by a recent government report¹⁰ which contains a "retrospective/prospective review" of the environmental archaeology of three regions (East Anglia, south-west England and northern England) and one historic town (York) that has been revealed by work sponsored by the laboratory over the past decade. These are the first regional overviews of past environments (as opposed to reports on the environments of specific sites) have been prepared. Although the reports stress problems resulting from lack of data, the information that has been assembled has produced several syntheses with profound implications for archaeology. For example, precise information on forest clearance and farming systems is emerging which, together with the results of aerial and ground surveys, radically changes the accepted view of the extent and nature of prehistoric and Roman settlements. Analysis of animal bone assemblages is throwing new light on dietary habits, animal husbandry and butchery practices. Analysis of large assemblages of human skeletal material, especially from urban cemeteries, is producing much invaluable — and often unexpected — palaeodemographic and palaeopathological data, which can be related directly to conventional archaeological data.

Whereas the enormous potential of environmental archaeology is clear, the

government report also emphasizes the inadequacy of funds to more than nibble at the edges of the subject, the material for which is becoming more voluminous with every excavation. Nevertheless, the report is a well-documented exposition of the value of treating human communities as components of a complex ecosystem rather than as isolated phenomena that do not interact with their environments. This is where the future lies for archaeology: let us hope that this will be realized by those who can make that future a reality. □

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Aggregation

Models of the sol – gel transition

from George Hentschel

ANYBODY who has seen a cold soup turn into jelly has witnessed a sol–gel transition. This is caused by the branching reactions that occur in the polymerization of polyfunctional monomers in a solvent. The gel point separates a sol phase, consisting of a distribution of growing but finite clusters in the liquid medium, from a gel phase where a macroscopically large branched network spans the system with fluid in its interstices. Yet, even today, it is not known whether monomer diffusion allows some reaction sites on the surface of a growing cluster, or whether one can treat all possible growth sites on an equal basis. A new kinetic-growth model, introduced by P. Meakin and Y. Termonia (*Phys. Rev. Lett.* **54**, 1083; 1985), now tackles possible diffusion-limited selection by combining aspects of both diffusion-limited aggregation (DLA) and the phenomenon of percolation. This is also critical because the dynamics of a fluid moving through a porous medium will cease to be determined by hydrodynamics when porosity is sufficiently ramified.

The model is a modification of the kinetic growth model of Z. Alexandrowicz for percolation clusters (*Phys. Lett.* **80A**, 284; 1980). Place a monomer at the centre S_0 of

a hypercubic lattice with coordination number f . Choose a probability P which represents the average fraction of new monomers joining the cluster per unit time. At time $t=1$, random variables z_i equally distributed in the interval $[0,1]$ are chosen for each nearest-neighbour site of S_0 . If $z_i < P$, a new monomer is placed at the site, whereas if $z_i > P$, the site is blocked for all times. This creates a set of new monomers S_1 . In the original model of Alexandrowicz, for all times $t \geq 2$ the algorithm described above is repeated for each new set of branch tips created at the previous step and not blocked. This identifies the sets $S_2, S_3, \dots, S_t$ of new monomers which join the growing cluster at each unit interval until for $P < P_c$ a point is reached where no new branch tips are created, as all possible growth sites are blocked. For $P > P_c$, the growth does not stop and a macroscopic cluster will span the lattice.

The novelty in the model of Meakin and Termonia is their contention that growth sites are not all created equal. As in DLA, the probability P_i for a branch tip on the surface to react with a monomer is larger than for one embedded in the cluster: monomers have to diffuse into the bulk to reach such a growth site and are likely to

have reacted before they can do so. To estimate the P_i for each new branch tip in this model, a large number of random walks from each vacant site is simulated and the fraction that escapes from the aggregate gives the relative probability of a monomer reaching that site. To find the absolute probabilities P_i , these relative probabilities have to be normalized so that an average fraction P is likely to be incorporated into the cluster at each step of the growth. Once the P_i have been estimated, each possible growth site is occupied or blocked by a new monomer according to whether a random number z_i chosen from the equal distribution $[0,1]$ is less than or greater than P_i . As in the case of percolation, a gel-like transition takes place at some critical rate of incorporation of monomers, P_c . The clusters are fractals with a fractal dimension which is that neither of DLA nor of percolation but, rather, more tenuous.

To see this model in the context of previous attempts to understand the gel point, note that diffusion has usually been neglected completely, and the rate-determining step assumed to be the reaction. All unreacted groups on a polyfunctional monomer were treated as equally likely to react, so there were no geometric constraints in the model. A Smoluchowski equation could be set up with reaction rates proportional to the product of unreacted species in each cluster, and solved for the cluster distribution. This model is soluble and exhibits a sol–gel transition. Though the model is satisfactory away from the gel point, the classical exponents do not agree with experimental results close to P_c .

One geometric constraint that can be introduced easily into the reaction process is to argue that some unreacted sites in the cluster may not be able to react because they are blocked, with some probability P by their neighbours. This would allow one to compare percolation and gelation to see whether they lie in the same universality class, as they both show transitions from finite to macroscopic spanning clusters. Unfortunately, percolation exponents are also in disagreement with experimental findings.

In the new model, the ease or difficulty of finding a partner in a unreacted group depends on the ability of a monomer to reach it, as well as blockage by its neighbours. The critical exponents of this model lie between those of classical theory and percolation. Meakin and Termonia compare their model with experimental tests and conclude that it agrees better than do either the percolation or the classical models, although discrepancies still exist. Clearly, monomer diffusion is important in clustering close to the sol–gel transition. □

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