Proceedings of the Geologists' Association 125 (2014) 155–169

Contents lists available at ScienceDirect

Proceedings of the Geologists' Association

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

Ultraphyllonite origin for slate, mid-Atlantic Piedmont, USA

David W. Valentino [a], Jeffrey R. Chiarenzelli [b,*]

[a] Department of Earth Sciences, State University of New York, Oswego, NY 13126, United States
[b] Department of Geology, St. Lawrence University, Canton, NY 13617, United States

ARTICLE INFO

Article history:
Received 12 August 2013
Received in revised form 13 December 2013
Accepted 15 December 2013
Available online 31 January 2014

Keywords:
Ultraphyllonite
Slate
Appalachian
Piedmont
Ductile shear zone
Peach Bottom

ABSTRACT

Structural, petrographic, and geochemical criteria are applied in combination to determine the petrologic origins of slaty rocks in polydeformed metasedimentary terranes. Multiple lines of evidence suggest that the Peach Bottom slate (PBs), mined over several centuries, is an ultraphyllonite. It occurs within an Alleghanian dextral retraining bend within the Appalachian Piedmont, as a segment of the Pleasant Grove-Huntington Valley shear zone system (>200 km long). The PBs differs markedly from other slates, in that, it contains abundant, micro-scale remnant porphyroclasts of higher-grade minerals. The PBs has major, trace and rare earth element geochemistry and $^{147}Sm/^{143}Nd$ ratios that are similar to the surrounding pelitic rocks. When compared to average slates, the geochemistry of the PBs exhibits depletion in alkali earth and alkali elements.

It is concluded that the PBs belt formed by ductile shear within a strike–slip duplex and is the low-grade metamorphic product derived by shearing higher-grade upper greenschist facies schists. This origin explains its extreme hardest, high density, and chemical homogeneity. With across strike thickness of ultraphyllonite approaching a kilometer and a strike length >30 km, its volume is similar to mylonite zones developed in granitoid rocks of higher grade terranes. Compared to these rocks, the PBs differs in composition, compositional homogeneity, fabric, and strain across the entire belt. The PBs cannot be a unique occurrence of a slate-belt that formed through deformation processes, therefore raising question about the origin of some pelitic slate-belts that occur within a similar tectonic setting in other orogens.

1. Introduction

Slate is a low-grade metamorphic rock consisting of preferentially aligned very fine-grained micas defining a cleavage. It is widely accepted that slate forms from mudrocks by low temperature prograde metamorphism. The prevalent slaty cleavage and microstructures in slate are indicative of coaxial deformation that occurs under the low temperature prograde metamorphic conditions. It has been argued that slaty cleavage is a result of oriented mica growth from the original clay and volume loss due to pressure solution processes (e.g. Wright and Platt, 1982; Wintsch et al., 1991; Goldstein et al., 1995; Ho et al., 2001). It is generally accepted that through progressive metamorphism, recrystallization of micas in slate will result in phyllite and ultimately coarse grained schist (e.g. Best, 2002; Winter, 2009).

Phyllonite is a fine-grained micaceous rock that develops by reaction softening under non-coaxial deformation conditions that operate in ductile shear zones (e.g. Goodwin and Wenk, 1995; Jefferies et al., 2006; O'Hara, 2007). Phyllonite can develop in sheared igneous and metasedimentary rocks; some examples having the texture of slate at the scale of an outcrop (e.g. Goodwin and Wenk, 1995). Microstructures and mineral fabrics in phyllonites are indicative of the physical and chemical breakdown of pre-existing minerals during shear zone deformation, such as the fluid controlled production of white mica at the expense of K-feldspar (Hippertt, 1998; O'Hara, 2007). Slate, as described above, is texturally distinct from phyllonite, and there would be little chance of mistaking one for the other if placed in proper geological context.

Outcropping in the mid-Atlantic Piedmont of Pennsylvania and Maryland, U.S.A., the Peach Bottom slate has long been recognized as an exceptional building stone as it was quarried for more than two hundred years (Fig. 1). The slate's remarkable physical properties were acknowledged during the Slate Exposition at the Crystal Palace in London in 1885 where, it was honored as having the highest quality and being the hardest slate on Earth (Behre, 1933; Berkheiser, 1994). Superficially, the Peach Bottom slate resembles classical slate formed by prograde metamorphism and deformation of mudrocks (Frazer, 1880; Knopf and Jonas, 1929; Behre, 1933; Agron, 1950; Freedman et al., 1964; Faill and Smith, 2010).

* Corresponding author. Tel.: +1 3152295202.
E-mail address: jchiaren@stlawu.edu (J.R. Chiarenzelli).

0016-7878/$ – see front matter © 2013 The Geologists' Association. Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.pgeola.2013.12.005

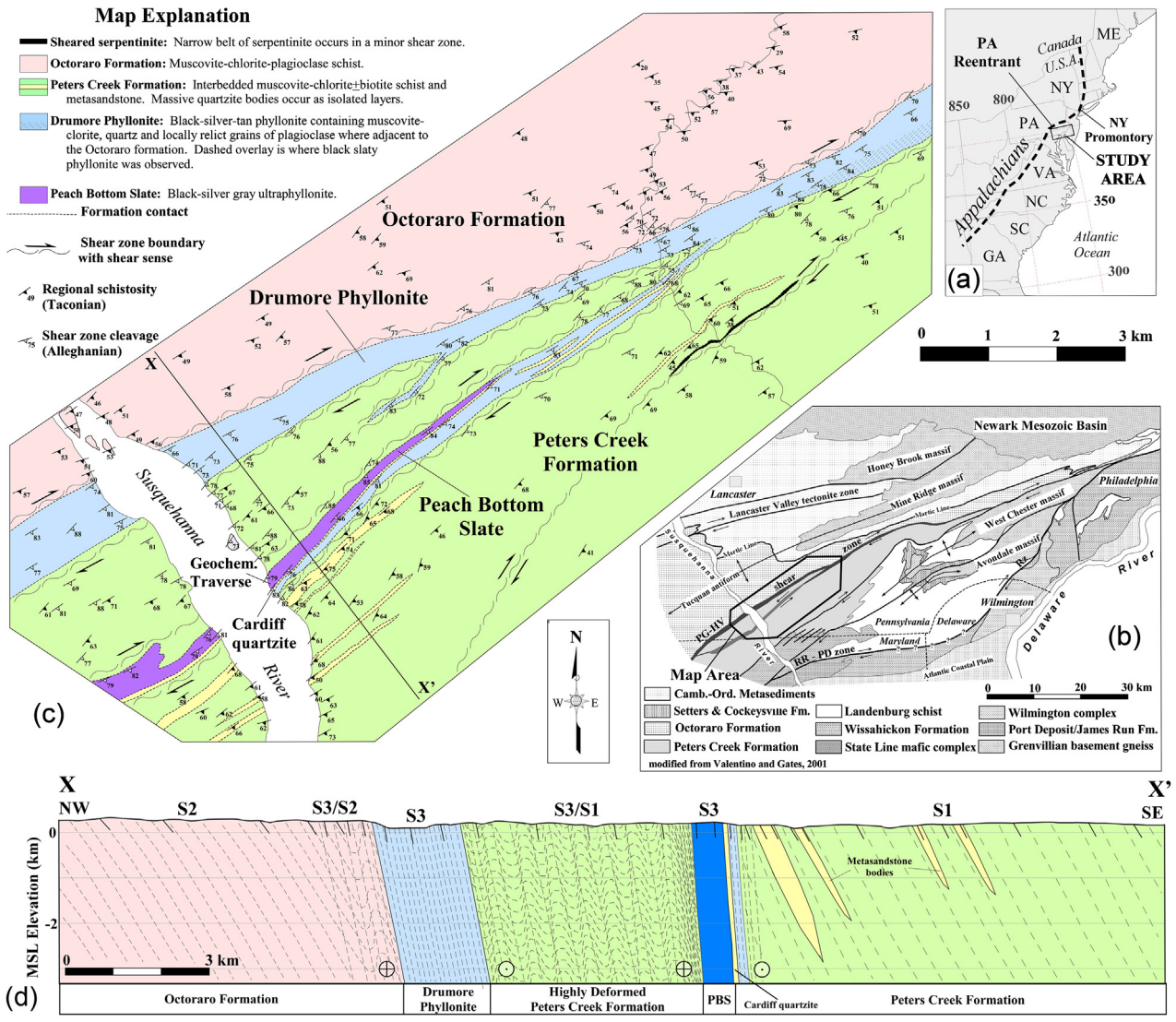

Fig. 1. Diagrams representing the location (a), tectonic (b), and geologic maps (c) of the lower Susquehanna River Valley, PA and Peach Bottom slate belt. Major Alleghanian structures show as black lines on the tectonic map. (d) Structural cross section along line X–X′ showing the regional schistosity and cleavage relationships. The regional formation name, Landenburg schist, in the inset map is from Alock (1994).

Nonetheless, the Peach Bottom slate differs significantly in several ways (Chiarenzelli and Valentino, 2006): (1) it is remarkably hard, dense, and durable; (2) lacks preserved bedding or other sedimentary structures that are common in slate; (3) occurs within a splay of a regional ductile shear zone system (Fig. 1); (4) contains kinematically significant porphyroclasts and fabrics that suggest non-coaxial shear; (5) is enveloped by, and is demonstrably derived from, higher grade phyllonite and schist; and (6) has a homogeneous composition that only differs slightly from adjacent schistose units, but is geochemically distinct from slate in other slate belts.

We herein present field, petrographic, microstructural and geochemical data that support a previously unrecognized origin for the Peach Bottom slate that may be applicable to other rocks superficially similar to slates. We suggest that the Peach Bottom slate originated by dynamic retrograde metamorphic processes of schistose protoliths within a transpressional ductile shear system. As described above, earlier researchers demonstrated that slaty rock fabric or phyllonite can form within highly sheared rocks (Goodwin and Wenk, 1995; Jefferies et al., 2006; O'Hara, 2007), but, there are no examples in the geological literature where slaty rocks formed in this manner are volumetrically significant, let alone extensively mined as slate. Therefore, due to the mineral composition, ultra-fine grain size and origin by deformation within a known regional shear zone, we herein utilize the existing term ultraphyllonite (Tabor and Hudleston, 1991) in describing the Peach Bottom slate. The example presented is probably not unique and this study may lead to the reevaluation of the process of formation of some slate-like rocks, formed in similar orogenic settings.

2. Regional geology

The mid-Atlantic Piedmont resides in the transition between the New York promontory and Pennsylvania reentrant (Fig. 1), has an east-northeast trending structural grain, and this geometry is nearly orthogonal to the general structural grain of the Appalachian orogen. The abrupt difference in structural trend in the mid-Atlantic region was influenced by the geometry of a Late Proterozoic rift, and reflects a transform fault that formed during the opening of the Iapetus Ocean (Rankin, 1975; Thomas, 1977). Furthermore, the ensuing rift to drift sedimentation resulted in basin fill that now makes up the vast expanse of greenschist to