Lithos 206–207 (2014) 321–337

Contents lists available at ScienceDirect

Lithos

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

The Cryogenian intra-continental rifting of Rodinia: Evidence from the Laurentian margin in eastern North America

Elizabeth McClellan [a,*], Esteban Gazel [b,1]

[a] Department of Geology, Radford University, P.O. Box 6939, Radford, VA 24142, United States
[b] Department of Geosciences, Virginia Tech, 5041 Derring Hall (0420), Blacksburg, VA 24061, United States

ARTICLE INFO

Article history:
Received 22 March 2014
Accepted 4 August 2014
Available online 14 August 2014

Keywords:
Wilson cycles
Rodinia
Continental rifting
Laurentian margin

ABSTRACT

The geologic history of the eastern North American (Laurentian) margin encompasses two complete Wilson cycles that brought about the assembly and subsequent disaggregation of two supercontinents, Rodinia and Pangea. In the southern and central Appalachian region, basement rocks were affected by two episodes of crustal extension separated by >100 m.y.; a Cryogenian phase spanning the interval 765–700 Ma and an Ediacaran event at ~565 Ma. During the Cryogenian phase, the Mesoproterozoic continental crust was intruded by numerous A-type felsic plutons and extensional mafic dikes. At ~760–750 Ma a bimodal volcanic sequence erupted onto the uplifted and eroded basement. This sequence, known as the Mount Rogers Formation (MRF), comprises a bimodal basalt–rhyolite lower section and an upper section of dominantly peralkaline rhyolitic sheets. Here, we provide new geochemical evidence from the well-preserved volcanic rocks of the Cryogenian lower MRF, with the goal of elucidating the process that induced the initial stage of the break-up of Rodinia and how this affected the evolution of the eastern Laurentian margin. The geochemical compositions of the Cryogenian lavas are remarkably similar to modern continental intra-plate settings (e.g., East African Rift, Yellowstone–Snake River Plain). Geochemical, geophysical and tectonic evidence suggests that the common denominator controlling the melting processes in these settings is deep mantle plume activity. Thus, evidence from the MRF suggests that the initial phase of extension of the Laurentian margin at ~760–750 Ma was possibly triggered by mantle plume activity. It is possible that lithospheric weakness caused by a mantle plume that impacted Rodinia triggered the regional extension and produced the intra-continental rifting that preceded the breakup of the Laurentian margin.

1. Introduction

Global cycles of continental collision and breakup have been recognized since the proposal of the plate tectonics model in the 60s (Wilson, 1965, 1966). Although this model is widely accepted today, it is still not clear what processes are responsible for those cycles, especially the breakup of supercontinents. The geologic history of the eastern North American (Laurentian) margin encompasses two complete Wilson cycles that brought about the assembly and subsequent disaggregation of two supercontinents, Rodinia and Pangea. The lithotectonic record involves several orogenic events, including the composite Grenville orogeny (~1.2–0.9 Ga) during the formation of Rodinia and three major collisional events (Taconic ~490–440 Ma, Acadian ~420–360 and Alleghanian ~320–260 Ma) that built the Appalachian orogen and culminated in the formation of Pangea (e.g., Hatcher, 2010). The record also holds evidence of the breakup of each supercontinent, and therefore can provide key information concerning the plate tectonics model and continental evolution. During the breakup of Pangea, the rift-to-drift transition along the eastern North American margin began with rifting in southeastern North America at ca. 230 Ma, followed by rapid emplacement of mafic magmas as flood basalts and dikes at 200 Ma, and initial seafloor spreading at 190–170 Ma (e.g., Labails et al., 2010; Schettino and Turco, 2009; Schlische et al., 2003). In contrast to the <50 million-year duration of events leading to the initial opening of the Central Atlantic, fragmentation of the eastern Laurentian margin of Rodinia was a protracted event that spanned ~200 million years, from early intracontinental rifting to the onset of seafloor spreading. Magmatic activity associated with final breakup of Rodinia and opening of the Iapetus Ocean is broadly referred to as the Central Iapetus magmatic event (Ernst and Buchan, 1997). Basaltic rocks were emplaced during three pulses, including the 615 Ma Long Range dikes in Newfoundland and southeastern Labrador, the 590 Ma Grenville dike swarm, and the 565–555 Ma Catoctin volcanics and related intrusions (Ernst and Bleeker, 2010; Puffer, 2002). The Central Iapetus magmatic event was preceded by Cryogenian (ca. 765–680 Ma) intracontinental rifting and magmatism (e.g., Ernst and Bleeker, 2010). In this study we present new field and geochemical evidence for the triggers and processes related to this early stage of rifting of the Laurentian margin.

* Corresponding author. Tel.: +1 540 831 5430.
E-mail addresses: emcclellan@radford.edu (E. McClellan), egazel@vt.edu (E. Gazel).
[1] Tel.: +1 540 231 2296.

http://dx.doi.org/10.1016/j.lithos.2014.08.006
0024-4937/

In the Blue Ridge province of the southern and central Appalachian region, rocks that record the Proterozoic history occur primarily in two allochthonous, fault-bounded inliers, the French Broad and Shenandoah massifs (Fig. 1). These two inliers together extend >700 km along strike and expose Mesoproterozoic basement rocks unconformably overlain by Neoproterozoic to early Cambrian volcanic and sedimentary deposits. Crystallization ages of basement gneisses and granitoids of 1.3–1.0 Ga correspond to the timing of Grenville collisional orogenic events (McLelland et al., 1996) related to assembly of Rodinia (Carrigan et al., 2003; Tollo et al., 2004a, 2010). The basement rocks of the Blue Ridge

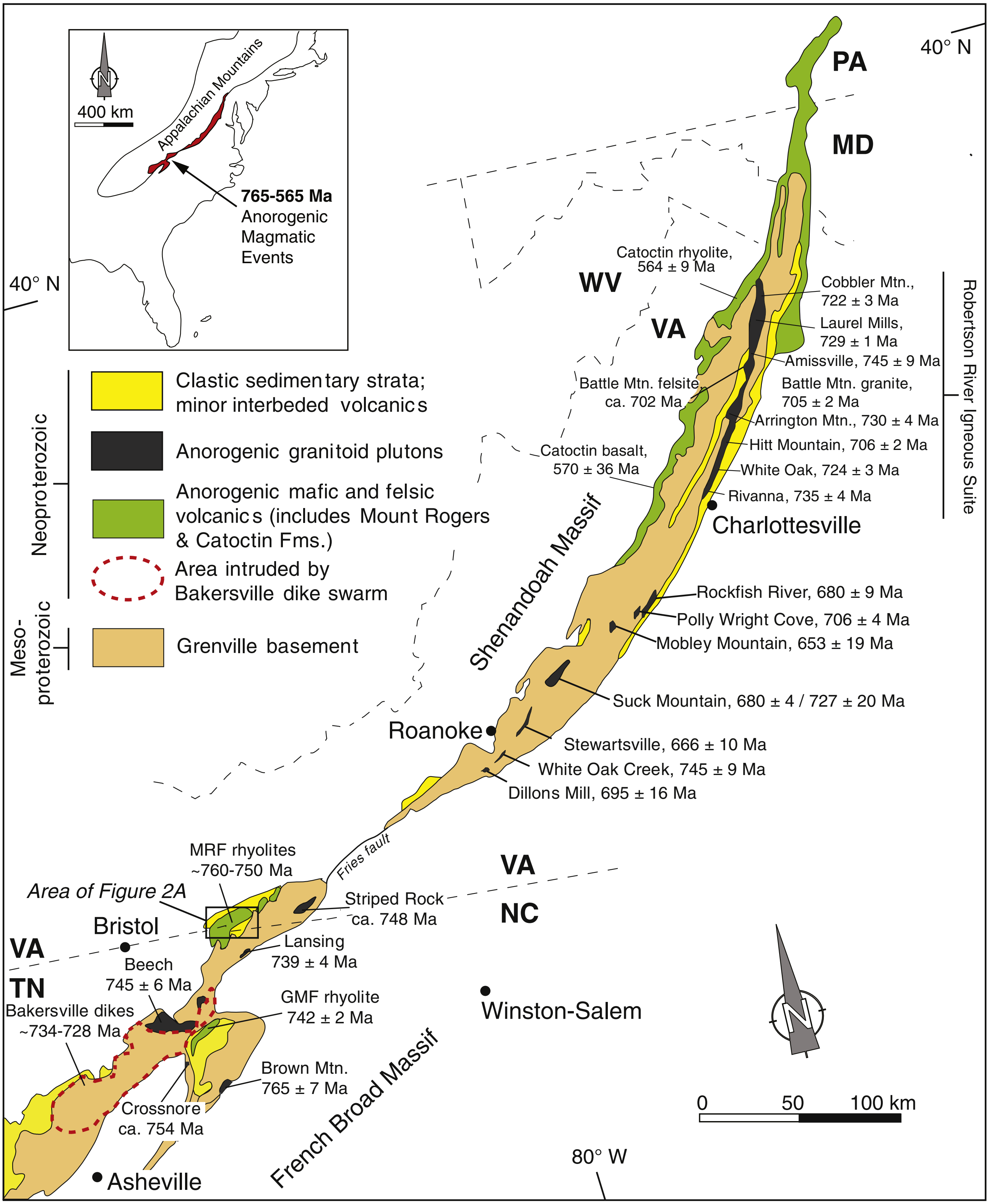

Fig. 1. Neoproterozoic anorogenic magmatic events along the Laurentian margin of eastern North America during the breakup of Rodinia, as represented by plutonic and volcanic rocks presently exposed in the French Broad and Shenandoah massifs of the Appalachian Blue Ridge. See Table 1 for references to isotopic ages. Modified from Burton and Southworth (2010) and Tollo et al. (2012).