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Indentation into a plastic fluid layer THOMASINA BALL, NEIL BALMFORTH, University of British Columbia, IAN HEWITT, University of Oxford — We study the indentation of a rigid object into a layer of a cohesive or non-cohesive plastic material. Existing approaches to this problem using slip-line theory assume that the penetration depth is relatively small, employing perturbation theory about a flat surface. Here, we use two alternative approaches to account for large penetration depths, and for the consequent spreading and uplift of the surrounding material. For a viscoplastic fluid, which reduces to an ideal plastic under the limit of vanishing viscosity, we adopt a viscoplastic version of lubrication theory. For a Mohr-Coulomb material, we adopt an extension of slip-line theory between two parallel plates to account for arbitrary indenter shapes. We compare the theoretical predictions of penetration and spreading with experiments in which a flat plate, circular cylinder or sphere are indented into layers of Carbopol or glass spheres with successively higher loads. There is a clear layer-depth dependence of the indentation and uplift for the viscoplastic material, with a much weaker dependence on layer depth for a Mohr-Coulomb material. Understanding the dynamics of indentation into a viscoplastic layer is of particular importance in the formation of footprints, either by animals or in an industrial process.

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