Laboratory experiments on air-particle gravity currents generated from the release of fluidized granular columns were carried out to investigate the emplacement mechanisms of pyroclastic flows. High-speed video analyses and non-invasive measurements of the pore fluid pressure were made to investigate the depositional processes of flows of fine (80 µm) particles. The low permeability of the granular material permitted relatively slow diffusion of the initial pore pressure within the flows until they came to halt. The flow structure consisted of a sliding head that caused underpressure relative to ambient pressure and whose magnitude correlated with the flow velocity. The flow head was followed by a body that generated overpressure and at the base of which a deposit aggraded at a nearly constant rate. Both the flow head and body were sheared pervasively as the internal velocity increased upwards. The combination of pressure advection from the source and relatively slow pressure diffusion resulted in long-lived high pore fluid pressure in the body of the flows during most their emplacement, which is consistent with their fluid-inertial behaviour. When the pressure had sufficiently decreased at late stage, the flows entered a granular-frictional regime and stopped. Complementary experiments on the release of dry granular columns evidenced partial auto-fluidization of the flow body, as some pore pressure was generated at early stages. This study suggests that pyroclastic flows on subhorizontal slopes can propagate as inertial fluidized gas-particle mixtures consisting of a sliding head and of a gradually depositing body.