Sedimentary Geology 336 (2016) 26–35

Contents lists available at ScienceDirect

Sedimentary Geology

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

Inferring tectonic provenance of siliciclastic rocks from their chemical compositions: A dissent

Abhijit Basu [a,*], Marion E. Bickford [b], Ryan Deasy [a]

[a] Department of Geological Sciences, Indiana University, 1001 E 10th Street, Bloomington, IN 47405, USA
[b] Department of Earth Sciences, 204 Heroy Geology Laboratory, Syracuse University, Syracuse, NY 13244, USA

ARTICLE INFO

Article history:
Received 22 June 2015
Received in revised form 17 October 2015
Accepted 23 November 2015
Available online 7 January 2016

Keywords:
Provenance
Regolith
Sandstone
Granite
St. Francois Mountain

ABSTRACT

Chemical compositions of siliciclastic sedimentary rocks are commonly used to infer their tectonic provenance. We have tested the universal applicability of the underlying principle in a small, but controlled study expecting 100% confirmation of the practice. A comparison is made between the chemical composition of the ~1480 Ma Butler Hill Granite in an uplifted cratonic block of the St. Francois Mountain Igneous Complex and that of a small ~1-m-thick regolith body, a weathered granite sample, and the basal quartz arenites of the ~520 Ma Lamotte Formation immediately above the regolith. The results show that in plots of K_2O/Na_2O vs. SiO_2/Al_2O_3, the regolith and sandstone samples correctly plot in the Passive Margin field, although the weathered granite plots in the Arc field. In plots of Th-Sc-Zr/10 and La-Th-Sc, the results plot in the Passive and Active Continental Margins and their extensions. In other common plots to discriminate tectonic provenance (e.g., SiO_2 vs. K_2O/Na_2O, $Fe_2O_3 + MgO$ vs. Al_2O_3/SiO_2, $Fe_2O_3 + MgO$ vs. TiO_2, Sc/Cr vs. La/Y) a few points plot in the Passive Margin field but scatter into and outside of other fields of tectonic provenances. The chondrite-normalized REE distributions show variable degrees of negative Eu anomalies, with flat HREE, conforming to a felsic source. The LREE distributions show both positive and negative Ce anomalies that can be ascribed to the variability of redox conditions during weathering and diagenesis of the original siliciclastic sediments. The variability of the Eu anomaly was likely affected by post-erosion processes in addition to whatever was inherited from the parent rocks. We conclude that chemical compositions can provide good clues, but are neither strong indicators nor unique identifiers of their tectonic provenance. Rather, they indicate a dominantly felsic or dominantly mafic, or a mixed set of source rocks.

1. Introduction

It has been long established that the mineralogical compositions and chemical compositions of detrital sediments and sedimentary rocks are indicative of their provenance (Johnson 1872; Krynine 1937; Pettijohn 1957; Dickinson 1970; Dickinson and Suczek 1979; Bhatia 1983; Caja et al. 2007; von Eynatten et al. 2012). There is a consensus that certain compositions proxy for associations of parent rocks that are representative of tectonic regimes of their occurrence (Dickinson 1985; McLennan et al. 1993; Dey et al. 2009; Ali et al. 2014). Detrital sedimentary rocks are the final surviving products of mechanical and chemical processes associated with weathering, transportation, deposition, recycling, and diagenesis. All or some of these processes may have been repeated several times in the history of a sedimentary rock, destroying many of the original properties of its parent rock assemblages (McCann 1991; Cox et al. 1995; Ghosh and Sarkar 2010; Garzanti et al. 2013). Therefore, reliance on (a) the properties of the more durable minerals, and (b) on the distribution of less mobile elements and their ratios has increased in all contemporary provenance studies (Mange-Rajetzky 1981; Bhatia and Taylor 1981; Morton 1985; Roser and Korsch 1986; Roser and Korsch 1988; Fedo et al. 1996; Cullers and Podkovyrov, 2002; Armstrong-Altrin et al. 2004; Götze 2009; Morton and Chenery 2009; Barbera et al. 2011; Ali et al. 2014; Imchen et al. 2014). The elements (or oxides) and their ratios that Bhatia (1983), Roser and Korsch (1986), and McLennan and Taylor (1991) had chosen (mainly SiO_2, Al_2O_3, $Fe_2O_3 + MgO$, K_2O, Na_2O, TiO_2, Th, Sc, Zr, Cr, Ni, Co, V, Y, La, and Eu anomaly) to discriminate tectonic provenance from the bulk chemical compositions of sedimentary rocks, continue to be trusted by most investigators. An underlying implicit assumption in all such studies is that the chemical signatures of the parent rock assemblages in a tectonic province persist in the daughter sediments they produce and are preserved in the corresponding sedimentary rocks. We applaud Sajid Ali and co-authors (Ali et al. 2014) who may be the only workers to state an explicit assumption: "…we assume that elemental ratios such as La/Sc, Th/Sc, Cr/Th, Th/Co, La/Co and Eu/Eu^* in the detrital silicate fraction of the sedimentary rocks behaved as a closed system

* Corresponding author at: Department of Geological Science, Indiana University, 1001 East 10th Street, Bloomington, IN 47405, USA.
E-mail address: basu@Indiana.edu (A. Basu).

http://dx.doi.org/10.1016/j.sedgeo.2015.11.013
0037-0738/

during transport and cementation". On the other hand, several studies have shown that the geochemical properties of certain minerals, siliciclastic sediments, sedimentary rocks, and even igneous rocks do not provide unique indications of their lithologic or tectonic provenance (Condie 1991; Panahi et al. 2000; Pe-Piper et al. 2008; Andersen 2013; Artemieva and Shulgin 2015). A few workers have experimented with discriminant function and principal component analyses of chemical compositions of siliciclastic sediments and sedimentary rocks (e.g., Bhatia 1983; Roser and Korsch 1988; Caracciolo et al. 2012; Armstrong-Altrin 2014). It appears that the elements mentioned above, especially Si, Al, Th, Sc, Cr, and Zr, dominate the loadings of the variables. In this short paper, it is not necessary to go into the details of the statistical methods and their putative success. Other cautionary notes have come from studies of sandstones and shales, a few of which are mentioned below.

In this paper, an examination of the efficacy of using the common geochemical denominators for tracking tectonic provenance of siliciclastic sedimentary rocks in an uplifted continental block is reported. For our purpose, we opted to select the most common parent rock (granite) in the simplest tectonic provenance (continental block–craton interior), with a recognizable regolith on top (that should retain the maximum geochemical inheritance from the parent granite before disintegrating and becoming part of the transported detritus), and a much younger seemingly proximal sandstone that may have been partially derived from the local granite.

2. Geological setting

The early Mesoproterozoic (ca. 1480 Ma) St. Francois Mountain granitic complex (Bickford and Mose 1975; Bickford et al. 2015) and the basal sandstone of the upper Cambrian (nominally 520 Ma) Lamotte Formation (Ojakangas 1963; Shukis and Ethridge 1975; Houseknecht and Ethridge 1978; Palmer et al., 2012) near Pilot Knob in southeastern Missouri constitute a good set of rock units for the study (Fig. 1). Because of multiple economic resources (Fe, W-Pb-Ag, Sn, Nb) and because the St. Francois Mountain volcano–plutonic complex is the only extensively exposed representative of the Granite–Rhyolite Provinces of the continental interior of the United States (Bickford et al. 2015), these rocks have been studied extensively (Tolman and Robertson, 1969; Blaxland 1974; Bickford and Mose 1975; Kisvarsanyi 1976; Paarlberg and Evans 1977; Kisvarsanyi et al., 1981; Bickford et al.,

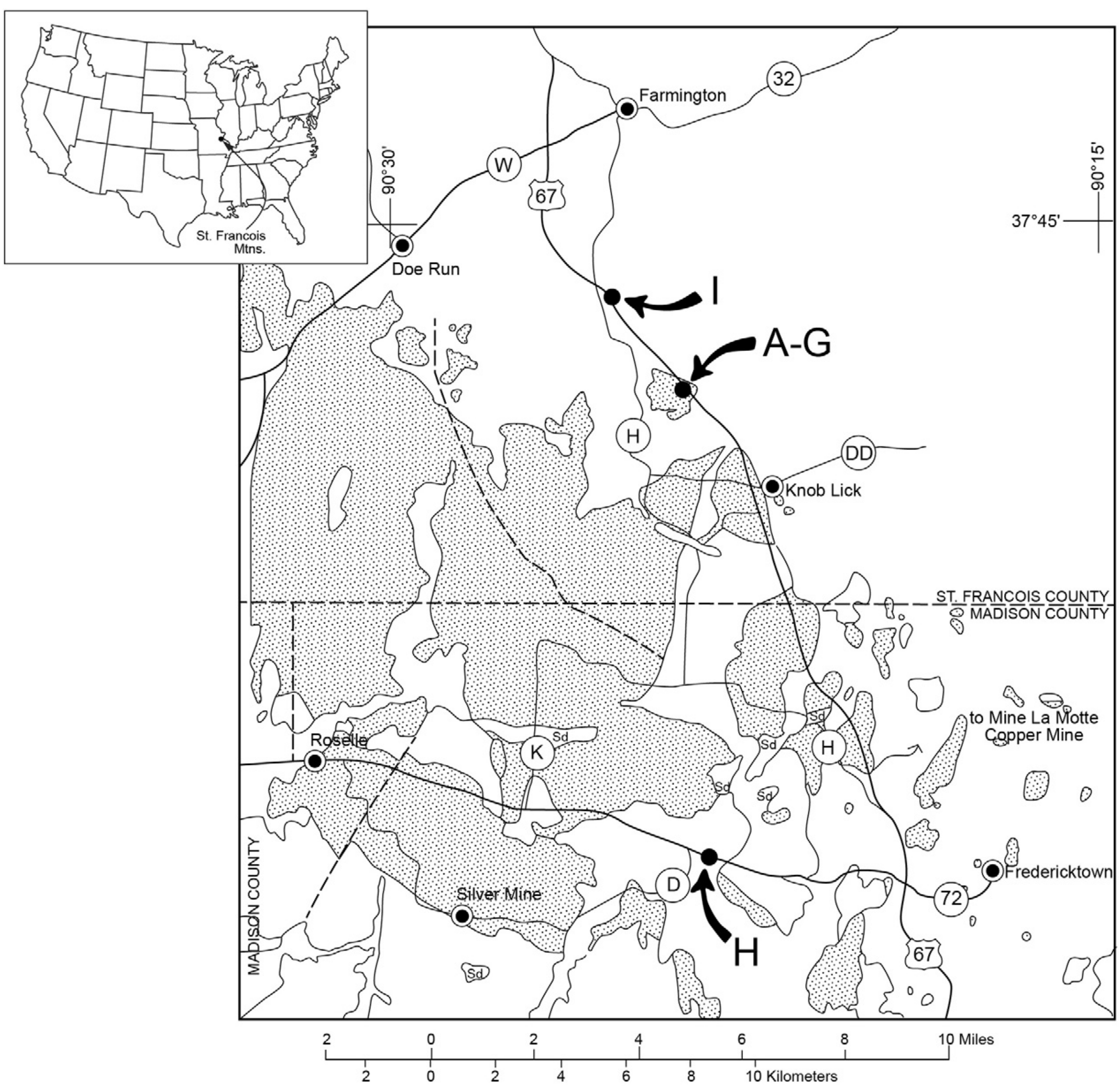

Fig. 1. Geological map of the sampling area in the St. Francois Mountain Igneous Complex (after Kisvarsanyi 1976). Upper case letters mark the locations of sampling.