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Interactive comment on "The Mohr–Coulomb criterion for intact rock strength and friction – a re-evaluation and consideration of failure under polyaxial stresses" *by* A. Hackston and E. Rutter

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Here we respond to the comments made by referee Blenkinsop. Interactive comment on "The Mohr–Coulomb criterion for intact rock strength and friction – a re-evaluation and consideration of failure under polyaxial stresses" By A. Hackston and E. Rutter T Blenkinsop (Referee) blenkinsopt@cardiff.ac.uk Received and published: 1 February 2016

After presenting a brief summary of the key points made in the paper Prof Blenkinsop poses a number of questions, which we have numbered below for ease of reference. The points are very helpful and all will be taken into account in the preparation of a

revised manuscript.

1) One question is why only the modified Lade and Mogi alternatives were considered. In the paper by Colmenares and Zoback, several other criteria were tested, and the general conclusion was that the modified Wiebols and Cook criterion was a good fit.

The paper is not intended to be a comprehensive testing of all the various failure criteria for various rock types that have been examined by authors such as Colmenares & Zoback (2002), Haimson & Chang (2000, 2002) and Kwaśniewski (2012), for example, which would require a substantial amplification of the treatment, but to focus for comparison on examples of two classes of polyaxial failure criteria – those based on functions of the stress invariants and those that are purely empirical. They predict very different results. From an overview of the analyses of several other authors it is clear that a criterion that might provide a best fit to one rock type may not be the best fit to another, and that this can also apply to the effects of material anisotropy and orientation with respect to the applied stresses. It remains unclear why this should be so and underlines the need for further research on this issue. However, we have tabulated our data in a form that will make it easy for others to test it against other criteria and to compare with other rock types as required.

2) There are also two versions of the Mogi criterion. In neither of these papers is Murrell's (1963, 1965) criterion tested.

We pointed out that there are two versions (1967 and 1971) of Mogi criteria. We did not pursue the second because it predicts extreme effects of the influence of the intermediate principal stress and the unfortunate property that it can make a physically unmeaningful prediction of two different values of maximum stress for a given value of intermediate principal stress, a point also made by Colmenares and Zoback (2002). The failure criterion of Murrell (1965) is based on the classical 'Griffith' failure criterion and is not in a form well suited to this type of analysis.

3) A minor point is the inconsistent terminology used for the test types, which is also a

problem through much of the literature. On page 3845, compression (stress) is used in one case and extension (strain) in the other. These terms are not used consistently: the conclusions refer to axially symmetric shortening. Maybe uniaxially symmetric shortening - as in the paragraph above and the abstract – is a consistent alternative.

4) Page 3847, Lines 4 and 11. The similar equations have different formats.

5) Page 3852, Line 24: should read (sigma1 = sigma2), I think.

Points 3, 4, and 5 are noted and will be corrected in the revised manuscript.

6) Page 3854, lines 10 – 20. It is not quite clear how the three parameters of the Mogi criterion were obtained: were they all simultaneous solved for?

The Mogi criterion fits are obtained by finding the beta value that brings the extension and shortening data onto a common best-fit curve on a log-log plot of maximum shear stress versus modified mean stress (fig.11). The parameters of the plot then provide the values of m and n.

7) Page 3855, lines 23/24. this is an awkward sentence, and I'm not sure of the meaning. Does it mean that when seeking a failure criterion, the influence on anisotropy can not be allowed for?

More care will be taken to clarify this point, which is that as the orientation of an anisotropic specimen is varied with respect to the principal stresses, the form of the best failure criterion to apply may change.

8) Fig. 5. Why do some points on the Pennant sandstone compression (sic) plot not have associated Mohr circles? Likewise for the Darlely Dale extension plot.

This is to avoid overcrowding and loss of clarity if all the Mohr circles were to be shown together will all of the plotted points. The tabulated data allows the consistency of the data to be explored as required.

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