Sedimentary Geology 318 (2015) 10–19

Contents lists available at ScienceDirect

Sedimentary Geology

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

Colour origin of Tortonian red mudstones within the Mersin area, southern Turkey

Muhsin Eren [a,*], Selahattin Kadir [b], Selim Kapur [c], Jennifer Huggett [d], Claudio Zucca [e]

[a] Mersin University, Department of Geological Engineering, TR-33343 Mersin, Turkey
[b] Eskisehir Osmangazi University, Department of Geological Engineering, TR-26480 Eskisehir, Turkey
[c] Çukurova University, Departments of Soil Science and Archeometry, TR-01330 Adana, Turkey
[d] Department of Earth Sciences, Natural History Museum, London SW7 5BD, UK
[e] Sassari University, Department Agriculture, V. le Italia, 39, 07100 Sassari, Italy

ARTICLE INFO

Article history:
Received 10 October 2014
Received in revised form 12 December 2014
Accepted 14 December 2014
Available online 20 December 2014

Editor: B. Jones

Keywords:
Reddening
Tortonian mudstone
Overbank deposits
Early diagenesis
Turkey

ABSTRACT

Fluvial red mudstones of Tortonian age (overbank deposits) are widespread in the Mersin area in southern Turkey. The XRD analysis reveals that the mudstones consist predominantly of smectite, containing 3.0 to 6.6 wt.% Fe_2O_3, of which ≤1% is present as hematite. However this is evidently sufficient hematite to yield a red colour to the whole rock. SEM images show that very fine hematite crystals are disseminated in the mudstones as pore-filling cement between smectite flakes. After reddening, some of the clay and hematite were most likely leached and accumulated with smectite in the shrink–swell fractures as infill. Reddening in the mudstone took place in a terrestrial environment and the hematite pigment formed from intrastratal water by inorganic precipitation at the initial stage of diagenesis. The free Fe^{2+} was most likely released from the Fe-bearing minerals in an aqueous reducing environment, with hematite being precipitated as cement during the dry periods.

1. Introduction

The term "red beds" is usually used to describe strata of reddish-coloured sedimentary rocks of different ages (Tucker, 1991). These red beds are quite variable, and most frequently represented by sandstones, limestones, conglomerates and mudstones. The red beds have been formed in various depositional environments including marine and non-marine environments. The red colour is due to the presence of finely dispersed hematite pigment (Fe_2O_3) (Van Houten, 1968, 1973; Turner, 1974; Einsele, 1992; Eren and Kadir, 1999, 2013). There is a great number of papers dealing with the origin of hematite pigment (e.g., Van Houten, 1968, 1973; Chukhrov, 1973; Franke and Paul, 1980; Mamet et al., 1997; Chen et al., 2010; Eren and Kadir, 1999, 2013). However, the origin of reddening in sedimentary rocks is still debated. There are two main hypotheses to explain the origin of the hematite pigment (Franke and Paul, 1980; Turner, 1980; Pye, 1983; Friedman et al., 1992; Einsele, 1992): (i) a detrital origin in which hematite derived from continental weathering during sedimentation (e.g., Krynine, 1949; Folk, 1976); and (ii) a diagenetic origin assuming that hematite formed authigenetically after deposition by alteration of iron-bearing detrital grains (e.g., Walker, 1967, 1974; Eren and Kadir, 1999, 2013). More recently, in the second hypothesis, a microbial origin was proposed for hematite pigment in carbonate rocks (Mamet et al., 1997; Préat et al., 1999; Préat et al., 2000; Boulvain et al., 2001; Della Porta et al., 2003; Mamet and Preat, 2006) and sandstones (Eren and Kadir, 2013). This paper investigates the origin of the hematite pigment in the Tortonian red mudstones (overbank deposits) and discusses their origin.

2. Geological setting

The study area is located in the residential area of Mersin city (Fig. 1) where Tertiary and Quaternary units are present (Eren et al., 2004, 2008; Figs. 2, 3). The Tertiary units are represented by the Karaisalı Formation (Burdigalian–Early Serravallian), the Güvenç Formation (Burdigalian–Serravallian) and the Kuzgun Formation (Tortonian). The Karaisalı Formation consists mainly of reefal limestone bearing abundant red algae and corals. The Güvenç Formation comprises predominantly grey coloured marlstone bearing various benthic foraminifers and includes argillaceous limestone intercalations. The Kuzgun Formation is subdivided into three members: the Kuzgun limestone, Sarıveli and Çiftlikköy members. The Kuzgun limestone member contains fore-reef slope deposits and reef cover sediments. The Sarıveli member consists of green coloured mudstone overlain by predominantly yellow coloured sandstone with yellow coloured mudstone intervals

* Corresponding author. Tel.: +90 324 3610001/7308; fax: +90 342 3610032.
E-mail addresses: m_eren@yahoo.com (M. Eren), skadir.euroclay@gmail.com (S. Kadir), kapurs@cu.edu.tr (S. Kapur), info@petroclays.com (J. Huggett), clzucca@uniss.it (C. Zucca).

http://dx.doi.org/10.1016/j.sedgeo.2014.12.003
0037-0738/

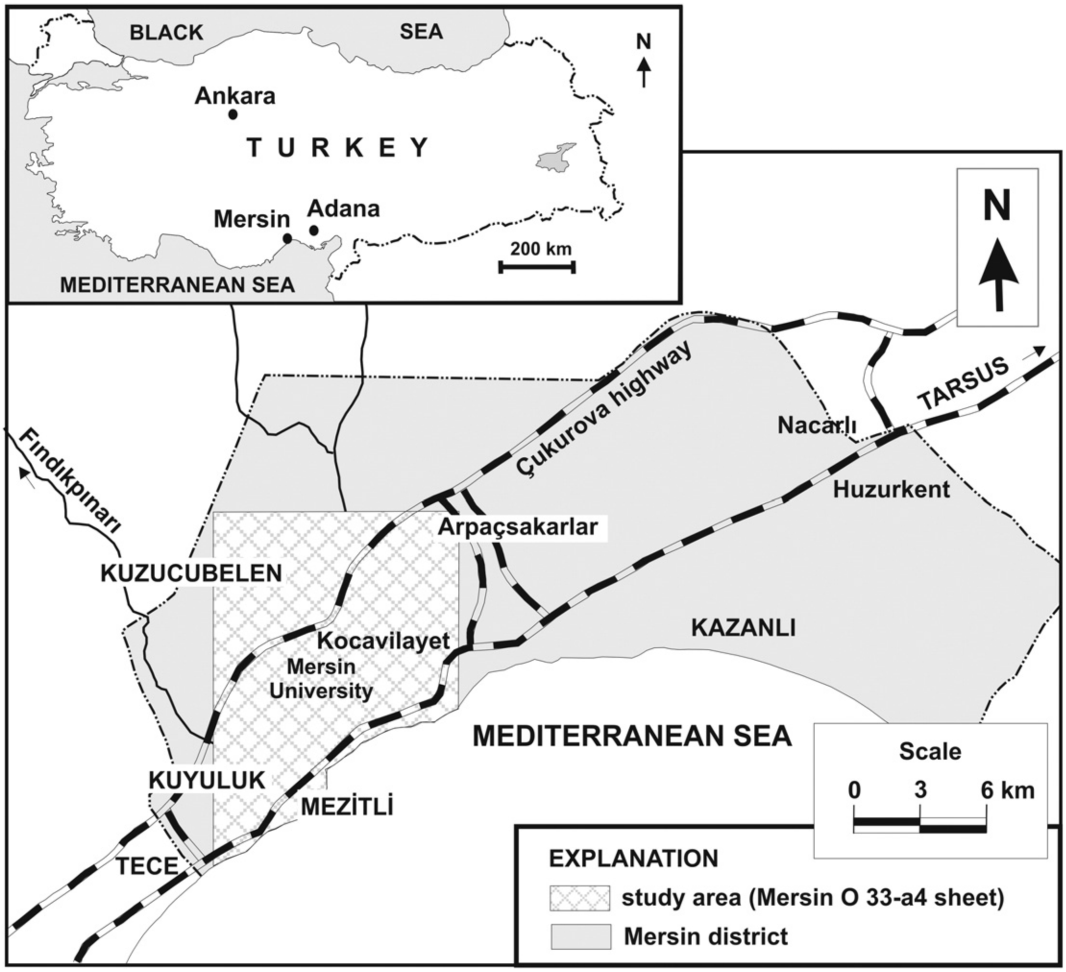

Fig. 1. Location map of the study area.

bearing marine fossils. The Çiftlikköy member is represented by ancient meandering river deposits with a thickness of 78 to 120 m, in which red coloured mudstones (overbank deposits) are dominant (Fig. 4). These mudstones alternate with coarse sandstones or granular sandstones (Fig. 4a, b). Calcrete nodules, tubes and fracture-fillings are common in the red mudstone (Fig. 4d). In some places, very thin black coloured manganese oxide coatings (Fig. 4c; Eren et al., 2014) are observed on the fracture surfaces. The Quaternary units comprise a hard laminated crust (hardpan calcrete), deltaic deposits, pebbly colluvial red soils (colluvium) and recent alluvium/terrace deposits.

3. Materials and methods

Twenty-three representative samples were collected from the Tortonian red mudstones and sandstones/granular sandstones from different localities in the Mersin city. Mineralogical characteristics of the bulk samples were determined by X-ray powder diffraction (XRD) analyses which were carried out using a Rigaku-Geigerflex diffractometer with CuKα radiation and a scanning speed of 1° 2θ/min at the General Directorate of Mineral Research and Exploration of Turkey (MTA). Randomly oriented mounts of powdered whole-rock samples were scanned to determine the mineralogy of each bulk sample. Samples for clay analysis (<2 μm) were prepared by separating the clay fraction using sedimentation and centrifuging the suspension after an overnight dispersion in distilled water. The clay particles were dispersed using ultrasonic vibration for approximately 15 min. Oriented specimens of the <2 μm fractions were prepared from each sample using the following procedure: air drying, solvating with ethylene-glycol at 60 °C for 2 h, and heating at 550 °C for 2 h. Semi-quantitative abundances of rock-forming minerals were obtained using Brindley's (1980) external standard method. The relative abundances of clay-mineral fractions were determined using their basal reflections and the mineral intensity factors of Moore and Reynolds (1989).

Chemical compositions of the selected samples were determined using inductively coupled plasma atomic emission spectroscopy (ICP-AES) at the ACME Analytical Laboratories Ltd., Vancouver, BC Canada. In the analyses, detection limits range from 0.01 to 0.1 wt.% for major elements and 0.1 to 5 ppm for trace elements. The dominantly amorphous/poorly and prevalently crystalline pedogenic forms of iron ($Fe_{oxalate}$ and $Fe_{citrate–dithionite–bicarbonate-CDB}$ respectively) were determined according to Holmgren (1967) and measured by atomic absorption spectrometry. The thin section (11 × 9 cm) of sample K5 for examination under transmitted and reflected light was prepared according to FitzPatrick (1993) from an epoxy resin impregnated sample. The petrographic examinations of the neighbouring four very weakly cemented sandstone/granular sandstone samples along with the mudstone were also performed. Scanning electron microscopy and energy-dispersive analyses (SEM–EDX) were performed on selected samples to determine characteristics of bulk samples and hematite pigment. The analyses were carried out at Oxford University, UK, using an FEI QUANTA SEM equipped with Oxford Instruments Aztec software and an EDX detector. For SEM–EDX analysis, representative samples were prepared by adhering the fresh, broken surface of the sample onto an aluminium sample holder with double-sided carbon tape and thinly coating with a film (~350 Å) of gold using a Giko ion coater.