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Report on a meeting of the Tectonic Studies Group on paleostresses and fault systems

RICHARD J. LISLE

Department of Earth Sciences, University College of Swansea, Swansea SA2 8PP, U.K.

ON 28th February, 1987 a meeting was organized at University College, Swansea, to discuss the latest developments in the methodology of paleostress determination. The theme of the meeting was slanted towards the determination of the principal stress directions using the orientation of structures such as fractures and stylolites from areas of little or no penetrative deformation.

Recent years have seen the proliferation of new techniques for the analysis of data from conjugate fault pairs with a relationship to principal stresses postulated by Anderson (1951), tension gashes and stylolitic surfaces. A major advance came with the realization that fault data need not be restricted to Andersonian faults possessing a simple relationship to the principal stresses but can include that from pre-existing faults which have undergone renewed slip in response to later superimposed stresses. The data from the latter category of faults have to include more than the fault orientation alone, since the attitude of a pre-existing fault will be independent of the orientation of the later imposed stress field. As Bott (1959) pointed out, it is the direction of slip on such oblique-slip faults that relates to the configuration of the imposed stresses. This means that slip direction data such as striations and other slickenside lineations contain vital information about the stress state at the time of slip on the fault and, if analyzed in conjunction with similar data from other faults involved in synchronous movement, can be used to estimate the orientation of the principal stresses. The possibility of deducing stresses in this way was pointed out by Arthaud (1969) who was a pioneer of this type of interpretation or 'striation analysis', as it has become known. In the seventies other methods of striation analysis were devised, more general in their theoretical foundation than Arthaud's technique. In certain of these, the data were processed numerically (e.g. Carey & Brunier 1974, Angelier 1975) in others the treatment was graphical (Angelier & Mechler 1977). More significantly, some of these improved techniques provided additional information about the stress tensor in addition to orientations of the principal stresses. This supplementary data consist of a ratio (*R or* Φ) expressing the 'shape' of the stress within a spectrum ranging from axial compression at one end to axial extension at the other (Lisle 1979). These methods have been widely used for the dynamic interpretation of structures in a variety of neotectonic areas from the Aegean to Taiwan.

The first session of the Swansea meeting was concerned with the techniques of striation analysis, with *Angelier,* in a keynote paper, giving a comprehensive and masterly review of available methods. As the programme (below) shows, several innovations in striation analysis methodology were described in this session.

In the second session, a different but complementary aspect of paleostress estimation was discussed. The study of microstructure, in contrast to striation analysis, offers the potential of estimating stress magnitude. In their keynote paper, *Rutter and Rowe* described a new method of estimating stress magnitude from the intensity of calcite twinning using data from experimentally deformed calcite rocks for the purpose of calibration. They applied the method to overthrusted limestones in Cantabria, N. Spain. From the same geographical area, *Blenkinsop and Drury* used microstructures in quartz to determine the stress history of a fault zone. The remaining talks in this session dealt with regional stress patterns. *Stel* deduced such a pattern in E. Spain from the orientations of stylolitic surface, *Turner* deduced a heterogeneous stress field from S. Pyrenean fracture orientations and related the stress fields to thrust fronts and *Andrews* discussed the problems of explaining a deduced stress field within the San Andreas Fault zone to the larger scale configuration of fault-blocks in Southern California.

In the third session, *Hancock*'s keynote paper reviewed field methods of classifying joints into sets or spectra. Only after joints had been grouped into genetic classes could stress directions be inferred. The programme was completed with talks on regional paleostress surveys (*Quirk, James and Ding, Ribeiro*) and on comparisons of stresses inferred from joints with contemporary stresses known from *in situ* measurements (*Hyett, Engelder*).

The papers and posters presented are listed below.

1st Session

J. Angelier (Paris). Stress-paleostress reconstructions using fault slip data.

J. L. Simon-Gomez and A. M. Casas-Sainz (Zaragoza). The *y–R* diagram: a new technique for fault analysis.

J. Kaper (Kateco, Weesp, Netherlands). Teccomp stress analysis system: a new computerized approach for studying fault systems.

R. Clayton (Provo, Utah). A stress field rotation determined from slickensides in an area of unusual fault patterns, S.W. Utah, U.S.A.

J. Guimerà and J. Amigó (Barcelona). Two examples of a continuous and progressive variation of a stress field from fault striation analysis.

F. Schrader (Bonn). Stress field determination from associations of shearing joints.

Z. Reches (Jerusalem). Direct method to determine the stress tensor from fault slip data.

2nd Session

E. Rutter and K. Rowe (London). Calibration and use of the calcite twinning paleopiezometer.

T. G. Blenkinsop (Keele) and M. R. Drury (Utrecht). The propagation mechanism and stress history of a fault determined from quartz microstructures.

H. Stel (Amsterdam). Paleostresses along faults in the Alicante Fold and Thrust Belt.

J. Turner (Bristol). Paleostress domains controlled by thrust front location in the S.W. Pyrenean Foreland Basin.

J. Andrews (Southampton). Stress fields associated with the San Andreas Fault, Mecca Hills, S. California.

3rd Session

P. Hancock (Bristol). Joint sets and spectra as stress indicators.

D. Quirk (Leicester). Stress history and mineralization in the S. Pennine Orefield.

P. James and P. Ding (Adelaide). Paleostress analysis of basement fractures from the E. Antarctic coastline between Mawson and Molodezhnaya: evidence for the style of continental break up between Antarctica and Peninsular India.

A. Ribeiro (Lisbon). Three-dimensional theories of rock faulting.

A. Hyett (London). The refraction of regional stresses by major fault systems.

T. Engelder (Pennsylvania). A comparison of deduced paleostress with current *in situ* stress in the N.E. United States.

Posters

E. Barrier and J. Angelier (Paris). Consistency between present stress and paleostress: seismotectonics and fault analysis in Taiwan.

F. Bergerat and J. Angelier (Paris). Minor faults in platform areas: a key to large-scale tectonics.

R. Capote and G. de Vicente (Madrid). Stress and strain evolution of the late-Hercynian tectonics in the Spanish central system.

B. Colletta, I. Moretti and J. Letouzey (Rueil Malmaison). Paleostress analysis in the Suez Rift.

G. de Vicente (Madrid). The 'slip model' and the *e/K* diagram.

P. Laurent (Montpellier). Determination of stress tensors from *e* twin lamellae in calcite in the southern border of the Rhine graben. Comparison with fault striation analyses.

M. Lespinasse (Nancy). Microfracturing and fluid inclusion trails: a tool for regional stress chronology.

M. R. Salih and R. J. Lisle (Swansea). Stresses from striation analysis in faulted Coal Measures at Ffos Las, S. Wales.

W. Sassi and E. Gailhardis-Carey (Paris). Mechanical interpretation of slip data in fault tectonics: introduction of a friction law to the Carey and Brunier model.

T. Villemin, J. Angelier and C. Sunwoo (Paris). Distribution of fault-fracture patterns: orientation, density, offset, length and spacing.

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