Journal of Structural Geology 64 (2014) 135–148

Contents lists available at ScienceDirect

Journal of Structural Geology

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

Extension and gold mineralisation in the hanging walls of active convergent continental shear zones

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ARTICLE INFO

Article history:
Received 14 February 2013
Received in revised form
7 August 2013
Accepted 8 August 2013
Available online 3 September 2013

Keywords:
Gold
Structure
Extension
Tectonics
Stress field
Convergent orogen

ABSTRACT

Orogenic gold-bearing quartz veins form in mountain belts adjacent to convergent tectonic boundaries. The vein systems, hosted in extensional structures within compressively deformed rocks, are a widespread feature of these orogens. In many cases the extensional structures that host gold-bearing veins have been superimposed on, and locally controlled by, compressional structures formed within the convergent orogen. Exploring these observations within the context of a three-dimensional mechanical model allows prediction of mechanisms and locations of extensional zones within convergent orogens. Our models explore the effect of convergence angle and mid-crustal strength on stress states and compare them to the Southern Alps and Taiwan. The dilatation zones coincide with the highest mountains, in the hanging walls of major plate boundary faults, and can extend as deep as the brittle–ductile transition. Extensional deformation is favoured in the topographic divide region of oblique orogens with mid-lower crustal rheology that promotes localisation rather than diffuse deformation. In the near surface, topography influences the stress state to a depth approximately equal to the topographic relief, bringing the rock closer to failure and rotating σ_1 to near vertical. The distribution of gold-bearing extensional veins may indicate the general position of the topographic divide within exhumed ancient orogens.

1. Introduction

Orogenic gold deposits have formed in convergent orogens throughout geological time, and are still forming in modern orogens (Bierlein and Crowe, 2000; Craw et al., 2002; Goldfarb et al., 2005; Groves et al., 1998, 2003). These gold deposits are hosted in a wide range of lithologies in primarily greenschist facies metamorphic rocks that have undergone compressional deformation (Bierlein and Crowe, 2000; Goldfarb et al., 2005; Groves et al., 1998, 2003). Most of these orogenic gold deposits are dominated by quartz veins that have filled dilational structural sites in compressively-deformed host rocks (Allibone et al., 2002; Cox et al., 1995; Kontak and Horne, 2010; MacKenzie et al., 2008; Sibson et al., 1988; Witt and Vanderhor, 1998). Many of these extensional structures formed locally during compressional deformation (Cox et al., 1995; Goldfarb et al., 2005; Witt and Vanderhor, 1998). In addition, structures that form in a regional extensional stress regime, within regionally compressively-deformed rocks, are widespread features in orogenic gold deposits (Bierlein and Crowe, 2000; Goldfarb et al., 2005; Vielreicher et al., 2010; Witt and Vanderhor, 1998). These structures include normal faults and steeply dipping extensional vein arrays, with dilational openings on the centimetre to metre scale, and the structures commonly postdate, and overprint, compressional structures.

This common occurrence of regional-scale superimposition of structures formed in an extensional stress regime on compressionally-deformed rocks in orogenic gold systems does not require changes in tectonic plate vectors, although plate tectonic vectors have apparently changed in some ancient settings (Allibone et al., 2002; Goldfarb et al., 1991). Instead, on-going transfer of rocks from a compressional regime to an extensional regime within the same orogen (Craw et al., 2002; Koons, 1995; Koons et al., 1998; Phillips and Powell, 2009; Upton et al., 2009a) can achieve the same end result. This process is different from the more localised changes in stress orientation at the local scale (metres to hundreds of metres) including variations in the interactions between different lithologies and structures (Cox et al., 1995; Upton et al., 2008; Witt and Vanderhor, 1998), or from variations in fluid pressures (Ridley, 1993; Sibson et al., 1988).

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0191-8141/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jsg.2013.08.004

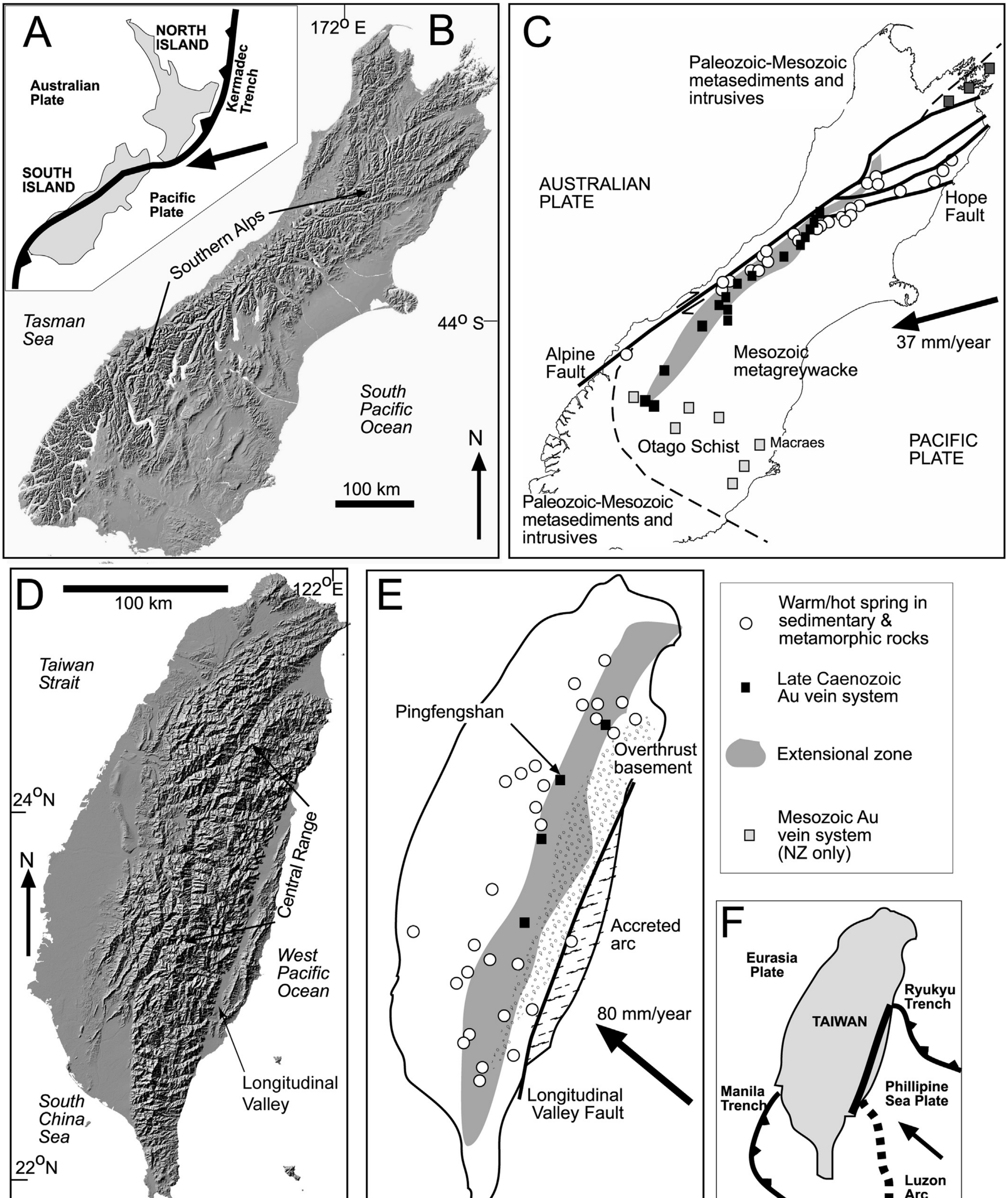

Fig. 1. A: Plate tectonic setting of New Zealand. B: Hillshade map of the South Island of New Zealand showing the Southern Alps. Elevations range from 0 to 3754 m. C: Map of the South Island showing major active faults, relative plate motion from DeMets et al. (1994), Mesozoic and late Caenozoic gold bearing veins, hot springs, and the region of the Southern Alps where extensional structures are found. D: Hillshade map of Taiwan. Elevations range from 0 to 3952 m. E: Map of Taiwan showing late Caenozoic gold bearing veins, hot springs, and the region of the Central Ranges where extensional structures are found. F: Plate tectonic setting of Taiwan.