- Indonesian word for mud-flow.
  - Name applied to phenomena associated with unconsolidated volcanic material and water.
  - May range from essentially debris flows at the dry end to hyperconcentrated stream flow.
Case History: Nevado del Ruiz, Nov. 1985

**Eruption History**

- Lahar generating eruptions in 1595 & 1845
- Nov. '84: Increased seismic, fumarolic activity, small phreatic explosions
- Initially unmonitored, but seismometers set up and hazard assessment completed by Oct. '85.
  - INGEOMINAS (Nat'l Bureau of Geology and Mines): a moderate eruption would produce "... a 100 percent probability of mudflows... with great danger for Armero..."

Summit of Nevado del Ruiz, Nov. 26, 1985
Nov 13, 1985

- Strong phreatic eruption at 3 PM. Ash falls on surrounding communities. Evacuation of Armero ordered, then cancelled.
- Explosive eruption at 9 PM generated eruptive column and small pyroclastic flows that melted ~10% of the summit glacier. Mix of meltwater, ice, & pyroclastic material then poured into river valleys.
The Lahars

- Once in the river valleys, the lahars were racing at 60 km/hr.
- Lahar volume increased by a factor of 4 due to erosion.
- Flows were up to 50 m thick in narrow river valleys.

Out of the mountains the lahars spread out, overrunning towns.

- Reached Armero around 11 PM in pulses:
  - 11:25 PM - clean water from upstream lake - water displaced by lahar - few cm in Armero
  - 11:35 PM - main pulse, 2-5 m deep in Armero
  - Additional smaller pulses until 1 AM
- 23,000 people killed, 4500 injured, $1 billion in damage.
- Total destructive runout of lahars was >100 km.
Primary and Secondary Lahars

- Primary (syneruptive) lahars can occur when an eruption melts ice or a crater lake is breached.
  - 0.01 km$^3$ eruption of Nevado del Ruiz produced a 0.1 km$^3$ lahar
  - Lahars also produced by May 18, 1980 MSH eruption
- Secondary lahars can result from debris avalanches (landslides) or from erosion of fresh, unconsolidated pyroclastic material.
  - Approximately 1/3 of the 10$^3$ km$^3$ pyroclastic material of the 1991 Pinatubo eruption has already been reworked in lahars; 50,000 people displaced

Physical Characteristics

- Consist of a wide range of particle sizes (clay sized to boulder sized) mixed in varying proportions with water.
- Exhibit the property of strength resulting from particle interactions due to high concentration of particles
  - At concentrations of < 20 or 30%, particle support is mostly by turbulence
  - From 30 to 60% (limit of hyperconcentrated flow), particle interactions greatly modify flow behavior with particles supported by a combination of turbulence and particle interactions
  - At >60%, particle support is mainly by particle interactions.
- When particles are fine, strength and resistance to flow come from cohesive (electrostatic) interactions. For larger particles, strength and resistance comes from kinetic interaction.
Characteristics of lahars

- Because of the wide variety of causes, lahars show a variety of behaviors
  - In particular, particle concentrations can change substantially over the course of the lahar
- Lahars beginning as floods (glacial melts, crater lake breaches, etc.) are initially erosive
  - “Bulking” is the term for the process by which lahars become more concentrated through erosion
- Lahars beginning as debris avalanches may add stream water and become more dilute
- Topographically constrained to stream valleys
- Downstream, sedimentation dominates
  - Load is dropped incrementally; high water marks on valley walls much higher than deposit thickness.

Lahars of the May 18 MSH eruption

- Also 27 bridges destroyed.
- Reduced carrying capacity of Cowlitz River by 2/3
Characteristics of deposits

- Again, wide variety of characteristics
- Usually poorly sorted
- More compact and less friable than “pyroclastic” deposits and debris avalanches.
- Presence of vesicles
- Longer runout than pyroclastic flows
- Can be either normally or inversely graded in high particle concentration flows

Toutle River Lahar Deposits

- Toutle River Lahar generated by the May 18, 1980 eruption of Mt. St. Helens.
- Initiated as debris avalanche (as section of volcano collapsed) and pyroclastic flows and progressed to hyperconcentrated flow
**Whaleback Bars**

![Image of Whaleback Bars]

**Progression of Deposits**

![Diagram of Progression of Deposits]

*Figure 10.* Portrait of the facies types described in Table 6. *igh*–Inversely graded bedding.
Grading & Sorting in Toutle River Deposit

- Note how the initial deposit is very poorly sorted.
- Distal deposit is better sorted due to loss of coarse fraction.

Lahars from earlier Eruptions

Note finer grained “sole unit”

Basal part
Inversely graded

Inversely graded
Lahar Deposits

- Because of bed friction, bottom layers move more slowly
- Consequently, larger particles work toward the front and margins
- Lower concentration flows can be normally graded as coarse material settles first
- Inverse grading is a consequence of “kinetic sieving”

Dish structure seen in some particle poor lahar deposits

Structure develops by dewatering of hyperconcentrated flow deposits
Jökulhlaups

- Jökulhlaups are floods produced when a subglacial eruption produces melting of the overlying glacier.
- These are occasional occurrences in Iceland, particularly along the south coast.