Tectonophysics 608 (2013) 1226–1237

Contents lists available at ScienceDirect

Tectonophysics

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

Deformation coupling between the Archean Pukaskwa intrusive complex and the Hemlo shear zone, Superior Province, Canada

Nathaniel T. Liodas [a], Aude Gébelin [b,c], Eric C. Ferré [a,*], Girmay M. Misgna [d]

[a] Department of Geology, Southern Illinois University, Carbondale, IL 62901, USA
[b] Biodiversity and Climate Research Centre (BiK-F), Senckenberganlage 25, 60325 Frankfurt/Main, Germany
[c] Department of Earth Sciences, University of Waterloo, Waterloo, Ontario N2L3G1, Canada
[d] Environmental Resources and Policy, Southern Illinois University, Carbondale, IL 62901, USA

ARTICLE INFO

Article history:
Received 19 February 2013
Received in revised form 12 June 2013
Accepted 20 June 2013
Available online 28 June 2013

Keywords:
Archean
Pukaskwa
Hemlo
TTG
Superior Province
AMS

ABSTRACT

Archean greenstone belts typically form narrow sheared basins separating bulbous tonalo–trondjhemo–granodioritic (TTG) intrusive complexes. The role played by gravity in the development of such dome-and-keel structures constitutes a key question in Archean tectonics. The Pukaskwa intrusive complex (PIC)–Hemlo greenstone belt system stands as a remarkable example of the dome-and-keel architecture that commonly occurs in Archean terrains. Abundant strain markers in the greenstone belt and in the Hemlo shear zone (HSZ) attest of late sinistral strike-slip kinematics (D_2) whereas, in general, the quartzofeldspathic coarse-grained rocks of the Pukaskwa intrusive complex bear little macroscopically visible kinematic indicators, most likely due to pervasive recrystallization. The PIC consists dominantly of a heterogeneous assemblage of TTG plutonic rocks and gneisses, which overall are less dense than the greenstone rocks. The study of anisotropy of magnetic susceptibility (AMS), based on 120 stations and 1947 specimens from the PIC, reveals east–west trending prolate and plano-linear fabrics across the northern margin of the complex, i.e., along the HSZ. Since geotherms were higher in the Archean than in the present, the effective viscosity of the TTG units would have been sufficiently low to allow their diapiric ascent through denser greenstone rocks. Here we propose an alternative model where thrust tectonics is responsible for the early structuration of the PIC. Later transpressive tectonics causes strain localization along internal strike-slip shear zones and along lithological boundaries.

1. Introduction

Density contrasts in a thin and hot lithosphere might have been the main force driving Archean orogenesis rather than plate tectonics (e.g., Chardon et al., 2009; Hamilton, 1998). Yet evidence for early plate tectonics makes this issue rather controversial (de Wit, 1998; Percival, 1994). The dynamic relationship between greenstone belts and tonalo–trondjhemo–granodioritic (TTG) complexes appears central in the "vertical tectonics" vs "horizontal tectonics" debate. The relatively low density of TTG complexes and associated anatectic gneisses might have allowed their diapiric rise through an overburden made of higher density mafic to ultramafic greenstone volcano-sedimentary rocks (Dixon and Summers, 1983). The geometry resulting from such process would resemble that of metamorphic core complexes (Lister and Davis, 1989). Alternatively, greenstone belts may have provided a buttress against which TTG complexes were emplaced. These two tectonic scenarios are not fundamentally incompatible and might have occurred simultaneously in the same region (Lin, 2005). Density-driven tectonics resulted in formation of large-scale dome-and-keel structures that characterize Archean terrains (Chardon et al., 1996; Harris et al., 2012; Lana et al., 2010; Lin, 2005; Sandiford et al., 2004; Shackleton, 1995; Van Kranendonk et al., 2010). Interference folding has also been proposed as a mechanism to explain structural domes within the Archean Chinamora batholith in Zimbabwe (Snowden and Bickle, 1976).

In order to advance our understanding of these important tectonic issues, we chose to study a representative example of a dome-and-keel structure in the Archean Superior Province, the Pukaskwa intrusive complex (PIC)–Hemlo shear zone (HSZ) system (Fig. 1). The Hemlo greenstone belt is part of the Wawa subprovince to the south of the Superior Province and is bounded to the south by the Pukaskwa granodiorite. A strong deformation can be defined along the northern margin of the granitic complex while moving away from the contact zone macroscopic structural markers become scarce. With the anisotropy of magnetic susceptibility study (AMS) being recognized as a powerful technique for quantifying strain in weakly deformed rocks, particularly in granitic, gneissic and migmatitic domains (Charles et al., 2009; Ferré et al., 2003, 2004; Gébelin et al., 2006; Hasalova et al., 2008; Kruckenberg et al., 2010, 2011; Polteau et al., 2008; Schulmann et al., 2009), we conducted a AMS study in the northern margin of the PIC to better understand its mechanism of emplacement and to investigate the role played by vertical and horizontal tectonics

* Corresponding author. Tel.: +1 6184537368; fax: +1 6184537393.
E-mail address: eferre@geo.siu.edu (E.C. Ferré).

0040-1951/$ – see front matter
http://dx.doi.org/10.1016/j.tecto.2013.06.022

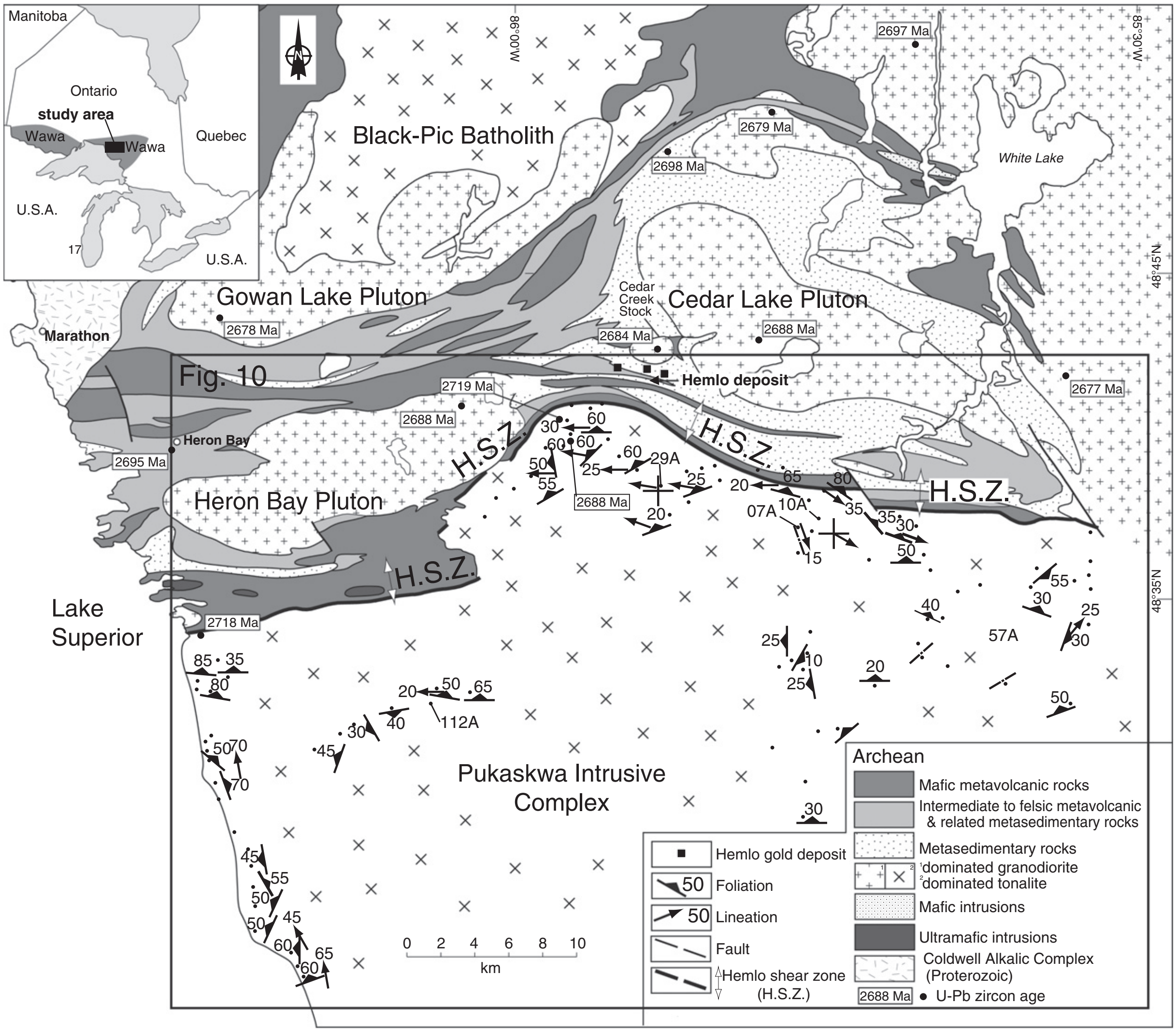

Fig. 1. Simplified geological map of the Hemlo greenstone belt modified after Lin (2001) showing the location of the Hemlo Shear Zone (H.S.Z.) and foliations and lineations measured in the northern margin of the Pukaskwa Granitic Complex (PIC). Small black dots indicate the locations of AMS data.

in Archean times. In these types of rocks, the AMS records the shape-preferred orientation of paramagnetic or ferromagnetic s.l. grains, which is generally acquired during plastic flow either at high- or low-temperatures. The AMS scalar parameters are calculated from the second rank tensor of magnetic susceptibility while the AMS vectorial parameters are given with respect to the geographic orientation of the specimen (Pokorny et al., 2004). The chosen example is not only representative of Archean processes but also relevant from an economic standpoint owing to the gold deposits hosted by the HSZ. The results of these investigations will advance our knowledge of Archean tectonics in the Superior Province, and potentially aid in the exploration of other prospective shear zones and intrusive complexes.

2. Regional setting

The Hemlo greenstone belt and the PIC are both located in the Wawa subprovince of the Superior Province in Ontario (Canada) (Fig. 1). The Superior Province forms the largest Archean terrain on Earth, covering an area of $\approx 1500 \times 2500$ km (e.g., Hamilton, 2007) and, like most Archean cratons, it originated from an amalgamation of different igneous and metamorphic terranes ranging in age between 3.10 and 2.65 Ga (e.g., Calvert and Ludden, 1999; Card, 1990). Geochronological data suggest that terrane assembly began with accretion of a magmatic arc (Card, 1990; Corfu and Muir, 1989a, 1989b; Percival et al., 2001; Williams et al., 1991).

2.1. Hemlo greenstone belt

The east–west striking Hemlo greenstone belt is bounded to the north and south by the two main large Black-Pic and Pukaskwa late Archean (~2720 Ma) tonalite–granodiorite granitoids (Beakhouse and Davis, 2005.), respectively. It is well known for containing one of the largest gold deposits in Canada localized along the HSZ (Fig. 1). The E–W trending HSZ affects over a ~2-km wide zone Archean supracrustal rocks of the greenstone belt as well as the northern margin of the PIC. The map pattern of the HSZ most likely results from the irregular contact between one of the intrusives in the PIC and the Hemlo greenstone belt rather than from post-shearing folding. The greenstone belt is composed of mylonitic Archean metasedimentary and felsic, intermediate and mafic metavolcanic rocks (e.g., Lin, 2001) which are intruded by late Archean (~2680 Ma; Beakhouse and Davis, 2005) granodiorite–quartz monzodiorite plutons (Fig. 1; Heron Bay, Gowan and Cedar Lake). The supracrustal rocks deposited from $\geq$2720 Ma to 2688 Ma (Corfu and Muir, 1989a, 1989b; Jackson, 1998) experienced three main ductile deformation events. The regional deformational fabric (D_1) is overprinted by a second and main regional event (D_2) that