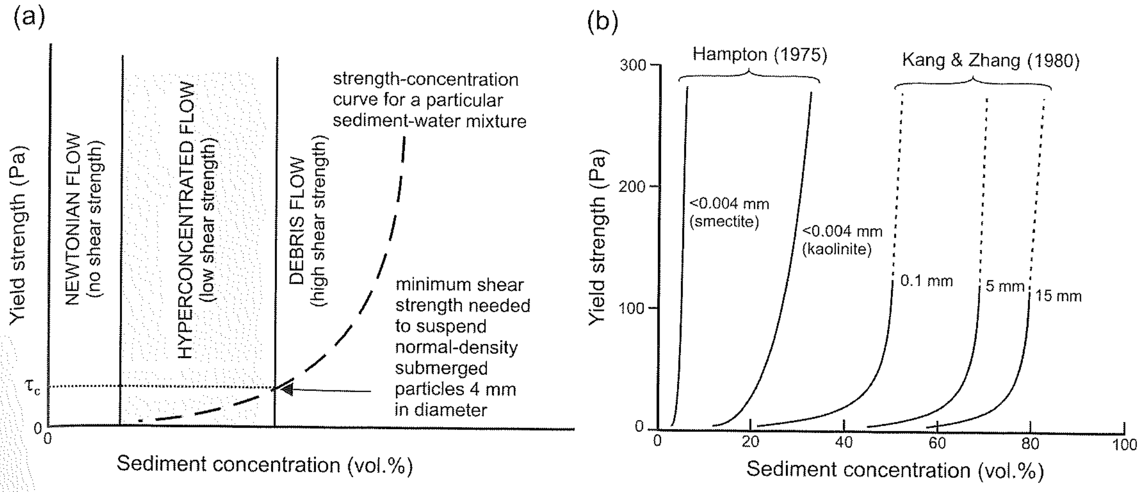

Figure 14.3 Yield strength of sediment–water mixtures as a function of suspended sediment concentration. (a) Definitions of flow type based on an idealized yield-strength–concentration curve for a poorly sorted sediment–water mixture. (b) Measured yield-strength–concentration curves for a range of sediment–water mixtures illustrating the effect of grain-size distributions (curves are marked with the median particle diameter) and compositions. Reprinted from Pierson (2005), with kind permission of Springer Science+Business Media.

and contraction (where shear causes expansion or collapse of pore space), intergranular friction (due to grain–grain contacts), fluidization (due to pore-fluid pressure exceeding hydrostatic), particle segregation, and minimal to moderate cohesion when stationary. Such flows commonly develop a relatively coarse and dry flow front, which behaves as a moving boulder dam (Fig. 14.4(c); Sharp and Nobles, 1953; Major and Iverson, 1999; Lavigne and Suwa, 2004) that can increase maximum stage height, and a body that usually appears to behave as a coherent but liquefied single-phase mass, or as a hyperconcentrated flow. Debris flows commonly develop steep lobate flow fronts, produce lateral levées, transport cobble- to boulder-sized clasts within the flow as well as along the channel bed, and form massive, very poorly sorted and ungraded matrix- to clast-supported deposits (Fig. 14.4(d)). Although debris flows can selectively deposit their coarsest clasts, they can also accrete sediment incrementally (Major, 1997) or deposit it en masse as shear stresses decline and intergranular friction, chiefly at the flow front, locks up the flow (Major and Iverson, 1999). The presence of clay-sized material can strongly influence flow behavior. *Cohesive* flows (defined as containing > 5% clay) are typically more mobile than *non-cohesive* flows (< 5% clay), and they can maintain their high-concentration integrity for great distances because they are resistant to dilution and transformation. Non-cohesive flows typically contain a narrower and coarser distribution of grain sizes, entrain water and deposit sediment more easily, and commonly transform distally to hyperconcentrated flow (Figs. 14.5, 14.6; Pierson and Scott, 1985; Scott, 1988).

14.4 Lahar characteristics

Real-time field measurements of the dynamic properties of lahars are rare, owing largely to their size, the challenges of predicting the timing of their occurrence, and financial constraints in many of the countries where lahars frequently occur. Nevertheless, a few field monitoring stations around the world have gathered data on individual events (Manville and Cronin, 2007) or on a recurrent series of flows (Suwa and Okuda, 1985; Pierson, 1986; Suwa, 1989; Ohsumi Works Office, 1995; Lavigne *et al.*, 2000b), variously recording discharge hydrographs, compositions, depths, volumes, flow-front and surface velocities, surface-velocity distributions, basal stresses