



A WHITE LAYER AT THE K/PG BOUNDARY IN MONMOUTH COUNTY NEW JERSEY: IMPACT RELATED OR POST-DEPOSITIONAL DIAGENESIS?

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Abstract

The K/Pg boundary is well exposed within the Crosswicks Creek basin in southern Monmouth County, New Jersey. It is represented by the uppermost Maastrichtian New Egypt Formation and Danian Hornerstown Formation. The New Egypt is composed of a chocolate brown micaceous glauconitic mud and is overlain by a sharp but bioturbated contact with the green glauconitic muddy sand of the Hornerstown Formation. A fossil concentration known as the main fossiliferous layer (MFL) is located within the bottom 30 cm of the Hornerstown. The process related to the formation of the MFL has been debated for many years. Obasi (et al. 2011) and Gallagher (2003) have proposed continuous sedimentation across the New Egypt/Hornerstown contact with the MFL being emplaced in situ. Landman (et al. 2007) suggest that the MFL is a fossil concentration due to a transgressive lag related to a diastem at the boundary. Within the Crosswicks Basin, there appears to be a discontinuous white layer at the top of the MFL. It consists of non-consolidated to crystalline lenses. The lenses are a few mm to up to 20 cm thick and can be as much as 2 meters long. They are composed of scattered glauconite grains within a white matrix. The matrix, which makes up over 90% of the composition of the white layer, was determined by XRD analysis to be siderite. Two possible hypotheses for the formation of this white layer are examined. The first relates it to the impact and events associated with the K/Pg bolide impact. The second suggests post-depositional diagenetic processes related to concretion formation. The fact that it is not universal and only occurs locally, forms lens shapes of mostly siderite and is stratigraphically positioned at a permeability change suggest that the process of formation was diagenetic concretion formation possibly related to microbial activity leading to reducing conditions not directly related to the impact event at the end of the Cretaceous.

Introduction

The Cretaceous/Paleogene (K/Pg) boundary on the New Jersey Coastal Plain is represented by glauconitic, fossiliferous, poorly consolidated layers (Ebel, et al., 2010). Within the Crosswicks Creek basin in Monmouth County, New Jersey, the K/Pg boundary is found at the contact of the Hornerstown and New Egypt formations. The Hornerstown Fm is characterized by a muddy sand recognized in the field by its intense green due to an abundance of glauconite. Other minerals in the Hornerstown Fm include limonite, pyrite, and collophane (Adams, 1963). The New Egypt formation is a gray to chocolate brown, glauconitic, sandy clay, locally indurated with siderite; pyrite and quartz are minor constituents (Staron et al., 2001; Obasi et al., 2011).

At the contact of these two layers is an assemblage of invertebrate and vertebrate fossils referred to as the Main Fossiliferous Layer, or MFL (Gallagher, 1993). The exact relation of the MFL and the K/Pg boundary is the subject of debate, with some placing the boundary within the MFL, while others have argued that the K/Pg boundary is above the MFL within the basal Hornerstown Fm. Obasi (et al., 2011) interpreted the MFL as a thanatocoenosis related to the K/Pg mass extinction event, while Landman (et al., 2007) believes the MFL represents a transgressive lag during the Danian.

Within the Crosswicks Creek basin, a discontinuous white layer is found at the top of the MFL. This layer consists of unlithified to crystalline lenses ranging in thickness from several mm to 20 cm and varying in length up to 2 meters. They are composed of scattered glauconite grains within a white matrix. Slabs of the white layer up to a meter in length are found throughout the stream beds in the Crosswicks Creek basin. Clasts attributed to rip-ups caused Chicxulub impact-related tsunamis are found at most New Jersey coastal plain sites just above the K/Pg boundary (Miller et al., 2010). These clasts, however, tend to contain foraminiferal assemblages and calcareous nanofossils, and have a clay composition (Olsson, Miller, Browning, Habib, & Sugarman, 1997). X-ray diffraction revealed that the matrix of the white layer at Crosswicks Creek is siderite (FeCO₃).

Methodology

Three locations were examined for this study: Contact Creek East (40°05'36" N, 74°32'07" W), Contact Creek West (40° 05'16" N, 74°33'04" W), and Meirs Farm (40°06'15" N, 74°31'37" W). Stratigraphic sections were measured, noting changes in lithology, bedding features, fossil content, and evidence of bioturbation. Samples were collected and examined with a Rigaku Micro X-ray Diffractometer for mineral composition. Thin sections were prepared and photographed using a Nikon Eclipse E600 microscope under both regular and polarized light. A Hitachi TM-1000 scanning electron microscope was used to determine elemental composition.

Study area

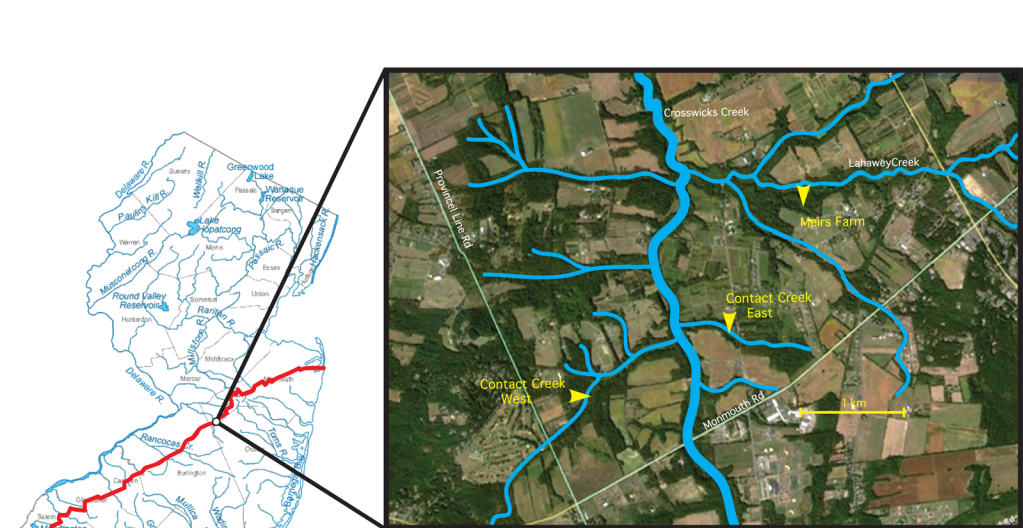


Figure 2 - Map of southern Monmouth County, NJ. Creeks and tributaries

Figure 1 - Map of New Jersey rivers and counties. Red line = K/Pg boundary (Retrieved from <http://geology.com/lakes-rivers-water/new-jersey.shtml>)

Contact Creek East



Figure 10: Siderite concretion 2 m in length, weathered slabs of siderite are found throughout the creek beds (red arrow)

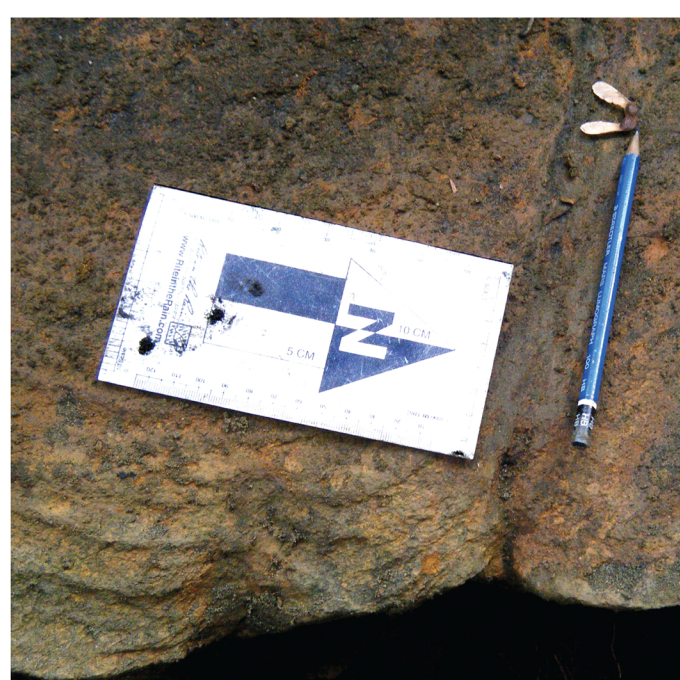


Figure 11: Siderite concretion showing signs of apparent lamination

Contact Creek West



Figure 12: Siderite concretion (red arrow) and unlithified siderite (orange arrow) within the basal Hornerstown Fm, just above the MFL

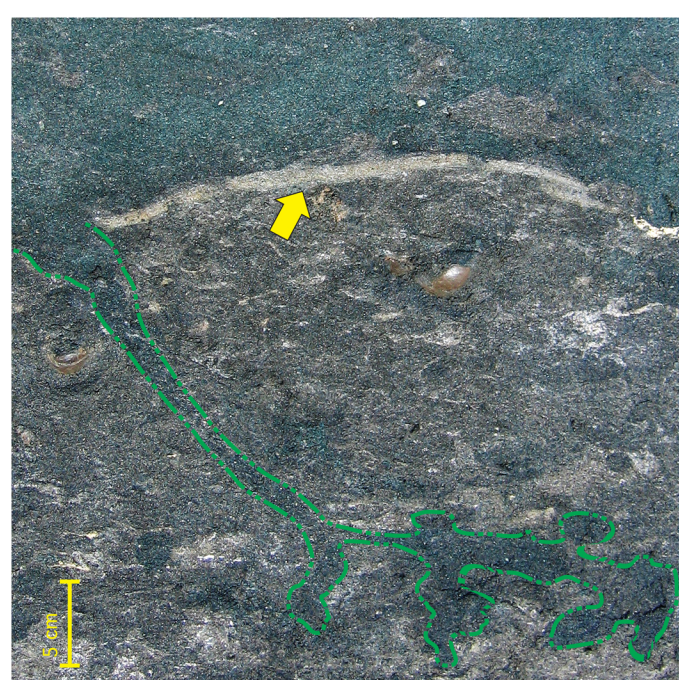


Figure 13: Siderite concretion layer (yellow arrow) found below the glauconitic Hornerstown Fm and above the MFL. Glauconite from the Hornerstown Fm piped down into a burrow into the MFL and New Egypt Fm (green lines)

Meirs Farm



Figure 14: A thin lens of semi-lithified siderite at Meirs Farm

Stratigraphy

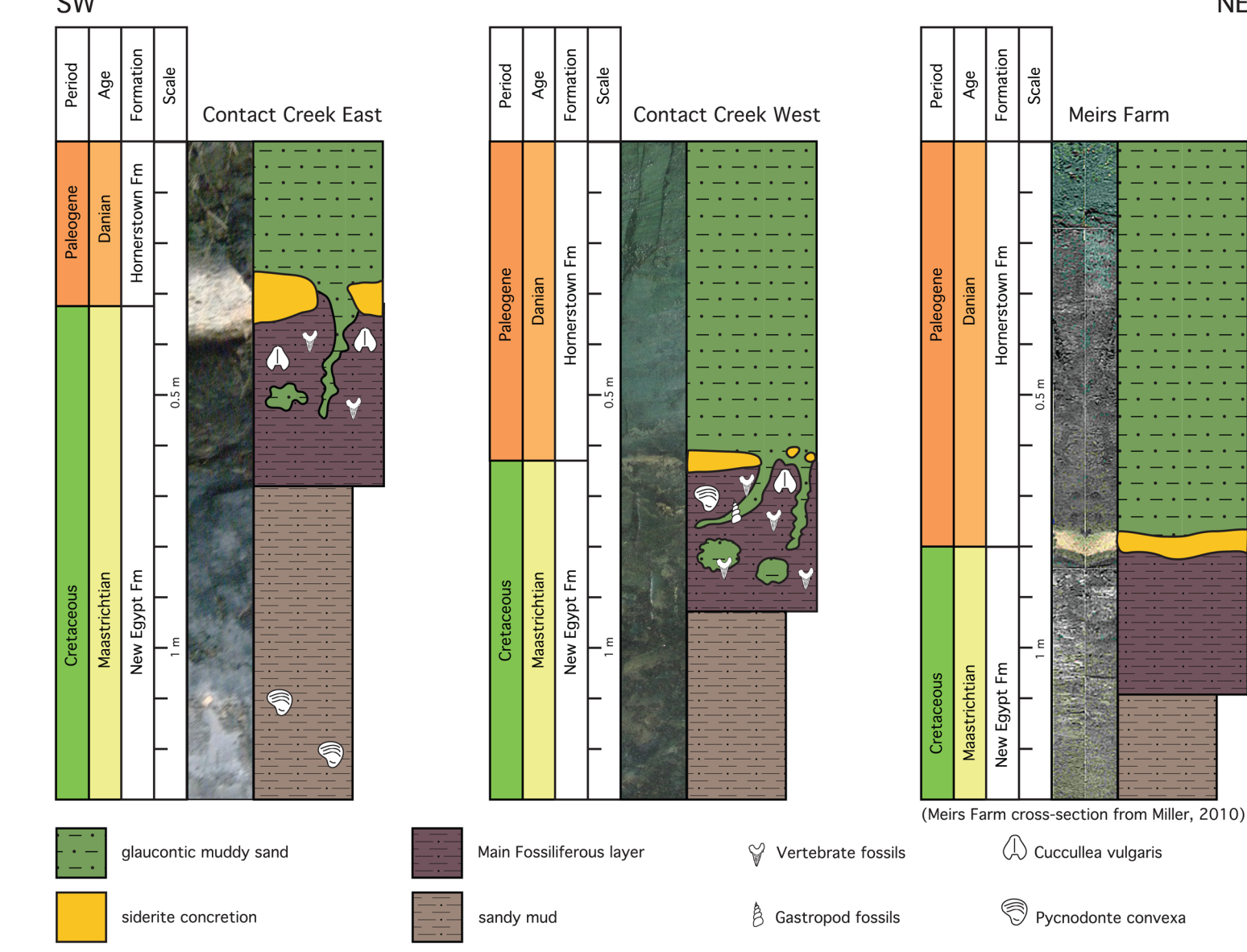


Figure 3: Correlation of three stratigraphic sections showing relative positions of siderite concretions

Thin sections

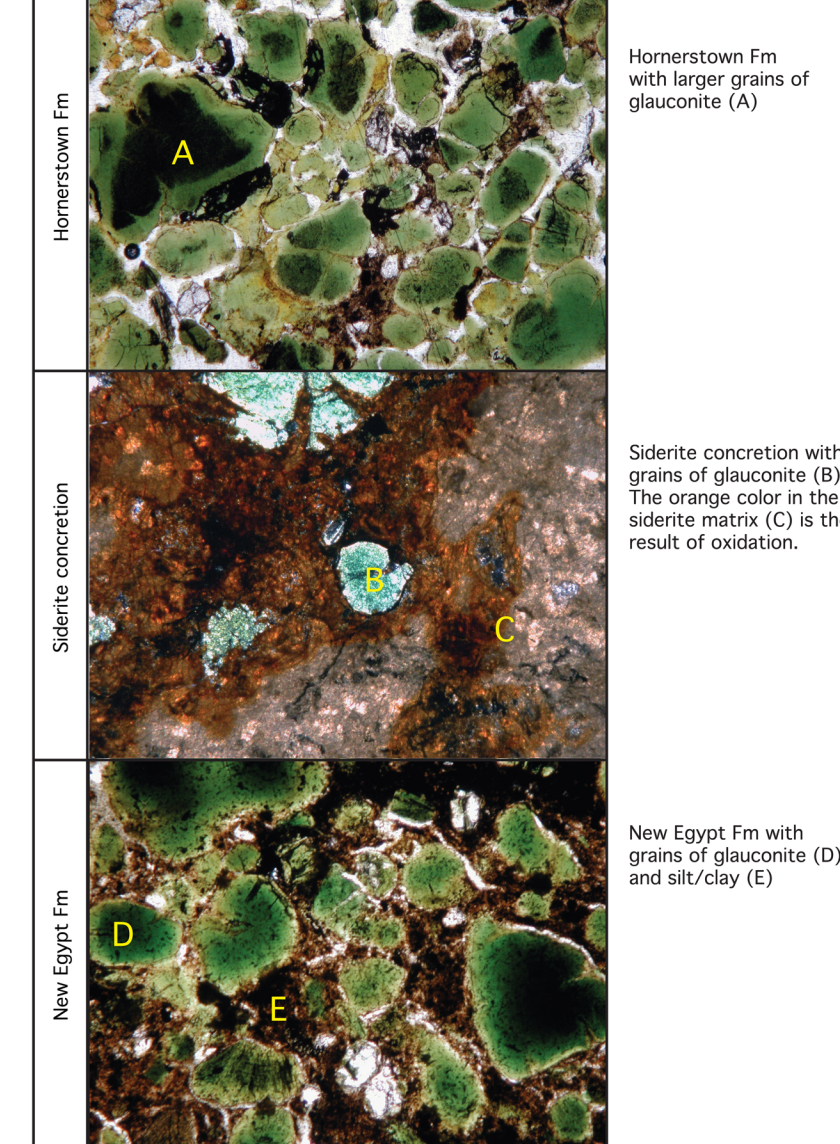


Figure 4: Thin sections of material from Contact Creek West. Images shown were taken under regular light. Field of view is 4 mm horizontally.

X-Ray Diffraction

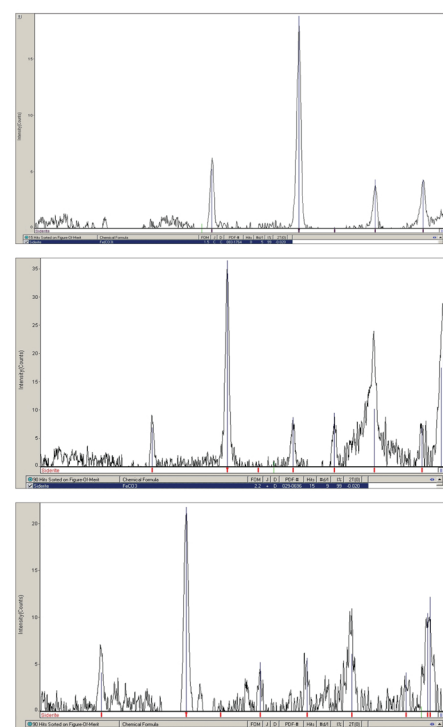


Figure 5: X-ray diffraction identifying the white layer as siderite

SEM Imagery and Elemental Composition

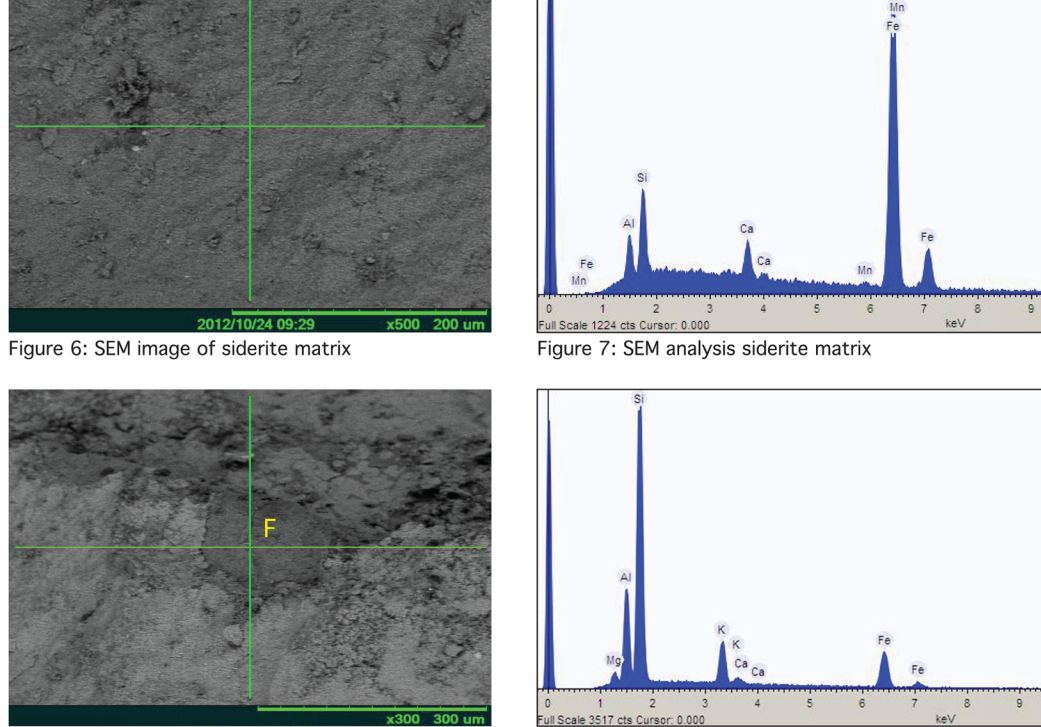


Figure 8: SEM image of a glauconite grain (F) within a matrix of siderite

Figure 9: SEM analysis of glauconite grain

Element	Weight %
Iron	87.0
Silicon	5.8
Aluminum	3.2
Calcium	3.0
Manganese	1.0

Table 1: Elemental composition of the siderite matrix of a concretion from Crosswicks Creek basin. The high Fe content, presence of Mn, relatively low levels of Ca, and absence of Mg indicate formation of siderite from freshwater.

Element	Weight %
Silicon	45.1
Iron	29.3
Aluminum	13.3
Potassium	9.6
Magnesium	2.1
Calcium	0.6

Table 2: Elemental composition of a glauconite grain within the siderite matrix of a concretion from Crosswicks Creek basin.

Discussion

In reducing conditions, the stable mineral of iron may be pyrite, siderite, or magnetite (Krauskopf, 1967). Concretion growth of diagenetic minerals is affected by numerous factors including pore water composition and source, transport mechanisms, distribution of solutes within sediment, the ratio of organic to inorganic matter, rate of burial, availability of oxidizing agents, in particular Fe(III) and S²⁻, and bacterial activity (Coleman, et al., 1985; Curtis & Coleman, 1986; Matsumoto & Iijima, 1981). Concretions form down-gradient of organic matter, parallel to the direction of groundwater flow (Mozley & Davis, 2005), concentrating where movement of waters is restricted by less permeable layers (Prothero & Schwab, 2004). The conditions in which siderite forms are severely limited (Berner, 1971). Siderite forms due to bacterial action during methanogenesis, producing bicarbonate ions that combine with Fe²⁺ (Posilovic, et al., 2008). Deep burial is not required for siderite concretions to form, as siderite may grow close to the sediment-water interface, where rates of iron reduction are high. (Fisher, et al., 1998). Siderite may form from marine or meteoric waters, with significant differences in chemical composition.

Characteristics of marine siderite

- Substitution of Mg (up to 41 mol%) for Fe
- Substitution of Ca (up to 15 mol%) for Fe
- Higher Mg²⁺/Ca²⁺ ratios
- Wide range of δ¹⁸O values

Characteristics of meteoric siderite

- Relatively pure (>90 mol% FeCO₃)
- Higher concentrations of Mn (>2 mol% MnCO₃)
- Lower Mg²⁺/Ca²⁺ ratios (Mozley, 1989)
- δ¹⁸O value of < -13 and a positive δ¹³C (Mozley & Wersin, 1992)

Conditions conducive to siderite formation from marine waters

- SO₄²⁻ reduction is restricted or SO₄²⁻ is exhausted (Hounslow, 2001; Posilovic et al., 2008)
- Rapid sedimentation removing muds from direct contact with the SO₄²⁻-rich overlying sea water (Curtis, Pearson, & Simogiyi, 1975)
- Marine water is more alkaline, siderite forms in pH ranges of 6-10 (Krauskopf, 1967)
- If organic matter quality or quantity is restricted, Fe(III) reducing bacteria may outcompete SO₄²⁻ reducing bacteria, as reducing Fe(III) is more energy efficient (Adams et al., 2006)

Conditions that inhibit siderite formation from marine waters

- Pyrite is the preferential sink for Fe in marine waters
- Marine water has a higher concentration of SO₄²⁻: 2710 ppm
- Marine water has a lower concentration of Fe: 2 ppb

Conditions conducive to siderite formation from meteoric waters

- Siderite is more likely to form in organic-rich, non-marine sedimentary environments
- Fresh water is SO₄²⁻-poor: 8.25 ppm; limiting pyrite formation (Posilovic et al., 2008)
- Higher concentration of Fe: 40 ppb (Drever, 1982)
- Can form in acidic freshwater environments, if the concentration of Fe ions is high (Krauskopf, 1967)
- Bacterial Fe reduction can raise pH, conditions that are conducive to siderite formation (Kantorowicz, 1985)

Conclusions

The siderite layer found at Crosswicks Creek basin occurs at the boundary of the Hornerstown and New Egypt formations, where the lithology sharply changes from a muddy sand to a sandy clay, with a noticeable difference in grain size.

The relative purity of the siderite, (87 % Fe, 3% Ca, with no Mg, see Table 1), and the presence of Mn suggest the siderite formed from meteoric water. Data taken from different points on the concretions is consistent; the siderite shows no variation in elemental composition from center to margin. Elemental homogeneity is evidence against prolonged siderite development during progressive burial (Baker et al., 1996). The siderite therefore formed from freshwater, with no influence from marine or mixed water. The concretions may be recent, as carbonate concretions can form in very short time frames (Pye et al., 1990).

The presence of siderite lenses at Crosswicks Creek basin and their absence at other K/Pg boundary sites may be the result of localized conditions. Siderite nucleates throughout the volume of concretions simultaneously and may not fill all available pore space (Fisher et al., 1998; Raiswell & Fisher, 2000). This pervasive growth model may help explain the lensing of the siderite concretions throughout the Crosswicks Creek basin. Poorly cemented siderite concretions at various stages of growth may be present throughout the basal Hornerstown Fm, but may be indistinguishable from the surrounding sediment.

Significance

- The siderite concretions are not directly related to impact ejecta.
- In situ alteration of impact-melt glass would result in the transformation of glasses to clay minerals such as smectite (Declercq, 2007), not siderite.
- No evidence related to the impact such as shocked quartz or spherules was found within the siderite matrix.
- As the siderite is non-marine in origin, it is not related to rapid sedimentation caused by impact-related tsunamis (Miller et al., 2010).
- The non-marine origin of the siderite also precludes any link to preferential reduction of Fe(III) by bacteria due to reduced availability of organic matter from a thanatocoenosis (Obasi et al., 2011).

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Acknowledgments

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