ancient trees have implications for the residence time of carbon in wood. From permanent plot data we know that about 50% of the above-ground biomass is contained in less than the largest 10% of the trees. Thus, although they are few, the largest trees represent a sizeable component of the forest's carbon budget, and the associated carbon can be very old. These results provide a first look at how ages are distributed among emergent trees of the central Amazon, and underscore the importance of age demographics in the ecological structure and function of these forests.

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Stratification in poured granular heaps

The stratification of poured granular mixtures into layers according to particle size has long been identified as an important mechanism by which such materials segregate[1,2]. The implications of this effect for the process industries have also been discussed[3,4]. Makse *et al.*[5] suggest that stratification takes place only when there is a marked difference in the shape of large and small grains; specifically, when the angle of repose of the coarse phase is much greater than that of the fines. Our experiments show that stratification can occur in the absence of such heterogeneity of particle shapes within the mixture.

We conclude that stratification of granular mixtures is a multidimensional issue. It is first necessary to establish a specific domain of interest within material parameter space. We consider non-percolating granular flows, where the size and density ratios between coarse and fine phases are sufficiently modest to prevent percolation of fines through the coarse phase from being the primary mechanism for segregation. Percolation is known to dominate if the size ratio is sufficiently high[6]. Under these conditions the fine phase drains through the coarse and is found near the bottom of the assembly.

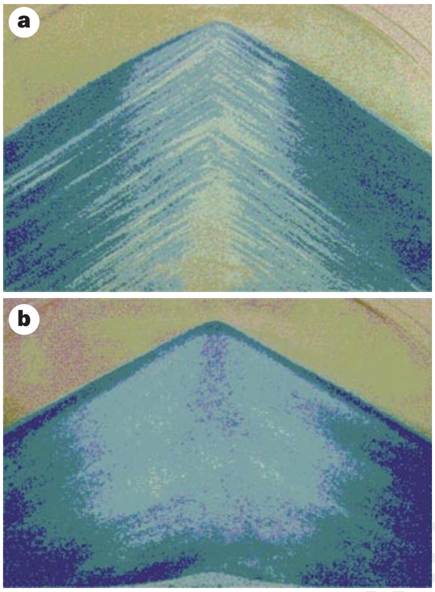

Figure 1 a, Stratified heap formed in slow feeding process; **b**, well-mixed heap formed in fast feeding process.

In a series of experiments, we poured a 20-kg mixture of borax pentahydrate granules into a quasi-two-dimensional hemispherical structure (Fig. 1a, b). The structure was 1 m in diameter, with two plates of Perspex separated by a gap of about 9 cm. The granulate had a continuous distribution of sizes from about 0.1 to 1.4 mm. The granules greater than 0.85 mm in diameter were regarded as the coarse phase and were coloured blue; the fine grains were white. The size ratio of the two phases, in terms of d_{50} measurements, was approximately 2:1 (0.51 and 1.00 mm for fine and coarse phases respectively), and the particle density of each phase was almost identical. The angles of repose of the two phases were 26.9° for the fines and 27.8° for the coarse, so there was negligible difference between the two. The results show that the rate at which material is poured into the structure is a crucial parameter. Figure 1a shows the heap formed in a slow filling process, with a fill time of 45 min (average fill rate 0.007 kg s^{-1}). There is marked stratification of the material into layers of fine and coarse. In contrast, Fig. 1b shows the heap formed with a fill time of 25 s (average fill rate 0.8 kg s^{-1}). The fine and coarse phases are relatively well mixed, with no stratification.

Stratification thus depends strongly on the fill rate, which parametrizes the overall impact (kinetic energy) of the incident feed stream on the growing heap. This effect has previously been identified for bulk segregation[7,8]. The controlling mechanism is of 'capture' of incident grains by the growing assembly. If the overall impact is high, incident grains can embed themselves within the growing assembly, so their freedom of movement is greatly restricted (provided that the mixture is non-percolating). If capture is relatively inefficient, the grains are relatively free to move, so coarser grains will roll over finer grains and stratified layers will be formed.

Only the efficiency of capture is affected by the shapes of the grains in the two phases. For example, the probability of a large grain's finding a geometrically stable position in which to embed itself, within an assembly of mostly smaller, near-spherical grains, is relatively low. Thus it is not, as has been previously suggested, a necessary condition for stratification that the angle of repose of the coarse grains should exceed that of the fines. Only the range of fill rates for stratification is affected by the particle shape profile within the mixture. If the angle of repose of the coarse grains greatly exceeds that of the fines, stratification will occur over a wide range of fill rates. However, if the feed rate is sufficiently slow, stratification can occur even if the angle of repose of the fines exceeds that of the coarse grains. In a further experiment, not shown here, we increased the overall angle of repose of the fine phase to 32° by adding a higher proportion of very fine material. We again saw stratification, but only under very slow filling conditions.

We are continuing to examine the relative importances of fill rate, size ratio and particle shape for stratification within poured granular mixtures.

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