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To what extent is the volume change of pressurized ellipsoidal sources retrievable from deformation and seismic data?

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We present expressions for the volume change of a pressurized ellipsoidal cavity, obtained by using expressions for the elastic field due to an ellipsoidal inclusion in an infinite medium given by Eshelby (1957). Eshelby's expressions are approximately valid also in a half-space, provided that the appropriate Green's functions are used (Davis, 1986). We show that previously-published widely-used expressions are correct for spheres, but underestimate the ratio of the volume change to the product of pressure and volume in any other case.

We discuss the capability to infer the shape of a single ellipsoidal cavity from far-field deformation, which is the same as from a moment tensor, whose eigenvalues are proportional to the product of the ellipsoid pressure and volume and depend on the axis ratios; the normalized eigenvectors of the moment tensor represent the directions of the axes of the ellipsoid.
Our results indicate that the dependence of the volume change on the moment tensor eigenvalue ratios generally allows an estimate of the volume change from far-field deformation data, but retrieval of the cavity shape (ellipsoid axis ratios) may be not robust if the ratio of the minor to intermediate axes is small.

Source properties retrieved from far-field deformation data are less reliable for cases of interconnected equally-pressurized ellipsoidal cavities. Neglecting stress induced at the surface of each cavity by nearby ones, we find that (i) if all the cavities share the same shape and orientation, but have different volumes, the ensemble of cavities is seen in the far field as a single ellipsoidal cavity, the shape of the apparent single ellipsoidal cavity is the same as the shape of the constituting cavities and not of the source region, and it is possible to compute the total volume change from surface displacements; (ii) if all the cavities share the same shape but have different orientations, a single ellipsoidal cavity might even be unable to give the same surface displacements as the ensemble of cavities and it is possible to compute the total volume change only if the cavity shape is assumed a priori; (iii) if the cavities are different both in shape and orientation, it is possible to compute the total volume change only if the product of pressure and total volume is assumed a priori.

Volume change due to sudden magma movement between paired cavities can originate seismic waves. Source moment tensor can be decomposed into isotropic, double-couple, and compensated linear-vector dipole force systems. We give relations for the moment tensor components and show that volume-change values obtained from the isotropic component only can be much smaller than those really involved in the magma exchange process. Our approach might improve modelling of non-DC earthquakes in volcanic and geothermal areas.