Journal of African Earth Sciences 97 (2014) 9–18

Contents lists available at ScienceDirect

Journal of African Earth Sciences

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

Significant shortening by pressure solution creep in the Dwyka diamictite, Cape Fold Belt, South Africa

Åke Fagereng *

Department of Geological Sciences, University of Cape Town, Rondebosch 7701, South Africa

ARTICLE INFO

Article history:
Received 28 January 2014
Received in revised form 25 April 2014
Accepted 28 April 2014
Available online 9 May 2014

Keywords:
Folds
Diamictite
Karoo
Fold-and-thrust belt
Pressure solution

ABSTRACT

The Dwyka diamictite preserves a record of horizontal shortening related to the development of the Cape Fold Belt at subgreenschist conditions. This shortening was accommodated by folding and thrust faulting, but pressure solution may also have contributed significantly to bulk deformation. Cleavage within the Dwyka group is, in the studied part of the Karoo Basin, subvertical to moderately south dipping, and approximately axial planar to regional folds. The cleavage is anastomosing, leading to the development of 'tombstone cleavage', and defined microscopically by thin seams of fine grained dark material. X-ray diffraction analyses show that the diamictite matrix is made up of quartz, feldspars, muscovite and chlorite. Element maps further indicate that the cleavage is defined predominantly by phyllosilicates and minor oxides, implying that it is made up of relatively insoluble material and hydrothermal alteration products. Overall, the cleavage therefore formed by dissolution and removal of mobile elements. This indicates that pressure solution likely accommodated a significant component of shortening during the Cape Orogeny, and provides an example of low temperature cleavage development during orogenesis.

1. Introduction

On short time scales, the upper crust deforms by high strain rate brittle deformation (Byerlee, 1978; Sibson, 1983; Kohlstedt et al., 1995); whereas on longer time scales, the upper crust can deform ductilely at slower strain rates by viscous deformation controlled by stress-driven, fluid-assisted, diffusive mass transfer (Durney, 1972; McClay, 1977; Rutter, 1983; Gratier et al., 2013). These deformation styles may coexist spatially, as illustrated by coeval folds and faults in foreland fold-and-thrust belts (e.g. Suppe, 1983; Mitra, 1990; Mantero et al., 2011). During such coeval brittle–viscous deformation, brittle deformation is envisaged to occur episodically at fast strain rates, between longer episodes dominated by continuous viscous deformation (e.g. Gratier and Gamond, 1990; Gratier et al., 2013).

The Cape Fold Belt records ductile behaviour of rocks deformed in the upper crust (du Toit, 1937; de Wit and Ransome, 1992; Fagereng, 2012), and represents a natural laboratory for the contribution of pressure solution to large scale folding. The Dwyka Group diamictite, at the base of the Karoo Supergroup which fills the foreland basin of the Cape Fold Belt, has a particularly striking subvertical to steeply inclined cleavage, here argued to result from pressure solution, the dissolution of material by grain boundary, fluid-assisted, stress-driven diffusion. The purpose of this paper is to describe the spaced solution cleavage in the Dwyka Group in detail, and discuss its formation and role in the development of the Cape Fold Belt, with implications for pressure solution in fold-and-thrust belts in general.

2. Geological setting

The Cape Fold Belt formed along the southern margin of Gondwana (du Toit, 1937; de Wit and Ransome, 1992; Hälbich, 1992), in response to compression and accretion in a fold belt that can be traced from the Sierra de la Ventana in Argentina, through South Africa, to the Trans-Antarctic Mountains (du Toit, 1937; de Wit and Ransome, 1992; Dalziel et al., 2000). In a South African context, deformation related to this fold belt affects clastic sedimentary rocks of the Ordovician to Early Carboniferous Cape Supergroup, and the Late Carboniferous to Middle Jurassic Karoo Supergroup. The Cape Fold Belt is divided into a 'western arm', with a north–south structural trend, and a 'southern arm', where structures generally strike east–west (Fig. 1a). The two arms meet northeast of Cape Town, in the syntaxis of the fold belt. The southern arm, in which the current study area is located, is characterized by north-verging folds and reverse faults recording predominantly north–south shortening (Hälbich, 1993; Paton et al., 2006; Lindeque et al., 2011) (Fig. 1b). Cross-section reconstructions and

* Tel.: +27 21 650 2926.
E-mail address: ake.fagereng@uct.ac.za

http://dx.doi.org/10.1016/j.jafrearsci.2014.04.022
1464-343X/© 2014 Elsevier Ltd. All rights reserved.

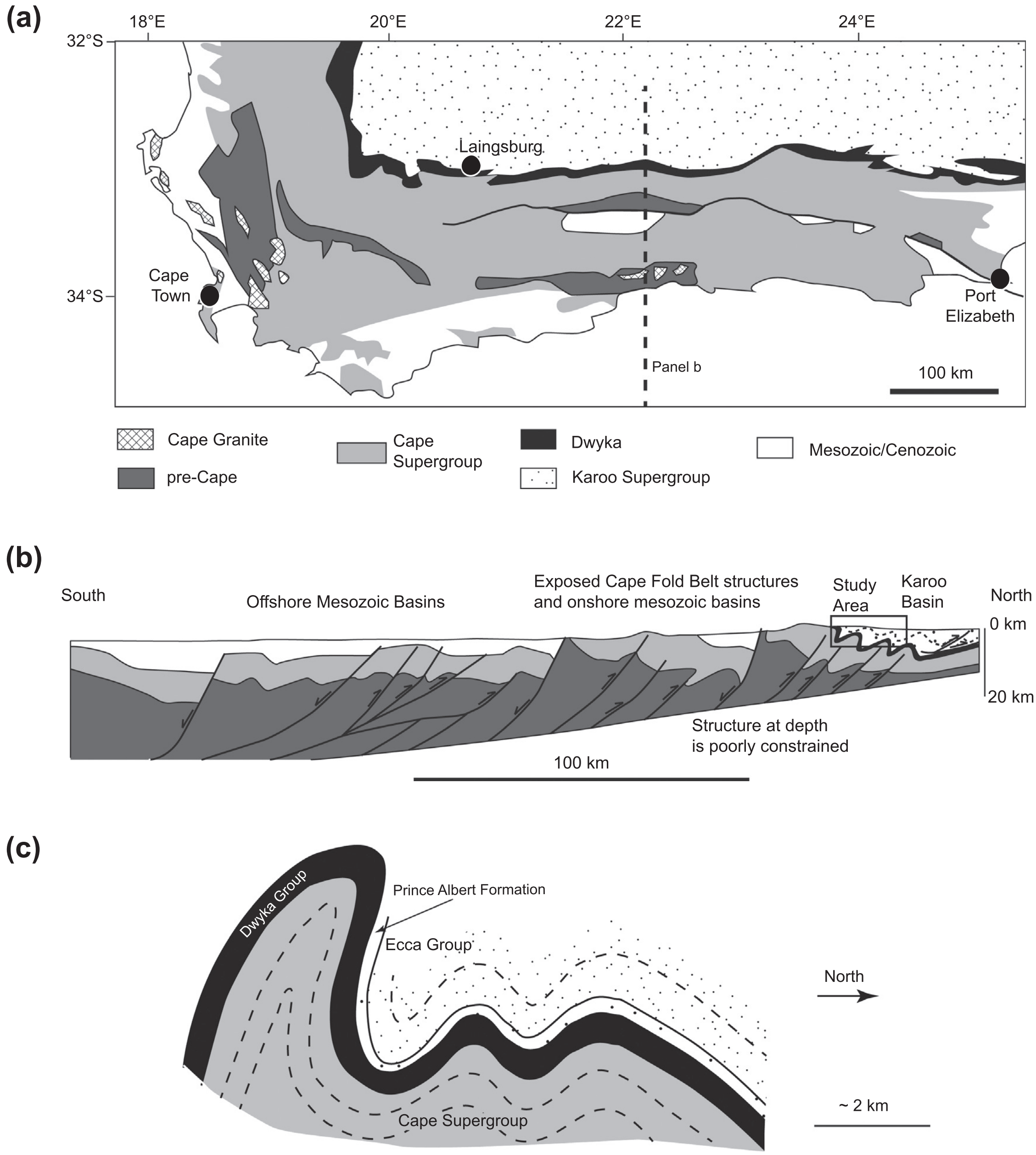

Fig. 1. (a) Map showing simplified lithostratigraphy of the Cape Fold Belt and the location of the study area near Laingsburg (after Paton et al., 2006; Tankard et al., 2009). The dashed line shows the location of the Cape Fold Belt-Agulhas Bank Transect (Hälbich, 1993), on which the cross-section in (b) is based. (b) Cross-section illustrating the north–south variation in geometry across the Cape Fold Belt (after Hälbich, 1993; Paton, 2006). The study area is along strike from the northern end of this cross section, where the base of the Karoo Supergroup crops out, and folding style changes from inclined to upright. (c) Simplified cross-section of the study area, illustrating the change in folding style from south to north.

field observations indicate at least two episodes of tectonic reactivation affecting rocks of the Cape and Karoo Supergroups: (1) formation of the Cape Fold Belt involved positive inversion of normal faults, developed before and during deposition of the Cape Supergroup in an intra-continental clastic margin; and (2) negative inversion of Cape Fold Belt related structures during the break-up of Gondwana (Paton et al., 2006).

The Cape Fold Belt is generally thought to reflect shallow angle subduction of the paleo-Pacific towards the north underneath Gondwana (Lock, 1980; de Wit and Ransome, 1992; Hälbich, 1992, 1993). Alternative tectonic models for the collision, however, include a transpressional setting (Tankard et al., 2009) and subduction towards the south, culminating in collision with a crustal block now part of South America (Lindeque et al., 2011). The Karoo Basin is considered to be a retro-arc foreland basin, which formed in response to the tectonic load caused by mountain building in the Cape Fold Belt (Catuneanu et al., 1998, 2005; Catuneanu, 2004). Tankard et al. (2009) have, however, suggested that the Cape Fold Belt initiated only in the Triassic, after the late Carboniferous initiation of sedimentation in the Karoo Basin. In their model, Karoo subsidence was facilitated by crustal-scale faults and not associated with a foreland basin. Irrespective of large-scale tectonic model, the Cape Fold Belt and Karoo Basin developed with some overlap in time, and the Karoo Basin was filled by sediments derived by erosion of the adjacent mountains of the Cape Fold Belt (e.g. Catuneanu et al., 2005 and references therein). The sediments of the Karoo Basin, in areas adjacent to the Cape Fold Belt, were then also deformed as a result of regional compression.