Percolation controls on vegetation growth and soil formation

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Topics of interest for North Sea oil exploration as investigated by Gene Stanley and associates include solute transport times and distances in disordered networks that represent the pore space. The theoretical results were expanded to treat disordered networks with a wide range of pore sizes. The most important percolation parameters turn out to be the fractal dimension of the backbone and for optimal paths. The theory turned out to predict entire solute arrival time distributions without use of adjustable parameters. Near the Earths surface, solutes transported vertically by rainwater, and described by 3D backbone fractal dimensionality, relate to the formation of soil. Plant roots search for nutrients in the top decimeters of the soil, with growth controlled by 2D optimal paths exponent. Derived results turn out to describe the spatio-temporal scaling of vegetation growth and soil formation. In each case the fundamental spatial scale is fixed by the pore separation, most commonly about 30 microns, while the time scale is fixed by the pore size and the water flow rate, corresponding to deep infiltration for soil formation and transpiration for plant growth. Problems disturbing plant physiologists and ecologists, to those of carbon cycling and chemical weathering are solved simultaneously. In vegetation growth, these span the range from the size dependence of trees of the same species on substrate, soil characteristics, fertilization, climate, and topography, to discrepancies in allometric scaling, the scaling of net primary productivity on transpiration, and the ability to predict the maximum underground size of vegetation on time scales up to 100,000 years. In the area of soil formation, the time scales treatable predictably exceed 50 million years, and the problems solved include the dependence of calcic and gypsic horizon depths on precipitation and evapotranspiration, as well as soil formation rates with their dependence on climate and topography, slope and surface water convergence, and erosion rate. Related problems that are solved include soil C and N sequestration rates, and the puzzling behavior of the field rates of chemical weathering. To give specific examples of just one relationship, we find that steady-state soil depths are given as the product of the particle size and the ratio of the soil infiltration rate to the erosion rate to the power 1.15. This result generates soil depths within 20 or 30% of observed soil depths around the world.

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