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Introduction to the Special Issue on New Dynamics in Palaeostress Analysis

This Special Issue contains papers presented at the New Dynamics in Palaeostress conference held under the auspices of the Tectonic Studies Group of the Geological Society of London in Burlington House on 10th September 2004. The impetus for organising this conference was the rapid developments in the subject that have occurred in the last few years; it is clearly undergoing a renaissance since the formative developments some three decades ago.

There seem to be at least two major aspects of the renewed research. On the one hand theoretical developments in analysing and visualising stress in the context of the Earth have been influential in preparing for the new dynamics. For example, although the concept of the reduced stress tensor has been used in palaeostress analysis for many years (e.g. Angelier, 1975), it is the linearisation of the problem that underlies several recent developments (e.g. Fry, 1999, 2001; Shan et al., 2003). New ways to measure and compare properties of the stress tensor are being developed (Orife and Lisle, 2003). Visualisation of stress space has also been addressed (e.g. Fry, 1999).

On the other hand, the problem of identifying homogeneous stress states from heterogeneous data has been tackled with increasing rigour and objectivity by both graphical and analytical schemes (e.g. Simón-Gómez, 1986; Huang, 1988; Hardcastle and Hills, 1991; Fry, 1992; Célérier, 1995; Yamaji, 2000; Nemcok and Lisle, 1995; Nemcok et al., 1999; Célérier and Séranne, 2001; Shan et al., 2003, 2004). A very interesting question is the extent that these methods can be successful without additional constraints (Liesa and Lisle, 2004).

Many attempts to separate stress tensors are driven partly by the need to solve tectonic problems, which has also given rise to developments such as methods that deal with faults without striations (e.g. Lisle et al., 2001; Orife et al., 2002). Testing methods with artificial data sets, and comparing results to those expected from random distributions of faults, are useful methods in evaluating new methods, but natural data sets will always be the ultimate challenge, especially since there are few, if any, situations in which complex stress histories can be accurately reconstructed from independent evidence. This is the ultimate test for fault slip analysis, which still needs to be made.

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Alternative methods of palaeostress analysis include twinning, the application of fracture mechanics, microboudinage and other materials-science based methods. Although we can look forward to further interesting theoretical developments in fault slip analysis, the results of this compilation hint that some of the best applications in the future are likely to integrate a variety of methods together. Examples could include the use of radiogenic and possibly stable isotopes to constrain ages of faulting, the use of additional field constraints on states of stress from fracture analysis and twinning, and the integration of seismological and geodetic results.

As the subject matures, it is to be hoped that palaeostress analysis will increasingly become a standard geological tool, in much the same way as strain analysis or balanced cross-sections are routine, rather than an esoteric preserve of the initiated. A desirable goal would be to integrate detailed palaeostress analysis with kinematic analyses and numerical modelling to produce a full understanding of mechanics on increasingly large scales.

Palaeostress analysis has some important practical applications. The mineral exploration industry can benefit from palaeostress analysis (e.g. Miller and Wilson, 2004), especially when combined with numerical modelling, in which the appropriate stress field for the model has not always been quantitatively constrained. Palaeostresses are most important in the understanding of hydrocarbon exploration. Groundwater flow pathways, patterns of fault slip and seismic and volcanic hazard assessment are also critically affected by palaeostress analysis: all of these are central in the search for nuclear waste disposal sites.

A vigorous debate has ensued for many years over whether fault slip analysis results should be construed in terms of stress, strain or strain rate (e.g. Marrett and Allmendinger, 1990; Twiss and Unruh, 1998; Gapais et al., 2000). There seems to be some confusion about the philosophy behind different methods of fault slip analysis and the structural geology community has a lot to learn from our more geophysically inclined colleagues who deal with both dynamic and kinematic problems at the Earth's surface today.

Palaeostress and fault slip analyses in general will probably undergo further rapid developments in the near future. Certainly a variety of proposals need further testing and they need to be formulated in such a way that they can be used routinely by the non-specialist structural geologist. A keen appreciation of goals and limitations of the methods is needed. Communication is therefore an important aim for the practitioners of the subject.

The 16 contributions in this SI have been grouped into four sections on:

1. Measurement errors and data quality in fault slip analyses
2. Separation of palaeostress tensors
3. Fault slip analyses from the field
4. Other palaeostress techniques

References

Angelier, J., 1975. Sur l'analyse de mesures recueillies sans des sites faillés: l'utilité d'une confrontation entre les méthodes dynamiques et cinématiques. Comptes Rendus de l'Académe des Sciences, Paris D281, 1805–1808.

Célérier, B., 1995. Tectonic regime and slip orientation of reactivated faults. Geophysical Journal International 121, 143–161.

Célérier, B., Séranne, M., 2001. Breddin's graph for tectonic regimes. Journal of Structural Geology 23, 789–801.

Fry, N., 1992. Stress ratio determinations from striated faults: a spherical plot for cases of near-vertical principal stress. Journal of Structural Geology 10, 1121–1131.

Fry, N., 1999. Striated faults: visual appreciation of their constraint on possible palaeostress tensors. Journal of Structural Geology 21, 7–21.

Fry, N., 2001. Stress space: striated faults, deformation twins, and their constraints on palaeostress. Journal of Structural Geology 23, 1–9.

Gapais, D., Cobbold, P.R., Bourgeois, O., Rouby, D., de Urreiztieta, M., 2000. Tectonic significance of fault-slip data. Journal of Structural Geology 22, 881–888.

Hardcastle, K.C., Hills, L.S., 1991. BRUTE3 and SELECT: Quickbasic 4 programs for determination of stress tensor configurations and separation of homogeneous populations of fault-slip data. Computers & Geosciences 17, 23–43.

Huang, Q., 1988. Computer-based method to separate heterogeneous sets of fault-slip data into sub-sets. Journal of Structural Geology 10, 297–299.

Liesa, C.L., Lisle, R.J., 2004. Reliability of methods to separate stress tensors from heterogeneous fault-slip data. Journal of Structural Geology 26, 559–572.

Lisle, R.J., Orife, T., Arlegui, L., 2001. A stress inversion method requiring only fault slip sense. Journal of Geophysical Research 106 (B2), 2281–2289.

Marrett, R., Allmendinger, R.W., 1990. Kinematic analysis of fault-slip data. Journal of Structural Geology 12, 973–986.

Miller, J.McL., Wilson, C.J.L., 2004. Structural analysis of faults related to a heterogeneous stress history: reconstruction of a dismembered gold deposit, Stawell, western Lachlan Fold Belt, Australia. Journal of Structural Geology 26, 1231–1256.

Nemcok, M., Lisle, R.J., 1995. A stress inversion procedure for polyphase fault/slip data sets. Journal of Structural Geology 17, 1445–1453.

Nemcok, M., Kovac, D., Lisle, R.J., 1999. Stress inversion procedure for polyphase calcite twin and fault/slip data sets. Journal of Structural Geology 21, 597–611.

Orife, T., Lisle, R.J., 2003. Numerical processing of palaeostress results. Journal of Structural Geology 25, 949–957.

Orife, T., Arlegui, L., Lisle, R.J., 2002. DIPSLIP: a QuickBASIC stress inversion program for analyzing sets of faults without slip lineations. Computers & Geosciences 28, 775–781.

Shan, Y., Suen, H., Lin, G., 2003. Separation of polyphase fault/slip data: an objective-function algorithm based on hard division. Journal of Structural Geology 25, 829–840.

Shan, Y., Li, Z., Lin, G., 2004. A stress inversion procedure for automatic recognition of polyphase fault/slip data sets. Journal of Structural Geology 26, 919–925.

Simón-Gómez, J.L., 1986. Analysis of a gradual change in stress regime: example from the eastern Iberian Chain. Tectonophysics 124, 37–53.

Twiss, R.J., Unruh, J.R., 1998. Analysis of fault slip inversions; do they constrain stress or strain rate? Journal of Geophysical Research 103 (B6), 12205–12222.

Yamaji, A., 2000. The multiple inverse method: a new technique to separate stresses from heterogeneous fault-slip data. Journal of Structural Geology 22, 441–452.

Tom Blenkinsop*
School of Earth Sciences James Cook University
Townsville, QLD4811, Australia
E-mail address: thomas.blenkinsop@jcu.edu.au

Richard Lisle
School of Earth, Ocean & Planetary Sciences
Cardiff University, Cardiff CF10 3YE, UK

David Ferrill
CNWRA Southwest Research Institute
6220 Culebra Rd., San Antonio TX 78232, USA
E-mail address: dferrill@swri.edu

* Corresponding author.