Marine Chemistry 121 (2010) 176–186

Contents lists available at ScienceDirect

Marine Chemistry

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

Earthquake-induced turbidite deposition as a previously unrecognized sink for hydrogen sulfide in the Black Sea sediments

Mustafa Yücel [a,*], George W. Luther III [a], Willard S. Moore [b]

[a] University of Delaware, College of Earth, Ocean and Environment, 700 Pilottown Road, Lewes, DE 19958, USA
[b] University of South Carolina, Department of Earth and Ocean Sciences, Columbia, SC 29208, USA

ARTICLE INFO

Article history:
Received 8 December 2009
Received in revised form 2 April 2010
Accepted 14 April 2010
Available online 27 April 2010

Keywords:
Black Sea
Sediments
Sulfur
Iron
Turbidites

ABSTRACT

The depth profiles of excess ^{210}Pb, ^{137}Cs, elemental sulfur, reactive iron and porewater hydrogen sulfide of a western central basin sediment core in the Black Sea collectively point to the presence of a 20 cm thick reactive iron rich turbidite layer. This layer was most probably deposited there after the 1999 earthquakes in Northwestern Turkey, which caused oxidation of porewater hydrogen sulfide and anomalous accumulation of the product elemental sulfur in the solid phase.

A time-variable mathematical model was constructed to explore the non-steady state diagenesis of Fe–S species in a turbidite mud emplaced on normal anoxic–sulfidic deep Black Sea sediments. The 20 cm thick turbidite layer initially contained 80 µmol (g dry wt.)$^{-1}$ of Fe(III) in the form of goethite, which led to the rapid (1 day) oxidation and depletion of porewater sulfide and formation of solid phase sulfur intermediates such as S(0) and FeS. S(0) accumulated faster than FeS and was present in the sediment at high concentrations after 5–8 years following the deposition of the turbidite. Reduced iron was in the solid phase long after the consumption of all Fe(III), enabling the coexistence of S(0) and solid phase reactive iron (which has not been sulfidized yet) for a long period of time. The porewaters had sub-micromolar concentrations of dissolved sulfide in the first 2 years after deposition with Fe(II) exceeding 1 mM. The turbidite layer should serve as a sink for the sulfide from the overlying waters for about 10 years after its deposition.

Considering the ubiquity of the deep-basin turbidites found in the Black Sea and the dense tectonic activity on the Northern Anatolian Fault in Northern Turkey, an estimated 0.144 Tg sulfur/year could be buried as S_8 and FeS_2 due to the earthquake-induced turbidites. This value is about 14% of the annual sulfur burial (as pyrite) and 3–5% of the annual sulfide oxidation due to lateral injections of oxic Mediterranean waters to the anoxic–sulfidic Black Sea waters. It is highly likely that earthquake-induced turbidites and subsequent sulfide oxidation in the deep basin represent a previously unrecognized sink in the budget of hydrogen sulfide in the Black Sea.

1. Introduction

Marine sediment diagenesis is not often at steady state. Changes in organic carbon input, bottom water oxygen content, sedimentation and biological activity lead to transient states through which the sediment geochemistry evolves (Sundby, 2006). One process that results in non-steady-state diagenesis is the deposition of turbidites (Anschutz et al., 2002; Chaillou et al., 2007; Deflandre et al., 2002; Wilson et al., 1986). A turbidite is a sediment layer that is deposited by a turbidity current, which is a type of gravity current driven by gravitational buoyancy forces resulting from the density difference between two fluids (Masson et al., 1996). The triggering mechanisms of turbidity currents can be due to slope failures, tidal currents, coastal floods and earthquakes (Deflandre et al., 2002; Heezen and Ewing, 1952; Masson et al., 1996, Meiburg and Kneller, 2010).

A classic example of a turbidity current in a deep sea environment is the one that was triggered by the Grand Banks (Newfoundland) Earthquake in November 1929. The magnitude of the earthquake was 7.2 and the resulting turbidity current broke all the submarine telegraph cables in sequence from north to south (downslope) over the next 13 h 20 min (Heezen and Ewing, 1952). The epicenter of the earthquake was on the continental slope and turbidites resulting from this event were found as far as 800 km from the epicenter. In recent decades, more attention has been given to turbidites and turbidity currents in marine and lake environments (Grantz et al., 1996; Sarı and Çağatay, 2006; Thomson et al., 1998; Thomson and Weaver, 1994; Thunell et al., 1999). Turbidity currents can even result in up to five meter thick “megaturbidites”, which were found as far as 1000 km

* Corresponding author. Present address: Université Paris 6 – Pierre et Marie Curie, Laboratory of Benthic Ecogeochemistry (LECOB), Observatoire Océanologique, 66650 Banyuls-sur-mer, France. Tel.: +33 04 68887361; fax: +33 04 68881699.
E-mail addresses: mustyucel@gmail.com (M. Yücel), luther@udel.edu (G.W. Luther), moore@geol.sc.edu (W.S. Moore).

0304-4203/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.marchem.2010.04.006

away from their source in the Madeira Abyssal Plain (offshore Northwest Africa) (Weaver et al., 1992). They seem to be highly effective agents of sediment transport from shelf/slope to deep marine environments and may cause the coexistence of geochemically different sedimentary layers in a benthic environment.

In the Black Sea, the Earth's largest anoxic–sulfidic water body, turbidites have also been found in the central parts of the deep anoxic basin (Crusius and Anderson, 1991; Jipa, 1974; Konovalov et al., 2007; Lyons, 1991). Jipa (1974) reported turbidite-containing deep basin cores that were sampled during 1969 R/V Atlantis Cruise. That study even found shells of shallow-water species within some of the turbidite layers. Jipa (1974) suggested that the agent of transport was turbidity currents that originated from the littoral or near littoral zone of the Black Sea but he did not comment on what triggered these turbidity currents. After the 1988 R/V Knorr cruises to the Black Sea, Lyons (1991) also pointed to the presence of gray-homogeneous deep basin turbidites embedded in olive green microlaminated Unit 1 sediments. Konuk et al. (1991) underlined the importance of tectonic events to trigger turbidity currents originating from the steep southern shelf of the Black Sea.

What was not realized in the previous works was the turbidites' potential to bring metal oxides to the anoxic basin and to cause the oxidation of hydrogen sulfide in the Black Sea. After the analysis of cores collected during April 2003 R/V Knorr expedition to the Black Sea, two recent papers (Konovalov et al., 2007 and Yücel et al., 2010) have reported the presence of Fe-oxide rich turbidites in the upper sediments of the two western Black Sea stations (8-30 and 9-06 — shown in Fig. 1A) and documented sulfide oxidation in these turbidites whereas the sampled eastern basin sediments did not contain turbidites. These turbidites were the result of a recent

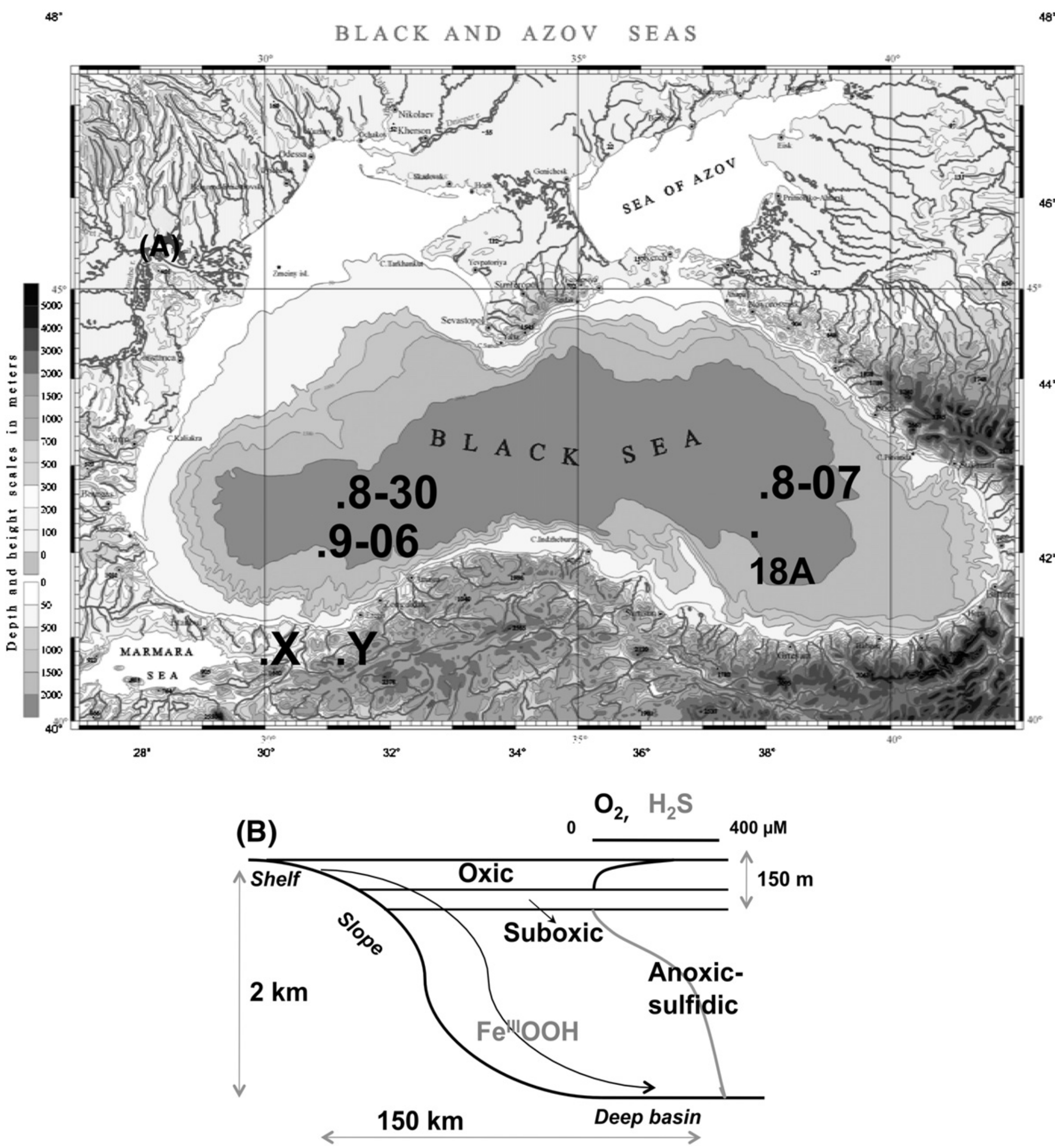

Fig. 1. (A) The map of the Black Sea with the locations of two western basin cores (8-30 and 9-06) that contained turbidites at their surfaces as of April 2003 (Konovalov et al., 2007). 8-07 was also sampled in 2003 and did not contain turbidites. 18A was sampled in a previous work (Crusius and Anderson, 1991) and is mentioned in Section 3. X is the epicenter of the August 17, 1999 earthquake (magnitude 7.4). Y is the epicenter of the November 12, 1999 earthquake (magnitude 7.2). (B) A schematic representation of the earthquake-triggered transport of FeOOH-rich shelf/slope sediments to the deep Black Sea along a north to south axis in the western basin.