Journal of Structural Geology 67 (2014) 235–252

Contents lists available at ScienceDirect

Journal of Structural Geology

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

Modeling 3D crustal structure in Lachlan Orogen, Victoria, Australia: Implications for gold deposition

Christopher J.L. Wilson [a,*], Lawrence D. Leader [b]

[a] School of Geosciences, Monash University, Clayton, Vic 3800, Australia
[b] Central Petroleum, 56-58 Jephson Street, Toowong, Queensland 4066, Australia

A R T I C L E I N F O

Article history:
Received 5 February 2013
Received in revised form
19 December 2013
Accepted 3 January 2014
Available online 22 January 2014

Keywords:
Faults
Numerical modeling
Strain
Fluid flow
Gold mineralization
Lachlan orogen

A B S T R A C T

We use numerical simulations to identify sites of dilation and areas of high, shear strain and fluid flow that may be related to gold deposition in faults that transect the western sub-province of the Lachlan Orogen. Our results can explain how a late tectonic history consisting of a switch from east–west compression to north–south transpression contributes to the formation of gold deposits in association with late fault movements. The models simulate incremental east–west shortenings of 4% and a superimposed 1% north–south shortening on major crustal-scale (intrazonal) faults and suggest that strain and fluid flow was greatest in the shallow-dipping fault segments (first order faults) that lie within the mafic rocks of the lower crust. The areas above the shallow-dipping segments of intrazonal faults (second order) become sites for the initiation of later (third-order) faults and fracture networks, within the higher-level metasedimentary rocks, strain decreases in the steeper segments of the intrazonal faults. These second-order faults are inferred to act as highly permeable channel-ways for fluid discharge and it is their geometry and a shift from east–west reverse-dip-slip to north–south reverse-oblique-slip fault kinematics that controls the final distribution of gold mineralization in the folded metasedimentary rocks. Changing the direction of principle compression, has a dramatic effect on the extent and location of volumetric strain (dilation) and fluid flow with localized deformation within bedding-parallel veins dispersing fluid flow. Increased dilation facilitates the influx of gold-bearing fluids that in combination with a fault–fracture network, and geochemical factors, have led to significant amounts of localized gold mineralization.

1. Introduction

Faults are considered to represent by far the most important fluid pathway responsible for gold deposition in the western sub-province of the Paleozoic Lachlan Orogen in Victoria, Australia (Fig. 1A). Most of the Victorian goldfields are hosted in strongly deformed and very low porosity greenschist facies metamorphic rocks (Miller et al., 2006; Wilson et al., 2009a), in which permeable faults formed by linking and reactivation of discrete fractures which acted as fluid pathways (Cox, 2005; Leader et al., 2012). Two geodynamic features of note in this western sub-province are the lithospheric crustal and thermal structures. Results from seismic reflection data pertaining to this portion of the Lachlan Orogen (Fig. 1) have been described by Willman et al. (2010) and provide high-resolution images of deep-crustal structures that can be linked to known gold deposits in the folded and faulted metasedimentary rocks. The events identified from the metamorphic-structural record and detailed geochemical and isotopic analyses suggest a high geothermal gradient is linked to heat producing granites in the upper crust (Gray, 1990) and to high-temperature–low pressure regional metamorphism (Phillips and Powell, 2010) that existed below crustal depths of 12–15 km, where potential sources for upper crustal gold deposits may occur.

Gold deposits were not only related in space and time to the structural development of their host rocks (Miller et al., 2006), but also were an integral part of the thermal and rheological history of deformation occurring at deeper crustal levels. The characteristics of the Victorian gold deposits, and their development in a pressure–temperature deformation framework have recently been discussed by Fu et al. (2012) and Wilson et al. (2013). However, gold mineralization is only one facet of a massive transfer of volatiles and solutes from deep-crustal levels through middle and upper crustal levels via fault and fracture networks. The source of gold and the by-products from the fluids is thought to be predominantly external to their present location and generally related to crustal-scale faults (Willman et al., 2010; Wilson et al., 2013).

* Corresponding author. Tel.: +61 399055764; fax: +61 3 99054903.
E-mail address: Chris.Wilson@monash.edu (C.J.L. Wilson).

0191-8141/$ – see front matter
http://dx.doi.org/10.1016/j.jsg.2014.01.007

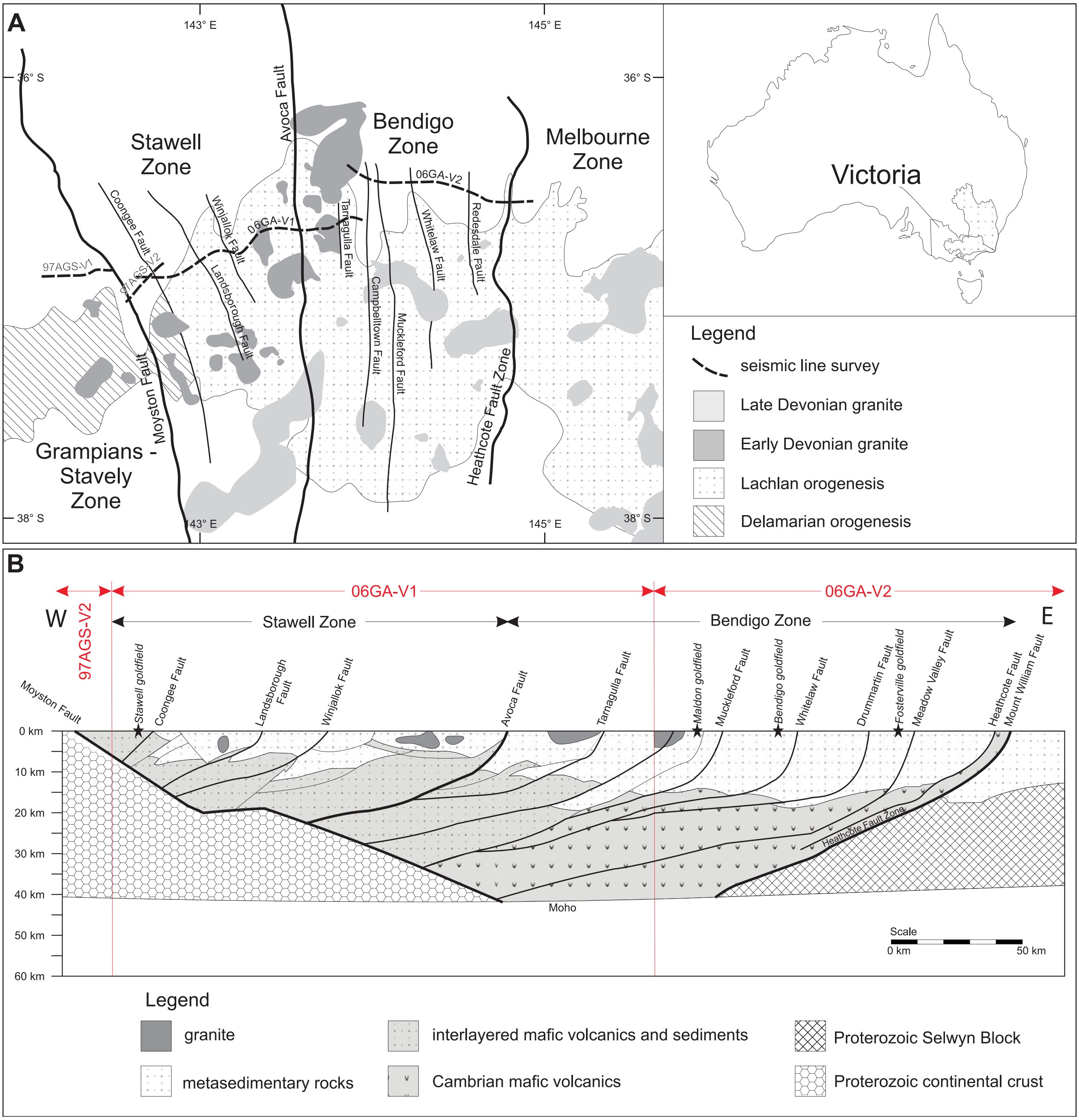

Fig. 1. Map and cross-section of the western sub-province of the Lachlan Orogen in central Victoria. (A) Distribution of the major geological units and the major intrazone faults of the Stawell and Bendigo Zones (after VandenBerg et al., 2000). The location of seismic lines 97AGS-V1, 97AGS-V2, 06GA-V1 and 06GA-V2 of the 1997 and 2006 deep-crustal seismic surveys is also shown. (B) Geologic interpretation from the seismic surveys of Korsch et al. (2002), Cayley et al. (2011) and the location of major goldfields within the Stawell and Bendigo Zones.

The Victorian gold province, regarded as a classic 'orogenic' gold province (e.g. Willman et al., 2010), has been disturbed numerous times by bounding and internal tectonic events. High-grade gold mineralization occurs after major east–west shortening and associated folding and major reverse faulting events (Willman, 2007). Each event may involve the pumping of hundreds of thousands of cubic km of fluids into and out of the crust, from depths of 12 or more km (Willman et al., 2010). Many workers have investigated the effects of fluid infiltration and accompanying mineralization within a fault zone and into secondary low-displacement faults and fold structures developed within the footwall and hangingwall of major crustal faults (e.g. Sibson, 1996; Faulkner and Rutter, 2003; Leader et al., 2012). The discharge of such fluids allows hydrothermally induced failure under low normal effective stresses (Sibson, 1996; Gessner, 2009) accompanied by the development of hydrothermal alteration assemblages (Dugdale et al., 2006, 2009). Recent modeling studies of sites of fluid advection in the Victorian crust (e.g. Schaubs et al., 2006; Robinson et al., 2006) have focussed