Journal of Structural Geology 36 (2012) 85–87

Contents lists available at SciVerse ScienceDirect

Journal of Structural Geology

journal homepage: www.elsevier.com/locate/jsg

Reply to comment and some questions on “Puzzles and the maximum-effective-moment (MEM) criterion in structural geology”

Yadong Zheng [a,*], Jinjiang Zhang [a], Tao Wang [b]

[a] *The Key Laboratory of Orogenic Belts and Crustal Evolution, Ministry of Education; School of Earth and Space Sciences, Peking University, Beijing 100871, China*
[b] *Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China*

ARTICLE INFO

Article history:
Received 25 November 2011
Received in revised form
6 December 2011
Accepted 11 December 2011
Available online 24 December 2011

Keyword:
Maximum-Effective Moment Criterion

We wish reply to the comment on our publication (Zheng et al., 2011), and would also like to take the opportunity to correct an error in the caption of our Fig. 1: α is wrongly defined as between σ_1 and the *normal* to shear bands/zones, while the correct definition is given in the main text in lines 9–10 on page 1379 which matches the graphical expression shown in Fig. 1.

Our reply to the questions that the commentator rises are as follows:

1. Direction of unit-length L

The commentator claims that the unit-length L direction should be parallel to the direction of pre-existed cleavage. However, the pre-existed cleavage merely implies the deformation in study related to an anisotropic media and the zero-moment related to an applied or external force on the media, which must be located either in the σ_1- or σ_3-direction. In order to obtain the maximum-moment, one of the two zero-moment directions should be taken as the starting point or zero-sum phase. Taking the unit-length in the σ_3 - direction implies that the maximum value of M_{eff} will appear in the directions of $\pm 35.3°$ to the σ_1 - direction. The conjugate angle predicted in this way should be 70.6°, which is the same as the commentator's and similar to the prediction of the slip-line theory of plasticity for uniaxial extensional cases. Although this result can also be obtained mathematically, the predicted orientation with respect to σ_1 departs greatly from observations in nature and experiments (Fig. 1 “of Zheng et al., 2011”) and is, therefore, invalid. Obviously, only the unit-length L in the σ_1 direction can be regarded as the MEM criterion. We do not see any self-contradiction here.

2. Facts speak louder than words

Comparisons are listed in Table 1 between our predictions and the commentator's with the typical cases described in Zheng et al. (2011). It is easy to judge, at first sight, which predictions are consistent with, and which contradict the observations. Besides, in the cases where the σ_1 is oblique to the pre-existed foliation as shown in Fig. 3 (Zheng et al. (2011) and Fig. 1 here), the actual angles are 110° and 108° respectively, which are almost the same as predicted by the MEM criterion.

According to the commentator's theory shown in his Fig. 5, however, only the antithetic shear zones with α-angle more than 35.3° and less than 54.7° to the σ_1-direction might occur. Obviously, the commentator's conclusions are not compatible with these observations and, therefore, are not acceptable. The major reason for the commentator's predictions diverging from the observations is probably that the commentator confined himself strictly to a mathematic analysis and disregarded observations in nature and experiments, so that no single example can be provided in the whole comment to confirm his predictions (Figs. 4 and 5).

DOI of original article: 10.1016/j.jsg.2011.12.003.
* Corresponding author.
E-mail address: ydzheng@pku.edu.cn (Y. Zheng).

0191-8141/$ – see front matter
doi:10.1016/j.jsg.2011.12.004

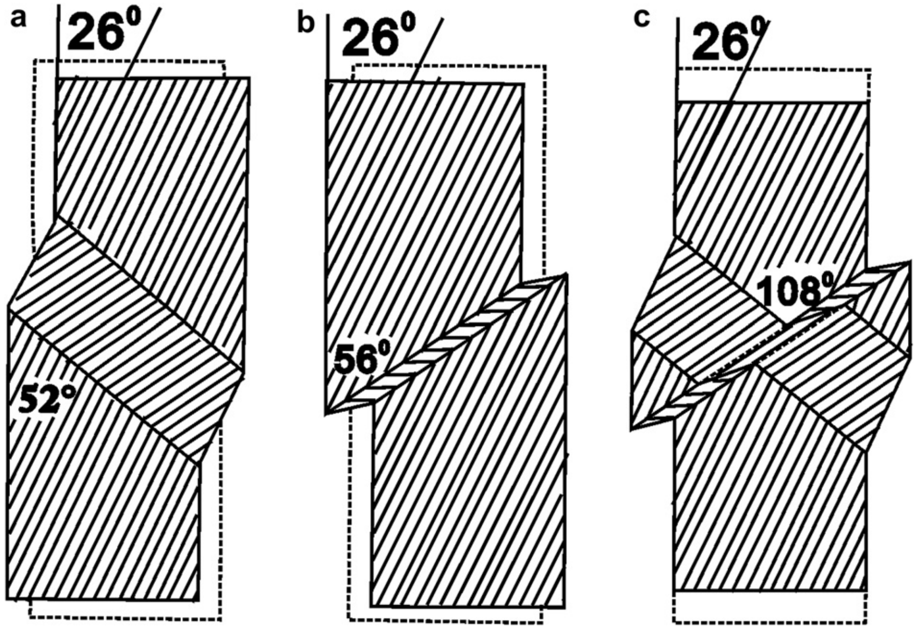

Fig. 1. Axial shortening of foliated body achieved by intersecting kinks: a. right-handed kink; b. left-handed kink; c. conjugate kinks (Paterson and Weiss, 1966).

Table 1
Comparisons between the predictions by the MEM criterion and the commentator's with the typical cases.

Typical case	Conjugate angle in σ_1-direction	Predicted by MEM criterion	Predicted by commentator's theory	Notes
A	109/110°	109/110°	Impossible to predict	Without existed foliation
B	109/110°	109/110°	70.6°	Shortening normal to foliation
C	109/110°	109/110°	70.6°	Shortening normal to bedding
D	109°	109/110°	70.6°	Shortening normal to foliation
E	110°	109/110°	70.6°	Shortening normal to foliation
F	110°	109/110°	70.6°	Shortening normal to foliation
G	110°	109/110°	~70.6°	Shortening normal to foliation
H	113°	109/110°	109.4°	Shortening parallel to bedding
I & J	Obtuse	109/110°	70.6°	Shortening normal to foliation
K	~110°	109/110°	70.6°	Shortening normal to bedding
L	Obtuse	109/110°	70.6°	Shortening normal to foliation

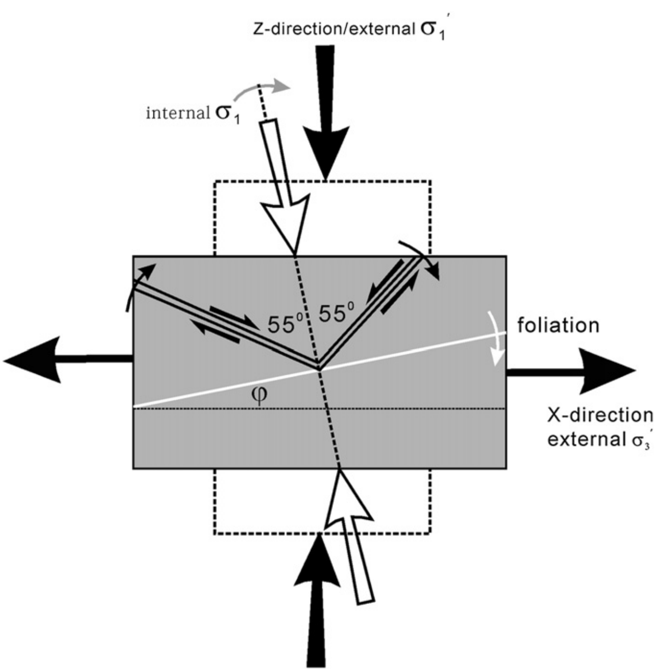

Fig. 2. Conjugate angle rotate **jointly** with layering towards the extension axis (σ_3') during shortening (based on the data of Gomez-Rivas (2008)).

3. 109 or 110°—nearly a material-invariant

Gómez-Rivas's thesis (2008) and Gomez-Rivas and Griera (2011), show: 'In models with oblique anisotropy, both sets of fractures rotate **jointly** with layering towards the extension axis (σ_3). Hence the dextral array rotates **in an opposite sense** than would be expected from the boundary condition' as shown in Fig. 2 and Table 2. Since Gómez-Rivas and Gomez-Rivas and Griera (2011) did not refer to the concept of the MEM criterion, his or their results must be more convincing.

The observations in nature and experiments confirm that the conjugate angle of 109° or 110° has nothing to do with the pre-existed foliation. The unpublished thesis by Gómez-Rivas (2008) and Gomez-Rivas and Griera (2011) provided solid evidence that the value of 109 or 110° is nearly a material-invariant rather than

Table 2
Conjugate angles of new fractures for different φ_0 at different shortening (Based on the data listed in Table 4.3 of Gomez-Rivas (2008).

$\varphi_{0\backslash shortening}$	20%	30%	40%	50%
0°	110°	110°	111°	109°
10°	103°	109°	115°	116°
20°	118°	116°	121°	120°
30°	115°	114°	117°	113°
40°	114°	116°	118°	120°
Mean value	112°	114°	116°	116°

φ_0 – the angle between foliation and X-direction.

what the commentator's concluded, namely that the direction of the maximum-effective-moment is related to the direction of the cleavage. The difference between Figs. 1 and 2 implies that the directions of the two shear zones do depend on whether the deformation partitioning occurs (as in Fig. 2) or not (Fig. 1) (Tikoff and Teyssier, 1994), as a result of anisotropy. However, the conjugate angle essentially remains constant.

Acknowledgement

Thanks to the editor for improving the English. This work was funded by NNSFC (Grant No. 90714006 and No. 40872133).

References

Gómez-Rivas, E., 2008. Localización de deformación en medios dúctiles y anisótropos: studio de campo, experimental y numérico. Tesis doctoral, Universitat Autònoma de Barceloma. (http://www.tesisenxarxa.net/TDX-1120108-151236/).

Gomez-Rivas, E., Griera, A., 2012. Shear fractures in anisotropic materials: an experimental approach. Journal of Structural Geology 34, 61–76.

Paterson, M.S., Weiss, L.E., 1966. Experimental deformation and folding in phyllite. Geological Society of America Bulletin 77, 343–374.

Tikoff, B., Teyssier, C., 1994. Strain modeling of displacement field partitioning in transpressional orogens. Journal of Structural Geology 21, 1497–1512.

Zheng, Y.D., Wang, T., Zheng, J.J., 2011. Puzzles and the maximum effective moment (MEM) criterion in structural geology. Journal of Structural Geology 33, 1394–1405.