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Rock magnetic identification and geochemical process models of greigite formation in Quaternary marine sediments from the Gulf of Mexico (IODP Hole U1319A)

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ABSTRACT

A 160 m mostly turbiditic late Pleistocene sediment sequence (IODP Expedition 308, Hole U1319A) from the Brazos-Trinity intraslope basin system off Texas was investigated with paleo- and rock magnetic methods. Numerous layers depleted in iron oxides and enriched by the ferrimagnetic iron-sulfide mineral greigite (Fe_3S_4) were detected by diagnostic magnetic properties. From the distribution of these layers, their stratigraphic context and the present geochemical zonation, we develop two conceptual reaction models of greigite formation in non-steady depositional environments. The "sulfidization model" predicts single or twin greigite layers by incomplete transformation of iron monosulfides with polysulfides around the sulfate methane transition (SMT). The "oxidation model" explains greigite formation by partial oxidation of iron monosulfides near the iron redox boundary during periods of downward shifting oxidation fronts. The stratigraphic record provides evidence that both these greigite formation processes act here at typical depths of about 12–14 mbsf and 3–4 mbsf. Numerous "fossil" greigite layers most likely preserved by rapid upward shifts of the redox zonation denote past SMT and sea floor positions characterized by stagnant hemipelagic sedimentation conditions. Six diagenetic stages from a pristine magnetite-dominated to a fully greigite-dominated magnetic mineralogy were differentiated by combination of various hysteresis and remanence parameters.

1. Introduction

Detrital input, biomineralization, and postdepositional geochemical alteration determine the magnetic mineral assemblage of marine sediments. Primary magnetic minerals, essentially iron oxides, carry information on sediment source areas, transport pathways and depositional environments, while secondary magnetic phases such as iron sulfides indicate diagenetic changes driven by organic carbon degradation and related redoxomorphic reactions.

Greigite (Fe_3S_4) is a widely distributed meta-stable ferrimagnetic iron-sulfide mineral forming authigenically in sulfidic sedimentary environments as precursor to pyrite (Sweeney and Kaplan, 1973; Jørgensen, 1977; Berner, 1984; Schoonen and Barnes, 1991; Wang and Morse, 1996; Wilkin and Barnes, 1997; Benning et al., 2000). It is found in organic-rich muds in high-accumulation environments like estuaries and river fans (Kasten et al., 1998), hemipelagic deposits (Berner, 1984; Horng et al., 1992; Oda and Torii, 2004) and gas hydrate systems (Larrasoaña et al., 2007) and anoxic basins (Lee and Jin, 1995; Sagnotti and Winkler, 1999). The abundance of greigite in aquatic sediments has often been underestimated because of its lower stability with respect to pyrite (FeS_2) (Sweeney and Kaplan, 1973; Jørgensen, 1977; Wilkin and Barnes, 1997) and its poor detectability by chemical analytics.

A major difference between greigite and pyrite is found in their magnetic properties. While pyrite is a weakly paramagnetic mineral, ferrimagnetic greigite has the capability of carrying a stable remanent magnetization. Its magnetic lattice is similar to that of magnetite, but coercivity is higher and susceptibility and saturation magnetization are lower (Hoffmann, 1992; Roberts, 1995). Diagnostic rock magnetic methods can therefore efficiently differentiate these iron mineral species (Torii et al., 1996; Rowan and Roberts, 2006).

This study identifies greigite enrichments in the mud-rich hemipelagic deposits of Hole U1319A from Brazos-Trinity Basin IV (Gulf of Mexico) visited in 2005 by Integrated Ocean Drilling Program (IODP) Expedition 308 (IODP Expedition Scientists, 2005). We present a simple greigite diagnostic and validate it by established rock magnetic methods. Based on rock magnetic stratigraphy and pore water geochemistry of the upper 40 mbsf section, we derive two conceptual models of (sub)oxic

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and sulfidic greigite formation based on non-steady state sedimentation and test model predictions against observations.

2. Geological setting and sample material

The Brazos-Trinity Basin system is situated on the hummocky upper continental slope of the northwestern Gulf of Mexico (150 to 1450 m water depth) downdip of a low-stand shelf-edge delta (Fig. 1). The upper four minibasins are connected and feed each-other in a 'fill-and-spill' style (Satterfield and Behrens, 1990; Badalini et al., 2000; Beaubouef and Friedmann, 2000). The basin system is paleogeographically and depositionally related to the interconnected submarine canyons of the Texas Brazos, Trinity, and Sabine rivers.

Brazos-Trinity Basin IV contains a 175 m thick succession of sand-rich, siliciclastic turbidite fan, local debris flow, intermediate distal fan and mass transport deposits intercalated with hemipelagic clays (Badalini et al., 2000; IODP Expedition Scientists, 2005; Flemings et al., 2006). Site U1319 (Latitude: 27°15.9751′N, Longitude: 94°24.1908′W) on the southern flank of the Brazos-Trinity Basin IV at 1430 m water depth was continuously cored to 157.5 mbsf with an average core recovery of 98.6%. Six lithostratigraphic units were recognized and interpreted in terms of sea-level controlled changes between hemipelagic and turbiditic conditions (IODP Expedition Scientists, 2005; Flemings et al., 2006):

- Unit I (0–3.33 mbsf): Foraminifer-bearing greenish gray clay; Holocene drape (Marine Isotope Stage = MIS 1)
- Unit II (3.33–17.25 mbsf): Clay with fine sand laminae (MIS 2–3); Subunits A (turbiditic), B (organic-rich mass transport deposit), C (turbiditic influx) and D (transition to Unit III)
- Unit III (17.25–23.5 mbsf): Hemipelagic foraminifer-bearing clay (MIS 3–5.1)

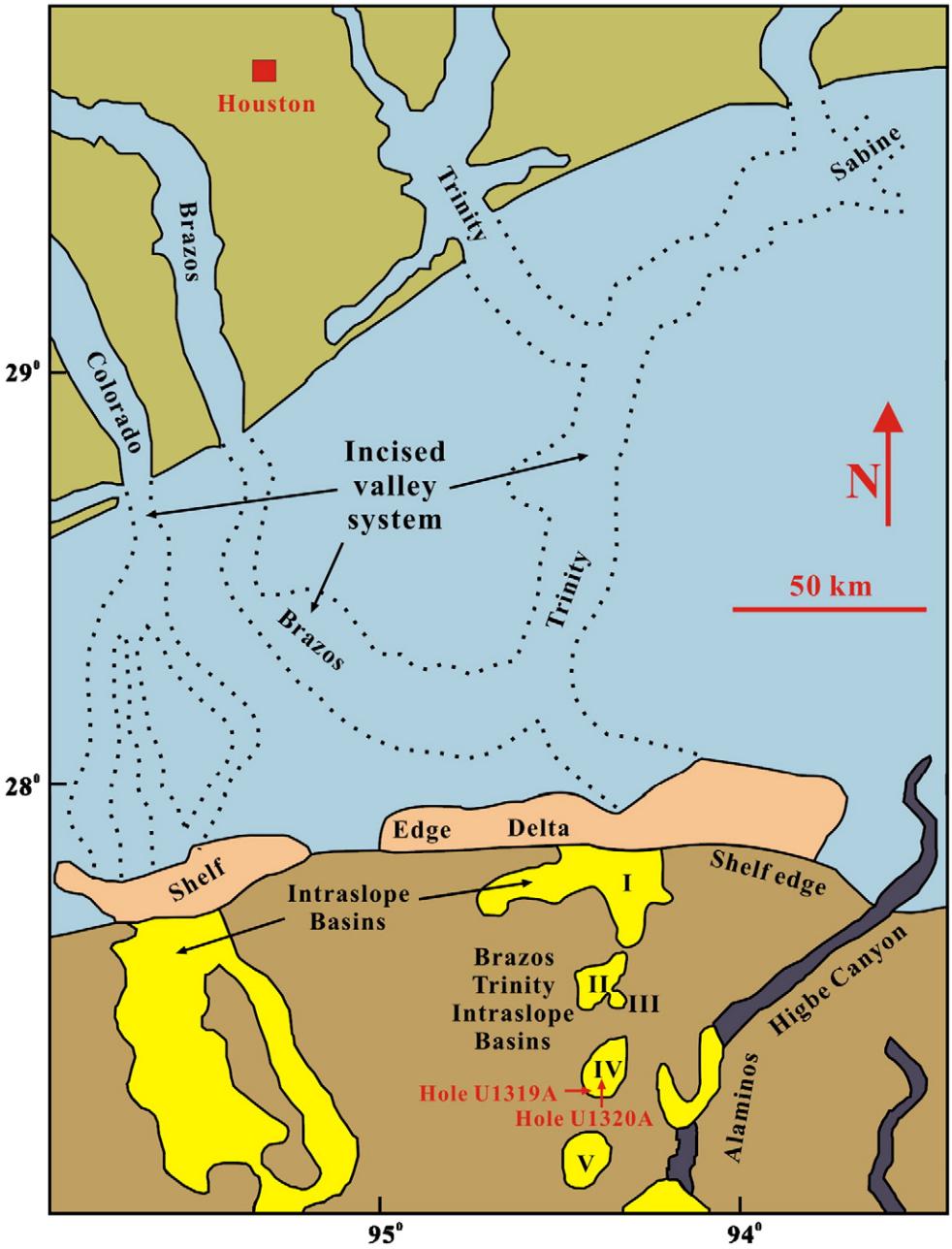

Fig. 1. IODP Expedition 308 Holes U1319A and U1320A in the Brazos-Trinity Basin IV offshore Texas. Physiography and latest Pleistocene paleogeographic features (adapted from Winker, 1996; Badalini et al., 2000).