Journal of Geochemical Exploration xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Journal of Geochemical Exploration

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

Stream sediment geochemistry as a tool for enhancing geological understanding: An overview of new data from south west England

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ARTICLE INFO

Article history:
Received 20 May 2015
Revised 3 November 2015
Accepted 12 January 2016
Available online xxxx

Keywords:
South west England
Stream sediment geochemistry
Compositional data analysis
Principal component analysis
Geochemical signature
Geological interpretation

ABSTRACT

The requirements for quantitative data in geological surveillance are ever increasing; traditional geological maps and 3D models are evolving into quantitative conceptual models based on a broad range of analytical measurements of surface and subsurface properties. The British Geological Survey's Geochemical Baseline Survey of the Environment (G-BASE) project provides one such source of data: national coverage of stream sediment, stream water and soil geochemistry. While this geochemical data is of obvious benefit to our understanding of the present day surface environment, the rich geological diversity of south west England provides an ideal setting in which to showcase the potential of such data to enhance our understanding of the underlying bedrock.

In this paper we use compositional data analysis to extract lithostratigraphic information from G-BASE stream sediment data. We find that variations in G-BASE stream sediment geochemistry correspond very closely to mapped variations in bedrock geology. Geochemical variations between the 16 lithostratigraphic domains into which we classify the region provide insight into the distinct geological histories of the lithologies within each domain, particularly in relation to depositional environments and sediment provenance.

1. Introduction

As the British Geological Survey's work moves into the 21st century the requirements for quantitative data are ever increasing. Legacy geological maps and 3D models based on qualitative observations of rock properties are being updated into quantitative conceptual models on the basis of analytical measurements of surface and subsurface properties. The Geochemical Baseline Survey of the Environment (G-BASE) project provides one such line of data: national coverage of stream sediment, stream water and soil geochemistry. The most recent regional dataset to become available is that of south west England. This is a geologically diverse region consisting of a spectrum of geological formations which preserve various stages of the region's Paleozoic tectonic cycle from passive margin to collisional orogenesis and subsequent erosion (Shail and Leveridge, 2009). While surface geochemical data is of obvious benefit to our understanding of the present day surface environment, south west England, with its rich geological history, provides an ideal setting in which to assess the potential of such quantitative datasets to enhance our understanding of the underlying bedrock.

Geochemical techniques are widely utilised for a variety of applications (Rollinson, 2014) but the high costs generally limit the number of samples that can be analysed and their use is often restricted to focused study areas as a result. In south west England rock sample geochemistry has been applied to various focused studies of metasediments (Dodson and Rex, 1970; Primmer, 1985; Warr et al., 1991), the granites (Floyd, 1972; Alderton et al., 1980; Charoy, 1986; Chesley et al., 1993; Darbyshire and Shepherd, 1994; Psyrillos et al., 1998) and other igneous lithologies (Floyd, 1984; Kirby, 1984; Floyd et al., 1993a; Sandeman et al., 1997; Clark et al., 1998). Previous work has been conducted towards gauging the geochemical baseline of various lithologies (Scott et al., 2002; LeBoutillier, 2004) but these have been limited in terms of sampling density and extent. Some other, wider scale geochemical surveys of soil and stream sediment which have focused on exploration for metallic ore deposits are reviewed in Moon (2010). The Wolfson geochemical atlas (Webb et al., 1978) provided full stream sediment coverage of England and Wales but has now been succeeded by the G-BASE stream sediment survey in terms of sensitivity of measurements and the range of analytes. Thus the new G-BASE data provides us with the best insight into the major and trace element geochemistry of south west England.

In this paper we use compositional data analysis to provide an overview of the geochemical signatures of bedrock domains in south west England. This study focuses on a selection of elements which have not been heavily remobilised by hydrothermal activity and mineralisation relating to the intrusion of the Cornubian Batholith, and are identified as having primarily lithostratigraphically constrained distributions. We implement domain-weighted compositional principal component analysis on the data to identify and maximise the geochemical contrasts between domains, and map the results of the data analysis in

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http://dx.doi.org/10.1016/j.gexplo.2016.01.010
0375-6742/

geographic space to allow a visualisation of the relationships between stream sediment geochemistry and regional scale bedrock geology. We then relate the geochemical features of each domain to their bedrock composition to examine what new evidence this data provides that may enhance geological understanding.

2. A brief geological history of south west England

The geology of south west England (summarised in Fig. 1) predominantly consists of a range of metasediments which were deposited in a series of east–west trending sedimentary palaeo-basins both in a passive margin setting during the Devonian (Rhenohyercynian passive margin sediments) and a retro-arc setting during the Carboniferous (Carboniferous foreland basin sediments). The granites of the Cornubian batholith were then intruded following the late Carboniferous to early Permian Variscan Orogeny. Post-Variscan sediments are also preserved in the east of the region but are fairly limited in extent within the adopted boundaries of the study area.

The tectonic evolution of the region began with a north–south extensional regime set up within the Avalonian terrane (the basement beneath south west England) at the start of the Devonian. The extension was caused by either slab rollback or slab-pull stresses as a result of the initiation of subduction in the Rheic Ocean (Stampfli and Borel, 2002), an ancient ocean which separated Avalonia from Gondwana to the south. This intra-Avalonian extensional zone, termed the Rhenohercynian zone, developed to form a narrow oceanic basin in the Devonian that was analogous in profile to the Red Sea today (Davies, 1984). This basin was the Gramscatho Basin (Leveridge and Shail, 2011a) and is where the contents of the Lizard Complex, the Start Complex and our two Gramscatho Basin domains were formed.

Though the Gramscatho Basin was the only basin to reach full oceanic maturity, a sequential series of east–west striking half grabens and grabens extended the rift zone northwards throughout the Devonian. Each basin was initially fed by sediment derived from the continent to the north, in parts intercalated with basalts, as the listric faulting provided conduits for magma. These were the Looe, South Devon and Tavy Basins, whose subsidence began in the Lower Devonian, late Lower Devonian and late Middle Devonian respectively (Leveridge, 2011) and continued throughout the Devonian so that each basin's sedimentation became increasingly pelagic. Meanwhile to the north the North Devon basin was subsiding independently throughout the Devonian but remained a fairly shallow marine environment thanks to a high rate of sediment input from northern uplands (Whittaker and Leveridge, 2011).

Closure of the Rheic Ocean was completed at the end of the Devonian, when Gondwana collided northwards into Avalonia (Nance et al.,

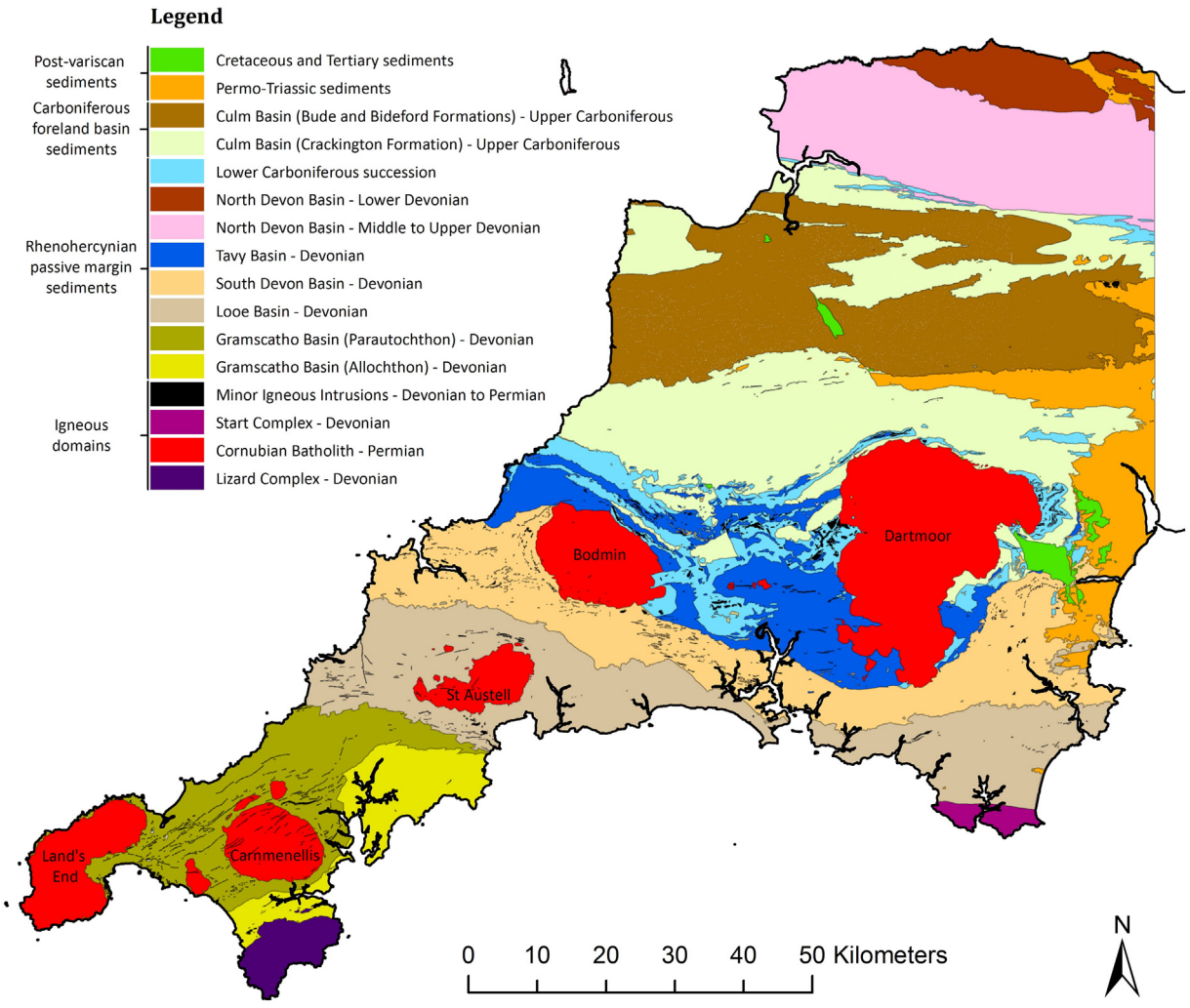

Fig. 1. The regional scale geology of south west England, classified into 16 geological domains for this study. The five major granites are labelled by name. Adapted from DiGMapGB-50 (Jackson and Green, 2003) after Shail and Leveridge (2009). See Fig. 2 for location in national context.

Please cite this article as: Kirkwood, C., et al., Stream sediment geochemistry as a tool for enhancing geological understanding: An overview of new data from south west England, J. Geochem. Explor. (2016), http://dx.doi.org/10.1016/j.gexplo.2016.01.010