCTION

The slopes around Cox Tor (SX 531 762) form the western half of the Merrivale SSSI. Much of the significance of the site arises from the fact that, unlike most tors at similar elevations, Cox Tor is formed from a metadolerite sill with an envelope of metamorphosed sedimentary rocks from the Tavistock Calcareous Group of the Culm Measures which are of Carboniferous age (Figure 1). The boundary between the Culm Measures and the Dartmoor Granite runs through the col between Cox Tor and Great Staple Tor and there is a clear contrast between well-drained brown earth soils on the Carboniferous rocks and poorly drained podzolic soils on the granite which have thin iron pans and are capped by 10-15 cm of amorphous peat. This contrast is reflected in both vegetation and fauna, the podzols being associated with the wet semi-natural *Molinia* heathland that covers most of the higher summits.

Two seminal papers by New Zealand geomorphologist Martin TePunga (TePunga, 1956 and 1957) drew attention to the role of Pleistocene periglacial processes in the evolution of Dartmoor landforms and since that time Merrivale has been a popular venue for fieldwork as it offers ready access to a group of classic granite tors, altiplanation terraces, and patterned ground. Cox Tor has extensive fields of "earth hummocks" which have previously been attributed to frost-heave in waterlogged soil during the same period of periglacial activity (Brunsden, 1964) and therefore regarded as relict features. The Cox Tor "hummocks" form the subject of this paper although it should be noted that the same features occur on the nearby summits of White Tor and Boulters Tor that have similar geology.

The author first examined the Cox Tor site in 1969 with an entomologist who endorsed the view that the "hummocks" were nest mounds produced by the yellow meadow ant *(Lasius flavus)*. The Quaternary Research Association visited the site during their 1996 field meeting when Matthew Bennett described excavations that he had recently carried out (Bennett *et al*., 1996). Bennett's sections were published in the excursion guide (Charman *et al*., 1996) but in poor weather the party failed to reach a general agreement on the interpretation. In January 2010 a literature search prior to the visit by the

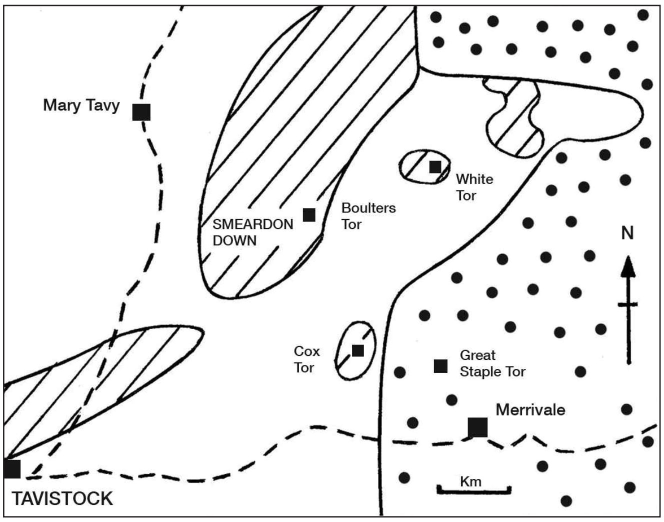


***Figure 1.*** *The study area showing the positions of the principal outcrops and locations referred to in the text. Basic igneous rocks within the Tavistock Calcareous Group are hatched and the Dartmoor Granite is stippled.*

Ussher Society produced references that were somewhat equivocal while the Educational Register of Geological Sites maintained by the Dartmoor National Park Authority (dartmoor-npa.gov.uk) stated that *"rare features also seen are assemblages of earth hummocks"*. This paper reconsiders the nature and distribution of the hummocks.

## THE DISTRIBUTION AND STRUCTURE OF THE COX TOR MOUNDS

### The form and distribution of the mounds

The mounds are distributed over an area of approximately 1 km$^2$ covering all of the terraces around the tor and sizes range from 1-2 m in diameter and up to 50 cm in height (Figure 2). They appear to post-date archaeological features to the north of the summit which would effectively rule out a periglacial origin.

***Figure 2.*** *Mounds on the north side of the summit of Cox Tor. Those in the foreground are composed entirely of soil while boulder cored mounds are visible at the base of the scree slope beyond. The auger is about one metre in length.*

Most are circular with a single rock core but there are elongate forms which have multiple cores where boulders are close together. This is common land and the slopes of Cox Tor are subject to heavy summer grazing by cattle, sheep and ponies that browse between the mounds. There is no fencing but animals confine their grazing to the area of brown earths which support better grassland reflecting the higher nutrient status. Cattle rarely stray onto the podzolic soils around Staple Tor and this appears to be a pattern of grazing that is long established. Trampling between the mounds helps to maintain the micro-relief by undercutting their curved bases to produce straight edges that give rise to the "kite" or "diamond shape" described by Bennett *et al.* (1996). The irregular tracks that result tend to follow the contours as grazing animals instinctively conserve energy by working across the slope.

## *Pedological factors*

Mounds are confined to the brown earths on the Carboniferous outcrop although there are a few wet areas where they have not developed. These mound-free areas have soils capped by 5-10 cm of peat and are transitional to the peaty gleyed podzols of the granite moorland which have a low oxygen concentration that would be inimical to ants seeking to hibernate at depth. The soil forming the mounds is a uniform and stoneless brown earth which dries reddish brown suggesting that it may have the wind-borne component typical of many head deposits. The texture is a silty clay and the high degree of sorting is a significant feature. A rock core is visible in many mounds and the typical form (Figure 3) has a substantial boulder wholly or partly concealed in a mound of friable, stoneless, soil which is stabilised by the overlying turf. Bennett *et al.* (1996) (in Charman *et al.*, 1996) refers to these as *"rock-cored hummocks"* and states that they form about 15% of a total sample of 500 features that he examined. This is probably an underestimate as the use of a soil auger on the mounds in which no rock is visible usually encounters rock 10-20 cm below the surface. A rock core appears to be a significant feature but is not always exposed and *L. flavus* has been observed to build similar structures in other upland areas where rocks are available to serve as both a support and a solar heat sink (Brian, 1977). Examples of active mounds showing various stages of development (Figure 4) can be found on Smeardon Down about 1 km to the north-west (SX 524 779). Many of the Cox Tor features are composed entirely of soil and it is impossible to tell from a visual inspection of their external profile which ones conceal a boulder unless it breaks the surface. The boulders rest on a stony base and Bennett *et al.* (1996) concluded from his excavations that the soil has accumulated around the boulder *in situ* and there was no evidence that the boulder had been pushed upwards through an overlying layer of soil.

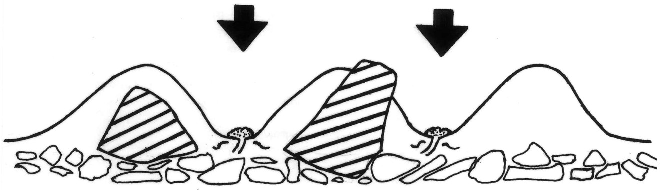

***Figure 3.*** *Cartoon illustrating the internal structure of mounds on the north side of Cox Tor. Two mounds have a boulder core (hatched) which is either concealed or partially exposed, the third mound is composed entirely of soil. The gullies between the mounds (indicated by arrows) have a soil fauna including moles and earthworms. The distance between the arrows is 1-2 metres.*

***Figure 4.*** *Dolerite boulders on the south side of Smeardon Down (290 m O.D.) looking north. Ants* (L. flavus) *have built up the soil around the base of the boulders. In the left foreground a ramp covers most of the near side of a boulder and the addition of a relatively small volume of soil will produce a mound much like those in Figure 2. Much of the boulder remains exposed which will maximise the effect of solar heating. The auger is about one metre in length.*

Mole hills are common in the sinuous gullies between the mounds on all the terraces around the tor and the soil (15-20 cm thick above the stony base) has a substantial earthworm population which is unusual on moorland. In contrast to the uniformly fine grained soil of the mounds, the fresh soil of the mole hills displays sharply angular rock chips (ranging up to 4 cm) and there are substantial deposits of animal dung from cattle, sheep and ponies, which browse the grass between the mounds but largely avoid the mounds themselves. The mounds and the gullies between them clearly function as two separate sub-systems, bioturbation accounts for their lack of clear soil horizons and the constant re-working incorporates organic matter and improves aeration and drainage. Brian (1977) notes that ants alone may deposit as much as 5 kg of soil/m$^2$/yr on the soil surface and are second only to earthworms in this regard.

## **THE CHARACTERISTICS OF *LASIUS FLAVUS* NEST MOUNDS**

Brian (1977) states that *Lasius flavus* is *"undoubtedly the most skilful soil-building ant in this country"* and mounds produced by *L. flavus* are characteristic of heaths, moorland and undisturbed pasture throughout the British Isles. The species is common in Europe but in Britain it reaches the northern limit of its range and is most common in the counties bordering the English Channel where average hours of sunshine reach a maximum of 6-7 hours/day during the spring and early summer.

*L. flavus* lives almost entirely underground where it feeds by "farming" root-sucking aphids and emerges only in late July or August to swarm when each colony releases several hundred queens that fly to start new colonies mostly within the locality. These colonies usually begin under large stones (which are readily available on Dartmoor) and workers are known to bring up soil from a metre or more below the surface, gradually building a porous mound which envelops the original shelter stone with soil. This soil is characteristically stoneless with a spongy texture which Brian (1977) describes as a *"soil/air foam"*. The use of a boulder as the original shelter stone may explain Brunsden's reference to *buttes gazonnees* (Brunsden 1968). Active mounds are typically circular, up to 1.5 m in diameter, about 50 cm high, and they may grow by as much as 10-15 cm per year. Due to environmental constraints this may well be the limiting size. Some indication of the persistence of ant colonies comes from Millard (*pers comm.* 2010) who states that around 80 years ago the farmer flattened the mounds on Flitwick Moor SSSI in Bedfordshire (TL 047 350) with a view to improving the pasture. Within a season or so the ants had re-built to the extent that a mower could no longer be used. Work by King (1987) has shown that the size of mounds is roughly proportional to age and he presents evidence that the largest mounds on abandoned farmland on the Marlborough Downs may have remained active for 150 years. Most significantly these mounds are composed of uniform, stoneless, soil which is carried to the surface as crumbs by worker ants and heaped on the top of the original soil profile which may be marked by a buried organic (Ao) horizon. The mound itself becomes an inversion of the original soil profile which is preserved beneath the mound and Bennett recorded just such a buried Ao horizon in his section (Bennett *et al*., 1996, table 7).

The microclimate within an active mound is critical as a minimum soil temperature of 8°C is needed to initiate activity in spring while higher thresholds of 10°C must be reached for egg-laying and 15°C – 20°C for metamorphosis. Colonies depend totally on solar heat to generate these temperatures and *L. flavus* is therefore able to colonise the whole range of grasslands from acid to neutral, but is restricted to open ground with no shade and a sunny aspect. Invasion of the site by trees, bracken, or even long grass soon results in the death of the colony if the shade makes it impossible to maintain the necessary soil temperatures. In marginal situations mounds are usually elliptical and orientated with their long axes SE-NW to provide a long and flat south west face to be heated by the mid-day sun. A further constraint is imposed by the problem of hibernation which generally lasts from September to April. The survivors overwinter in galleries which are excavated below the mound itself, and on permanently waterlogged or peaty ground *L. flavus* gives way to surface foragers such as members of the genus *Myrmica* which may nest above ground on *Molinia* tussocks or in woody shrubs such as heather (Brian, 1977).

## Discussion

Almost all of the large ant-hills in permanent pastures in Britain are the work of *L. flavus* and the distribution and physical form of the mound system around Cox Tor is consistent with our knowledge of the ecology of this species and its likely response to the resources and physical constraints of the site. At the same time the mounds themselves are a part of the soil forming process where physical and biotic components interact in a system which has most of the characteristics of a lowland meadow. It is instructive to compare the Cox Tor mounds with established *L. flavus* mounds developed on well-drained alluvium on Flitwick Moor (Figure 5). The Cox Tor mounds are more closely packed than those on Flitwick Moor but there are close parallels in terms of size, shape and vegetation pattern. A significant contrast is that the Flitwick mounds are constructed without the support of a boulder and are resilient, fragile, and easily trampled by browsing cattle. These observations indicate that ants adapt their building technique to make the best use of available resources in order to create a characteristic external form. The established view that mounds on Cox Tor at 442 m OD are the product of "frost-heave" (Brunsden, 1964) is at odds with the evidence of similar forms at 62 m OD on recent alluvium in Bedfordshire. Comparison with Flitwick Moor demonstrates that *L. flavus* is able to build up to 50 cm high on recent alluvium without the aid of stones as a support, while taking advantage of the full range of geological resources available at more favoured sites. The location of mounds reflects the soil conditions so that they are only present where free drainage down the soil profile allows ants to hibernate at depth and the soils can support low-growing herbaceous vegetation to host the aphids that are a vital part of a *commensal* relationship.

Cox Tor is unusual in that it lacks the *visible* boulder fields or 'clitters' that are characteristic of the slopes around the granite tors, although substantial quantities of waste must have been produced in the development of the altiplanation terraces recognised by TePunga (1956, 1957). Boulders *are* present, they protrude from the soil as the cores of hummocks and were exposed in the shallow trenches excavated by Bennett *et al*., (1996). Furthermore substantial blocks of metadolerite that are sharply angular and relatively unweathered are exposed on the summit indicating that this material does not disintegrate any more readily than the granite. Dartmoor has escaped glaciation and, as there are no tills or erratics, soils are formed in situ and carry the geochemical signature of the underlying bedrock. This has been supported by a comparatively high stocking density and the resulting input of manure. The brown earths therefore reflect the higher nutrient status of the dolerite regolith and support a healthy macro-fauna of moles, earthworms and ants which have incorporated organic matter and moved fines to the surface in the manner described by Charles Darwin in his classic paper *'On the formation of mould'* read to the Geological Society of London in 1837. During the course of the Holocene this re-working is likely to have destroyed any relict periglacial structures formed in soft material. In contrast, the granite-derived soils exposed in section in the roadside pits near Merrivale Quarry display sharp horizon boundaries that evidence a lack of physical mixing by burrowing soil fauna. There is no sign of cryoturbation or structures indicative of frost boils and there are no records of similar "hummock" fields on the surrounding slopes beyond the boundaries of the Carboniferous outcrop.

*L. flavus* is commonly associated with geological anomalies, especially where the rocks are calcareous, even if the overlying soils are slightly leached. Although the species is predominantly southern in its distribution, Collingwood (1961) refers to an isolated colony which is confined to a small

***Figure 5.*** *Mound field in rough pasture on Flitwick Moor in Bedfordshire developed on recent alluvium. The mounds were flattened by the farmer and the soil scattered during the 1930s. They were re-built within a year or two and are actively maintained by ants* (Lasius flavus) *without the benefit of a support stone. The larger mounds are about 0.5 metres in height.*

limestone outcrop in Caithness and records that he collected similar specimens from a site *"high up on Dartmoor"*. This indicates that constraints imposed by elevation, aspect or latitude can be mitigated by positive factors such as soil fertility to offer tolerable conditions.

There are well-documented studies of mound systems on a scale such as that seen on Cox Tor, but active mound systems are often closely grazed by rabbits exploiting the pasture afforded by the micro-habitat of the mound itself (King, 1977a) which may have elevated nutrient levels to which both ants and rabbits contribute. The vegetation of an active mound is typified by a limited range of low-growing herbs which contrasts with the grasses grazed by cattle etc in the spaces between the mounds. This was more obvious when the author visited Cox Tor in 1969 than it is today. On sandy alluvium at Flitwick, where rabbits are absent, colonies appear to depend on summer drought to "burn off" the vegetation on the crest of the mound to allow direct heating of the soil. On the loams of Cox Tor with much higher rainfall than Bedfordshire the mounds on the western slopes are grass covered, relatively firm, and rarely more than 25 cm in height, indicating that their colonies have become extinct with the resulting collapse of their characteristic texture. It is beyond the scope of this paper to detail the nature of the changes that have taken place but these are dealt with effectively by King (1977b). Most have been invaded by bracken *(Pteridium aquilinum)* while isolated gorse bushes *(Ulex spp.)* usually take advantage of the better drainage afforded by the crest of former mounds. The mounds on higher ground to the north of the summit have a permanent cover of longer grass and/or moss which is ungrazed but the extent to which their ant colonies have become extinct has not yet been confirmed. Mound fields on nearby White Tor (SX 543 787) and Boulters Tor (SX 525 781) are in a similar condition.

A tentative explanation for the limiting size and spacing of mounds lies in a form of negative feedback. Rocks that have served as a heat sink become progressively buried (Figure 4) and there is a simultaneous reduction in surface/volume ratio so that it becomes progressively more difficult to attain the essential soil temperatures. As the soil surface of the mounds consolidates, mosses such as *Polytrichum spp.* become established while grazing pressure and the heaping of freshly excavated soil become the only controls preventing the loss of the more nutritious herbs that sustain the community. On Flitwick Moor the fragile soil mounds are regularly destroyed by cattle and rebuilt, Dartmoor mounds are more robust and cattle and ponies seem to avoid them concentrating their attention on the gullies which offer better grazing. This allows slow growing vegetation with mosses and gorse to become established and insulate the soil surface.

## CONCLUSIONS

From the form and structure of the mounds and their close resemblance to both active and inactive mounds on Smeardon Down it is reasonable to conclude that the Cox Tor mounds are also the work of *L. flavus* while their location and extent is an indirect response to the geochemistry of the underlying bedrock. The large mounds formed around boulders which were noted by Brunsden (1964) will certainly have been established before the devastation of Dartmoor's rabbit population by myxomatosis during the late 1950s. It is likely that the removal of grazing pressure by rabbits or even sheep has allowed tall grasses and mosses to become established so that soil temperatures within the mounds no longer reach the critical thresholds essential to the survival of *L. flavus* communities. The ant fauna on the slopes around Cox Tor now appears to be dominated by *M. ruginodis* which is a more adaptable species that thrives in long grassland, feeding and nesting on the surface without investing energy in a permanent mound. This species will excavate a temporary nest under a flat stone which is sufficiently exposed to the summer sun to develop the required temperatures or simply occupy part of a former *L. flavus* mound. Its presence confirms that conditions remain suitable for a viable ant population and the species change is likely to correspond with changes in the grazing regime.


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