ELSEVIER

Journal of Structural Geology 28 (2006) 1891–1892

JOURNAL OF STRUCTURAL GEOLOGY

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Preface

Tectonic inversion and structural inheritance in mountain belts

Collisional mountain belts are the product of deformation of former continental margins. During the past 20 years it has become increasingly evident that the pre-existing faults, basin structures and the stratigraphic variations they generate can play a significant role in influencing the structural evolution of later compressional tectonics. This Special Issue contains a collection of papers that explore how this type of geological inheritance is manifest in the structural evolution of continental crust, especially associated with orogenesis. It arises from the one-day symposium (G23.03) on “Tectonic inversion processes and structural inheritance in mountain belts” held at the 32nd International Geological Congress in Florence, August 2004, that attracted some 31 oral and poster presentations. The papers here are a selection of those presented in Florence together with others on the same theme that have matured over the same period. Although this is the first such selection to be published in the *Journal of Structural Geology*, all the papers presented here build upon a legacy that includes earlier compilations. In this regard, two Special Publications of the Geological Society, London (Cooper and Williams, 1989; Buchanan and Buchanan, 1995) have been especially influential. Further inversion tectonic concepts are reviewed by Coward (1994). However, these collections have only briefly touched on the application of inversion tectonic models to mountain belts.

The symposium at IGC and the collection of papers here are timely as it is increasingly being realised that the hitherto popular “thin-skinned” structural models, where deformation in the sedimentary cover is considered to be extensively decoupled from the rest of the lithosphere, are of limited application. Different mountain belts, or even different parts of the same mountain belt, can show different patterns of strain localization and variable styles of deformation (see Mazzoli and Butler, 2006). New insights on well-studied mountain belts are offered from deep reflection seismic surveys, better-located earthquake foci and geodetic data. Additionally, a range of potential analogue structures from areas of relatively low contraction in sedimentary basins have been imaged in the pursuit of hydrocarbon resources that offer new perspectives on some thrust structures in mountain belts. But often the key insight has arisen through the better integration of stratigraphic data into structural models, together with the increased enthusiasm amongst some dynamic stratigraphers to work on complexly deformed sections. Commonly the best evidence for pre-existing structures that might have influenced orogenic structures is to be found in the stratigraphic record. Thus multidisciplinary approaches yield surprising results beyond the reach of specialised deformation studies alone.

The 16 papers in this special edition offer a range of different multidisciplinary approaches that illustrate structural inheritance in mountain belts. They provide a good flavour of the topics presented at the IGC symposium and offer a useful introduction to the subject.

Butler, Tavarnelli and Grasso set the scene with an overview of the inversion concepts as they may apply to orogenic systems drawing on examples from the Apennine–Alps system. They examine inheritance across a range of scales, examining the influence of pre-existing faults, before exploring how different models of continental rheology may be reflected in styles of inversion tectonics. The role of pre-existing faults on structural evolution of thrust systems is commonly only evident from restored sections. This approach is adopted by Saura and Teixell in their analysis of structural evolution of the southern margin of the axial zone of the Pyrenees. They show that basement structures are located by border faults to Permo-Carboniferous basins and that lateral variations in these early structures are manifest in rotations and along-strike complexity in the thrust systems. Three-dimensional complexities and their origin in complex inversion of early normal faults also form the theme of the structural study of the evolution in the Cordillera Oriental of the Argentinean Andes by Carrera, Muñoz, Sàbat, Mon and Roca. The interplay between detachment-dominated and basement-involved contraction is explored using the Cape fold belt of South Africa by Paton, Macdonald and Underhill. Linking onshore and offshore geology via seismic profiles they deduce a complex history of inversion through the Mesozoic. Polyphase reactivation is also the theme of the study of the Gubbio Fault in the Apennines by De Paola, Mirabella, Barchi and Burchielli. The special tectonic setting means that the fault zone has experienced repeated extension, contraction and extension along the same kinematic axis.

Crustal scale applications of inversion concepts link the next suite of papers. El Harfi, Guiraud and Lang integrate geophysical and geological data to reinterpret the deep structure of the High Atlas of Morocco. They adopt a “thick-skinned” model where basement and cover structures are directly coupled through inversion of Mesozoic basin structures. Basement involvement is also the theme followed by Mouthereau and Lacombe in their re-interpretation of the active fold-thrust

0191-8141/$ - see front matter
doi:10.1016/j.jsg.2006.09.001

system of western Taiwan. Variations in structural style both across and along strike are related to different availability of pre-existing structures.

In active settings and on a crustal scale, understanding which faults are prone to reactivation can be important for assessing earthquake hazard. This theme underscores the study of active thrusting in NW South Island, New Zealand by Ghisetti and Sibson. New thrust segments are deduced to form short-cuts from steep, reactivating normal faults and these geometries thought to control seismic rupturing in the middle crust. Kato, Sato and Umino are also motivated to understand seismogenic faulting, applying reactivation models to the back-arc rift basin in northern Honshu, Japan. They link earthquake focal determinations, seismic reflection profiles and balanced cross-sections to demonstrate a complex pattern of inversion, reactivation and thrust short-cuts of Miocene extensional faults.

Contractional deformation in zones of oblique continental convergence can be manifest by complex structural styles. In this regard, pre-existing structures can control the degree of strain partitioning during regional transpression. This theme is picked up by Zanchi, Berra, Mattei and Sabouri in their study of the central Alborz range. They conclude that the modern structural activity is profoundly controlled by pre-existing structures inherited from basin faults created in the foredeep to the Triassic Cimmerian orogenic belt. Oblique inversion of pre-existing basin faults is also a theme followed by Quintana, Alonso, Pulgar and Rodríguez Fernández in an examination of the Basque–Cantabrian basin on NW Spain. They show that a Mesozoic fault that compartmentalized extensional basin formation subsequently controlled strain partitioning during Alpine compression, locally manifest by buttressing and complex fault zone kinematics. On a larger scale, Schattner, Ben-Avraham, Lazar and Hüebscher examine the role of structures that define the continental margin in the Eastern Mediterranean in the distribution of transpression along the Levant, associated with the Dead Sea Fault system.

Two papers deal with insights gained from analogue experiments. Del Ventisette, Montanari, Sani and Bonini continue the theme of oblique inversion by showing the results of sand-box models designed to mimic deformation above salt. In contrast Ravaglia, Seno, Toscani and Fantoni use more complex, layered models to mimic the structural complexities displayed by the buried thrust front to the southern Alps, beneath the Po plain.

The final two papers in the Special Issue use unusual methods to explore structural inheritance, especially using highly limited data to deduce tectonic history. Vos, Bierlein, Barlow and Betts use a variety of geophysical data to image the Palmerville Fault in NE Australia. They deduce that this structure, which controls late Palaeozoic crustal shortening, originated as a major basin-bounding fault during the early–middle Palaeozoic. The study forms a dramatic counterpoint to the approach followed by Eyal, Osadetz and Feinstein in their investigation of the Okanagan core-complex in the Canadian Rocky Mountains. Here the challenge lies in up-scaling outcrop scale observations to deduce larger-scale tectonics. The authors use the kinematics of reactivated three-dimensional arrays of joints to deduce the evolution of stress regimes.

In summary, the collection of papers in this Special Issue offer a range of new structural interpretations, some applied to well-known tectonic settings, some to novel regions. Thus, although many of the concepts of inversion tectonics are well-established, these papers should promote further tests and applications of these ideas in particular and in the application of structural geology to illuminate models of continental deformation in general.

Acknowledgements

We are grateful to the organizing committee of the 32nd International Geological Congress at Florence for their support and Rod Graham for giving a stimulating invited lecture placing inversion concepts in their historical and commercial context. We also wish to thank the JSG Editor, Bob Holdsworth and all the reviewers of papers considered for this special edition for their assistance namely: Mark B. Allen, Ian G. Alsop, Andy Barnicoat, Jan kees Blom, Marco Bonini, Fernando Calamita, Riccardo Caputo, Peter Cobbold, Cristiano Collettini, Chris Elders, Dominique Frizon de Lamotte, Francesca Ghisetti, Giovanna Giorgetti, Scott D. Giorgis, Gabriel Gutiérrez-Alonso, Martin Hand, Robert E. Holdsworth, Hemin A. Koyi, Carmelo Monaco, Chris K. Morley, Josep Anton Muñoz, Alan E.M. Nairn, David C.P. Peacock, Martyn H. Pedley, Claus D. Reuther, Silvio Seno, Rick Sibson, Fabrizio Storti, Sarah E. Tindall, Luigi Tortorici, Pierre Tricart, Gian Battista Vai, Chris Wibberly, John walsh.

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Available online 12 October 2006