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On the use of the stabilised Q1P0 element for geodynamical simulations and why this is a bad choice for buyoancy-driven flows.

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Many Finite Element geodynamical codes (Fullsack,1995; Zhong et al., 2000; Thieulot, 2011) are based on bi/tri-linear velocity constant pressure element (commonly called Q1P0), because of its ease of programming and rather low memory footprint, despite the presence of (pressure) checkerboard modes. However, it is long known that the Q1P0 is not inf-sup stable and does not lend itself to the use of iterative solvers, which makes it a less than ideal candidate for high resolution 3D models.

Other attempts were made more recently (Burstedde et al., 2013; Le Pourhiet et al., 2012) with the use of the stabilised Q1Q1 element (bi/tri-linear velocity and pressure). This element, while also attractive from an implementation and memory standpoint, suffers a major drawback due to the artificial compressibility introduced by the polynomial projection stabilization. These observations have shifted part of the community towards the Finite Difference Method while the remaining part is now embracing infsup stable second order elements [May et al., 2015; Kronbichler,2012).

Rather surprinsingly, a third option exists when it comes to first order elements in the form of the stabilised Q1P0 element, but virtually no literature exists concerning its use for geodynamical applications. I will then recall the specificity of the stabilisation and will carry out a series of benchmark experiments and geodynamical tests to assess its performance. While being shown to work as expected in benchmark experiments, the stabilised Q1P0 element turns out to introduce first-order numerical artefacts in the velocity and pressure solutions in the case of buoyancy-driven flows.

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