Chemie der Erde 76 (2016) 197–210

Contents lists available at ScienceDirect

Chemie der Erde

journal homepage: www.elsevier.de/chemer

Geochemical mapping based on geological units: A case study from the Marnoso-arenacea formation (Northern Apennines, Italy)

Valerio Lancianese*, Enrico Dinelli

I.G.R.G., Università di Bologna, via S.Alberto 163, 48123 Ravenna, Italy

ARTICLE INFO

Article history:
Received 13 January 2014
Received in revised form 5 January 2015
Accepted 5 November 2015
Editorial handling - S. Norra

Keywords:
Geochemical mapping
Geochemistry
Stream sediments
Provenance
R-mode factor analysis
Marnoso-arenacea formation
Geological members
Sediment composition
Source rock weathering
Apennines

ABSTRACT

Geochemical maps can provide us with much information on geology, earth surface processes and anthropogenic pressure and are valuable tools for ore prospecting and land management. Stream sediments represent an integral of the various possible sources of sediments upstream from the sampling point therefore there can be multiple signal sources but generally the prevailing signal source is the one related to bedrock geology. Stream sediments collected from active second-order channels including singular geological units, were selected in order to determine the geochemical characteristics of each unit. The aim of this study was to analyse their potential for using them to integrate geological interpretation and produce a geologically-oriented geochemical map. From the 770 samples collected for a regional geochemical mapping program, we selected 149 samples whose catchment basin included only one of the members recognized within the Marnoso–Arenacea formation. This Middle-Upper Miocene (Langhian–Tortonian) turbiditic unit forms the backbone of the Romagna Apennines and has been subdivided into 14 members according to age and lithostratigraphic criteria. The results indicate that there are marked differences in the composition of the members of the Marnoso Arenecea formation which indicate the provenance of the sediment and the palaeogeographic evolution of the units. By means of univariate and multivariate statistical analyses (Factor analyses) two main types of sediment compositions are identified: Tortonian members are characterized by sialic coarse grain- sediments while the Langhian–Serravallian members are richer in carbonate fraction, slightly enriched in a mafic contribution. This study elaborated the geochemical data from a geological point of view by integrating the information available in literature to spatially extend the interpretation based on limited site observation as for petrographic studies. In general, the geochemical map based on a geological unit could be a useful tool for carrying out the geological reconstruction of a complex area.

1. Introduction

Since the early 1980's, the geochemistry of clastic (Bhatia, 1983, 1985a,b; McLennan and Taylor, 1983, 1993; Taylor and McLennan, 1985; Roser and Korsch, 1986, 1988; Condie et al., 1992, 1993), lake (Krishnamurthy et al., 1986; Fontes et al., 1993; Mullins, 1998; Willemse and Tornqvist, 1999; Last and Smol, 2001; Jin et al., 2001, 2003; Laird et al., 2003; Rose et al., 2004) and stream sediments (Swennen and Van der Sluys, 1998; Cannon et al., 2004; Ortiz and Roser, 2006a,b; Ranasinghe et al., 2008, 2009; Singh, 2010; Bhuiyan et al., 2011) have been used for evaluating tectonic setting and provenance studies since the original signature of the source remains preserved in the sediments. The chemical composition of sediments have been analysed in various ways: some trace elements like Cr, Ni and Co, which are enriched in mafic and ultramafic rocks and Zr and REEs that indicate the control of heavy minerals such as monazite, zircon and apatite, generally remain immobile throughout the process of sediment production and are useful indicators of source region composition (Singh, 2010) both in absolute concentration and as ratios between elements (Taylor and McLennan, 1985; McLennan et al., 1993; Condie, 1993). Other proxies often considered are: (a) the SiO_2/Al_2O_3 ratio, which suggests clay matrix control and grain size; (b) Na_2O and possibly CaO and Sr, if carbonates are missing, which can be controlled by feldspar occurrences.

Stream sediments are composite samples of the outcropping rocks and surface material upstream from the sampling point (Levinson, 1974; Meyer et al., 1979; Rose et al., 1979; Darnley, 1990; Hale and Plant, 1994), are key characteristics for exploration, mapping and management and are useful for determining background

* Corresponding author.
E-mail address: valerio.lancianese2@unibo.it (V. Lancianese).

http://dx.doi.org/10.1016/j.chemer.2015.11.001
0009-2819/

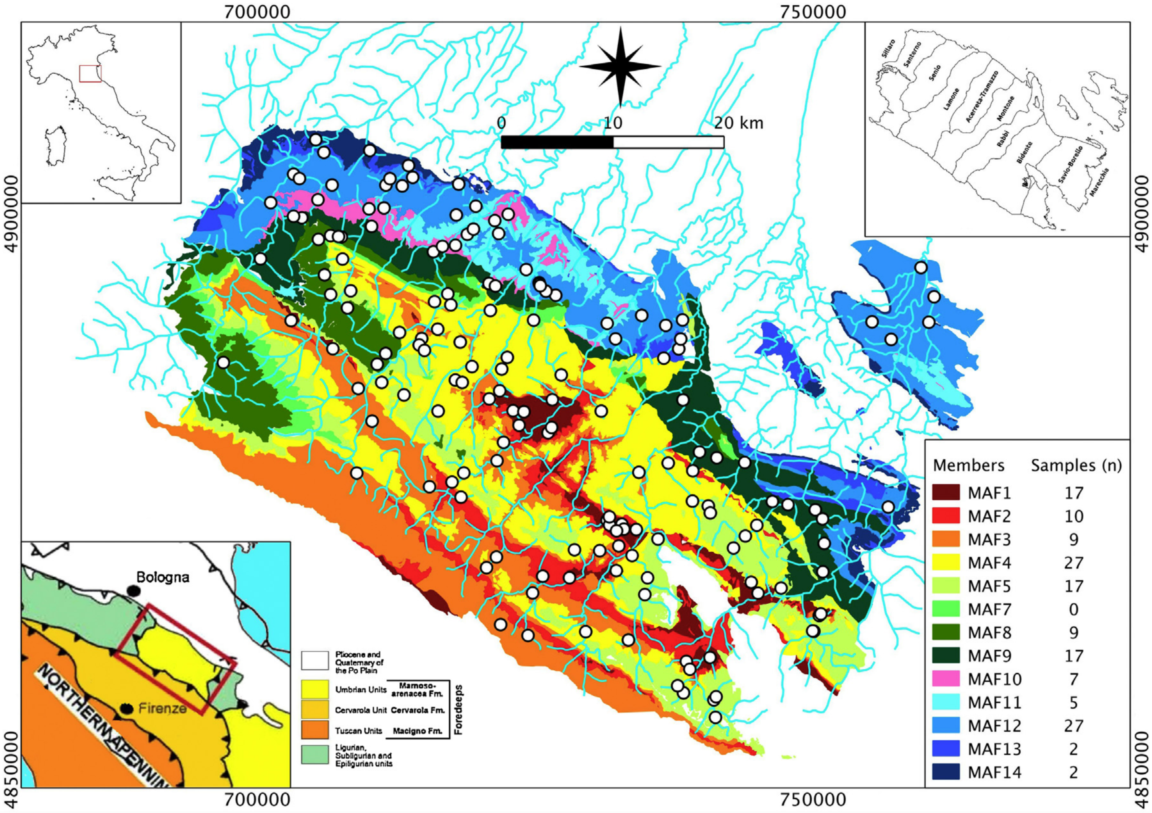

Fig. 1. Geological map of MAF modified from the source available at Servizio Geologico, Sismico e dei Suoli Regione Emilia Romagna showing the 13 members recognized by Martelli et al. (1994) and the number of samples selected for each member (lower right insert). The area is part of the catchment of nine rivers (upper right insert): Santerno, Senio, Lamone, Acerreta–Tramazzo, Montone, Rabbi, Bidente, Savio–Borello. It is limited to the north-west and to the south-east by two allocthonous units of Sillaro valley and Marecchia valley. The MAF (lower left insert) is part of the Umbrian Units between Ligurian, Subligurian, Epiligurian units at north-west and south-east, the Pliocene and Quaternary unit at north-east and Cervarola unit at south-west (from Muzzi Magalhaes and Tinterri, 2010).

concentrations (Bölviken et al., 1990). Therefore stream sediment is one of the best media in provenance studies and for determining tectonic setting (Carranza and Martin, 1997; Chandrajith et al., 2000; Ohta et al., 2004; Cannon et al., 2004; Singh, 2010; Tripathy et al., 2013). The grain-size fraction selected may significantly affect the analytical results of the stream sediment samples, since there appear to be higher concentrations of metals in the fine grain-size fractions (Förstner and Müller, 1974). In particular some authors (Chandrajith et al., 2000) point out how different grain-size fractions (<63 micron, 63–125 micron, 125–177 micron or 177–250 micron) contain different levels of transition elements which are generally absorbed in fine-grained sediments generally decreases in concentrations with the increase in grain size (Das et al., 2006). Some of the major elements (Al_2O_3, Fe_2O_3, MnO, MgO, CaO, and K_2O) increase in the finer sediments while SiO_2 increases in coarser samples. Moreover, a strong correlation is observed between sediment grain size and total organic matter due to the greater absorption capacity of fine sediments with large surface areas (Meyers and Eadie, 1993; Meyers and Lallier-vergés, 1999).

When considering these factors and an area where sedimentary rocks with different grain size fractions such as sandstones and marls occur and are characterized by various provenance supplies, it is essential to use a size fraction that represents a wide range of signals, in order to accurately determine the geochemical signatures of the study area and limit the effect of factors that could influence the results such as hydraulic sorting and weathering (McLennan, 1989; Nesbitt and Young, 1996; Nesbitt et al., 1996). For example, many authors suggest the potential of <0.200 mm fraction (Rose et al., 1979; Hale and Plant, 1994; Demetriades, 2014), which includes the fractions from fine-to medium-grained bed load material (fine sand–silt–clay).

If an adequate sample density is available, it is possible to highlight the lithological effect of specific geological units (Cocker, 1999; Lima et al., 2003; Ohta et al. 2005; Albanese et al., 2007; Breward, 2007) by observing the differences that characterize several rock types (e.g.: ultramafic, granitoid and sedimentary). For this study a high-density stream sediment sampling and a detailed geological map were used to investigate the geochemical evolution within each single geological unit which showed a strong correlation between geological evolution and geochemical composition. The aim is to show how geological landscape units can represent a key of representation in the geochemical mapping approach: this is an interesting topic since the geochemical map obtained, based on the geological unit, could prove to be a useful tool for carrying out the geological reconstruction of a complex area and obtaining a clear visualization of the spatial distribution of the chemical elements.

2. Study area

2.1. Geologic and stratigraphic setting

The study area, which covers approximately 2433 km^2, is located in the Romagna Apennines (Northern Italy). It lies between 11° 14′ 13.83” E and 12° 16′ 17.17” E; 44° 17′ 24.43” N and 43° 38′ 41.65” N and is delimited in the northwest and the southeast by two allochthonous units of the Sillaro valley and of the Marecchia valley (Fig. 1). This regional-scale area, as defined by Reimann et al. (2010), includes the northern part of the Marnoso-arenacea Formation (MAF), a turbiditic unit deposited in the Tuscan–Umbrian portion of the Inner Periadriatic basin during the Miocene epoch (Cipriani and Malesani, 1963a,b,c; Ricci Lucchi, 1978; Ricci Lucchi