CONTROL ID: 1788774
TITLE: Analytical Expressions for Deformation from an Arbitrarily Oriented Spheroid in a Half-Space

AUTHORS (FIRST NAME, LAST NAME): Peter F Cervelli[1]
INSTITUTIONS (ALL): 1. US Geological Survey, Menlo Park, CA, United States.

ABSTRACT BODY: Deformation from magma chambers can be modeled by an elastic half-space with an embedded cavity subject to uniform pressure change along its interior surface. For a small number of cavity shapes, such as a sphere or a prolate spheroid, closed-form, analytical expressions for deformation have been derived, although these only approximate the uniform-pressure-change boundary condition, with the approximation becoming more accurate as the ratio of source depth to source dimension increases.

Using the method of Elshelby [1957] and Yang [1988], which consists of a distribution of double forces and centers of dilatation along the vertical axis, I have derived expressions for displacement from a finite spheroid of arbitrary orientation and aspect ratio that are exact in an infinite elastic medium and approximate in a half-space. The approximation, like those for other cavity shapes, becomes increasingly accurate as the depth to source ratio grows larger, and is accurate to within a few percent in most real-world cases. I have also derived expressions for the deformation-gradient tensor, i.e., the derivatives of each component of displacement with respect to each coordinate direction. These can be transformed easily into the strain and stress tensors. The expressions give deformation both at the surface and at any point within the half-space, and include conditional statements that account for limiting cases that would otherwise prove singular.

I have developed MATLAB code for these expressions (and their derivatives), which I use to demonstrate the accuracy of the approximation by showing how well the uniform-pressure-change boundary condition is satisfied in a variety of cases. I also show that a vertical, oblate spheroid with a zero-length vertical axis is equivalent to the penny-shaped crack of Fialko [2001] in an infinite medium and an excellent approximation in a half-space. Finally, because, in many cases, volume change is more tangible than pressure change, I have derived an equation that relates these two quantities for the spheroid: volume change equals pressure change × 2/3 × π/μ × a constant that depends on Poisson's ratio and the spheroid geometry.

Eshelby, J. D., The determination of the elastic field of an ellipsoidal inclusion and related problems, Proc. R. Soc. London, Ser. A, 241, 376-396, 1957.

Fialko, Y., Khazan, Y, and Simons, M. Deformation due to a pressurized horizontal circular crack in an elastic half-space, with applications to volcano geodesy, Geophys. J. Int., no. 146, 181-190, 2001.

Yang, X., Davis, P. M., and Dieterich, J.H, Deformation from inflation of a dipping finite prolate spheroid in an Elastic Half-Space as a model for volcanic stressing, J. Geophys. Res., vol. 93, no. B5, 4249-4257, 1988.

http://volcanoes.usgs.gov/software/spheroid

KEYWORDS: 8439 VOLCANOLOGY Physics and chemistry of magma bodies, 1211 GEODESY AND GRAVITY Non-tectonic deformation, 1294 GEODESY AND GRAVITY Instruments and techniques, 8494 VOLCANOLOGY Instruments and techniques.

(No Image Selected)
(No Table Selected)

Additional Details
Previously Presented Material:

Contact Details
CONTACT (NAME ONLY): Peter Cervelli
CONTACT (E-MAIL ONLY): pcervelli@usgs.gov
TITLE OF TEAM:

Session: **V44C-06**