[PS]Sedimentary Characteristics of Fine-Grained Resurge Facies, Wetumpka Marine Impact Structure, Central Alabama*

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Abstract

Marine impact craters have interior, crater-filling breccias of high permeability and porosity and are potentially self-sealing with the deposition of a resurge facies, a fine-grained unit characteristic of many marine impacts. Therefore, marine impact craters may be an ideal hydrocarbon reservoir within a petroliferous basin. However, the stratigraphic, sedimentologic, and genetic parameters of the aqueous resurge facies in such craters are not fully understood, particularly those formed in shallow marine settings.

Located in central Alabama, the well-preserved and surficially exposed Wetumpka shallow marine impact structure is a good field laboratory to study both the sedimentary crater-filling breccias and fine-grained resurge facies. Formed within the lowermost transgressive systems tract of the Upper Cretaceous Selma Group, during the deposition of the lowermost Mooreville Chalk, the Wetumpka marine impact structure has a mixed-target stratigraphy of pre-Mesozoic crystalline bedrock, Upper Cretaceous unconsolidated sediments, and 30-100 meters of water depth.

Utilizing a shallow drill-core of ~ 100 m, crater-filling mega-slumped sands and their overlying glauconitic, calcareous mudstone resurge unit have been studied in detail. This paper reports on the on-going sedimentologic and stratigraphic investigation based on core description, adjacent outcrop description, thin-section petrography, and x-ray computed tomography (CT). Preliminary results from x-ray CT of cores have revealed internal, inclined bedding structures, and brecciation of penecontemporaneous, transported sea floor mud clasts that are delineated by intact burrows and density contrasts between clasts and a disaggregated mud matrix. The internal sedimentological and stratigraphic characteristics reveal alternation between predominately matrix-supported mud-breccias and uni-directional cross-stratified units. Hydrodynamic genesis of these deposits is thought to be successive muddy debris flows followed by rapid suspension sedimentation. Increased

understanding of the mode of emplacement of the impact-derived, fine-grained capping unit at Wetumpka could help predict the reservoir characteristics of analogous, sub-surface impact structures within petroliferous basins. Supported by NASA grant NNX09AD90G and the Fred A. and Jean C. Dix Named Grant part of the AAPG Foundation Grants-in-Aid program.

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SEDIMENTARY CHARACTERISTICS OF FINE-GRAINED RESURGE FACIES, WETUMPKA IMPACT STRUCTURE, CENTRAL ALABAMA

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Abstract

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Utilizing a shallow drill-core of ~ 100 m, crater-filling mega-slumped sands and their overlying glauconitic, calcareous mudstone resurge unit have been studied in detail. This paper reports on the on-going sedimentologic and stratigraphic investigation based on core description, adjacent outcrop description, thin-section petrography, and x-ray computed tomography (CT). Preliminary results from x-ray CT of cores have revealed internal, inclined bedding structures, and brecciation of penecontemporaneous, transported sea floor mud clasts that are delineated by intact burrows and density contrasts between clasts and a disaggregated mud matrix. The internal sedimentological and stratigraphic characteristics reveal alternation between predominately matrix-supported mud-breccias and uni-directional cross-stratified units. Hydrodynamic genesis of these deposits is thought to be successive muddy debris flows followed by rapid suspension sedimentation. Increased understanding of the mode of emplacement of the impact-derived, fine-grained capping unit at Wetumpka could help predict the reservoir characteristics of analogous, sub-surface impact structures within petroliferous basins.

Introduction

Impact craters have experienced a near exponential rate of discovery within the last 40 years with conservative estimates of 714 phanerozoic undiscovered craters >1km remaining (Stewart 2011). Furthermore, according to Donofrio (1998), impact craters within petroliferous basins have a 50% commerical success rate.

The Wetumpka marine impact crater is not known to contain fluid hydrocarbons. However, despite being surficially exposed, Wetumpka is in an excellent state of stratigraphic preservation. Thus, Wetumpka can provide us with the opportunity to better understand the sealing potential of the resurge facies of shallow marine impact craters.

Methods

This study uses observations and field studies from proximal outcrops, oriented drill core from a resurge deposit, thin-section petrography, and proximal exposures of original Mooreville Chalk to study the resurge facies. In addition, to the very fine-grained character of this unit, X-ray Comoputed Tomography was utilized to discern and measure orientions of sedimentary structures within drill core with the use of conjugate sets of X-ray CT along with some limited 3D reconstructions.

Target Stratigraphy

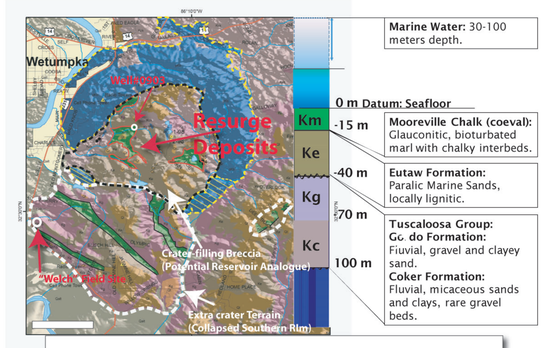


Figure 1. Shaded Relief Map of Geological Units, Target Stratigraphy, and Crater Terrains

Based on the correlation of mega-slumped sand facies within #0903 with proximal outcrop, the western resurge deposits ('chalk meadows') are preserved in rotated downthrown blocks due to late-stage modification of the crater interior by settling of the crater-filling breccias or mega slumping. Furthermore, a recently discovered semi-intact Eutaw through Mooreville Chalk outcropped, rotated block at the 'Welch' outcrop has allowed us to investigate proximal, unaltered Mooreville Chalk and a possible outlier of preserved resurge.

Geological Map modified from Johnson (2007).

Resurge Facies Petrography

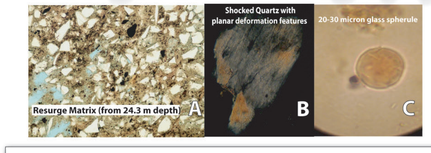


Fig.2 . Provenance of Resurge Facies.

Despite the dominance of Eutaw and Tuscaloosa sands and crystalline basement within target stratigraphy, the resurge is predominately monolithic, sourced from coveal seafloor deposition of Mooreville Chalk. Nevertheless, a fine-grained component of ejecta (B,C) is evident with optical microscopy. Spherules (C), in particular, indicate the interior chalk meadows (resurge deposits) are sourced from outside the crater.

Impact ejecta microphotographs were taken by Scott Harris.

Resurge Stratigraphy

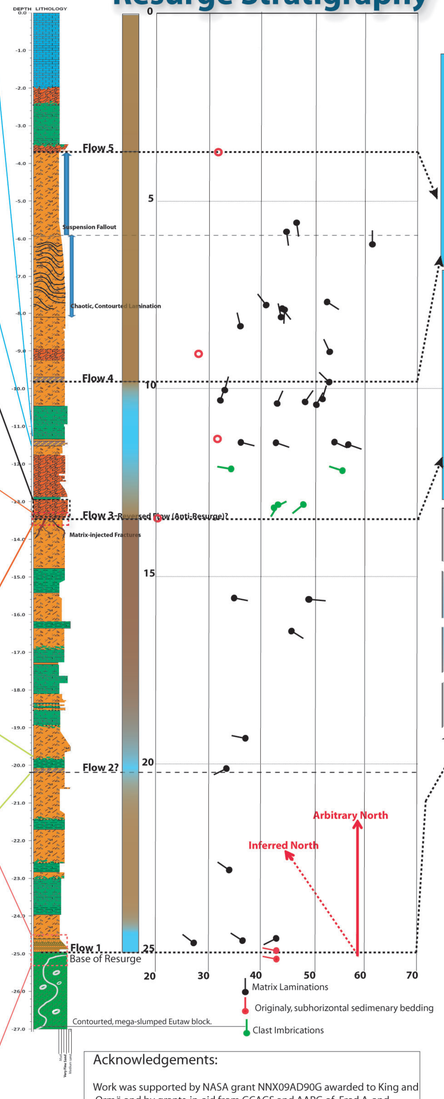


Fig. 3. Mudflow to Aqueous Transition

Lithofacies 5 (L5)- Polylithic-laminated matrix. This is an uncommon facies in which strongly expressed laminations of contrasting and alternating lithology resemble cross-beds and cross-lamination. Internally, they do not exhibit clasts but often have clasts resting on up-permost laminations accompanied with compaction features.

Lithofacies 6 (not shown) - Enigmatic chalk. This uppermost unit is a phosphatic, fossiliferous chalk with modern diagenetic overprinting of caliche nodules that has been previously proposed as a secular deposit [4]. However, within the CT images subtle features such as internal, inclined lamination, burrows, and wide fractures could mean this is, in fact, lithofacies 4.

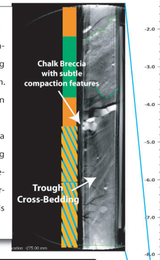


Fig. 4. Stacked Mudflow Contacts

Lithofacies 2 (L2) - Matrix-dominated breccia. This is a glauconitic, calcareous shale that is sandy in parts with weakly-expressed inclined laminations, 'swirled' fabrics, generally sparse and small pebble-sized breccia, and possible boudinaged thick laminae of contrasting densities. This is the dominant lithofacies of the resurge unit, occurring between other lithofacies from the lithofacies 1 to the base of lithofacies 6.

Lithofacies 3 (L3)- Clast-dominated breccia. This lithofacies is of lesser occurrence than lithofacies 2, and although could be, in some cases, a fully disaggregated lithofacies 4, this facies is prevalent within the middle of the resurge unit. It is characterized as a normally graded unit of breccia that transitions from clast-supported to matrix supported . Maximum thickness is 0.8 m with some apparent imbrications within two intervals.

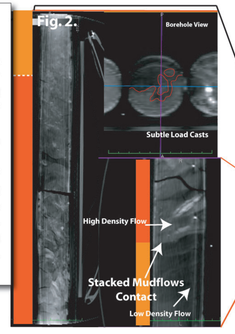


Fig.5. Coeval Sea Floor Ripups

Lithofacies 4 (L4) - Transported Mooreville Chalk. When clast size exceeds the confines of the drill-core in the horizontal dimension, they are defined as "blocks." Such blocks are interpreted based on intact internal bedding, trace fossils, and other sedimentary structures . Blocks range at a minimum size of 0.065 m to a maximal observed-minimum of 1.0 m. Orientation of blocks are commonly similarly aligned with matrix inclination trends. Lithology ranges from chalk to marl which are often caught 'frozen' in the process of disaggregation and dismemberment and exhibit wide matrix-filled fractures.

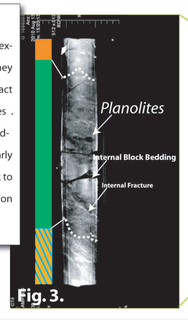
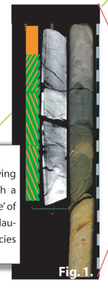
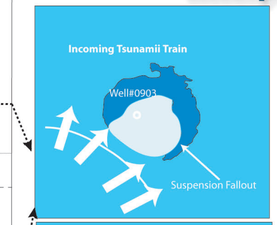


Fig. 6. Mixing-Shear Zone

Lithofacies 1 (L1)- Basal shear zone. The facies exhibits an underlying planar, well-sorted fine sands that are slightly intercalated with a muddy, glauconitic, sandy flame structure. Above the 'mixing zone' of the flame structure is a cross-laminated muddy, non-calcareous, glauconitic fine sand that fines upward and is gradational with lithofacies 2.

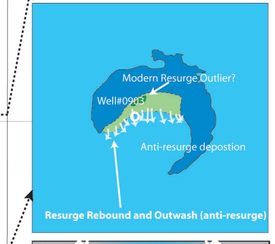


Interpretation



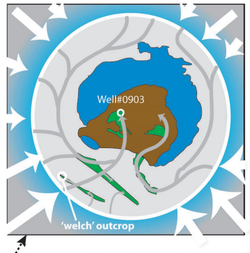
Oscillatory Resurge

Oscillatory resurge (tsunamiite wavetrains) is typical of marine impact craters. Within flow 4, there is evidence of fine-grained suspension fallout. This is preceeded by contourted, laminated coarse silts which could be local slumps of unstably deposited prograding mudflow. The periods of low or no hydrodynamic activity (suspension fallout) between chalky-mudflows could be brief lulls between sediment-laden Tsunamiites derived from distal parts of the surrounding hemi-pelagic marine shelf.



Anti-Resurge

Similarily to studies of Lockne Impact Crater from Ormo et al. (2007), Wetumpka appears to have a anti-resurge component. However, instead of a central water spout, the resurge is rebounding of the northern rim and depositing a reverse-flow (southernly), and more aqueous, prograding clast-rich breccia. Evidence in favor or resurge is supported by current directions within outflow of trough crossbedding and clast imbrications of L3 as well as the high clast density, which are typical of anti-resurge.



Primary Resurge

Following the collapse of the southern rim, the collapse of the water crater brought heavily sediment-laden resurge into the crater in a northerly direction. Because proportionately little crystalline basement or Tuscaloosa is found within the resurge, this study proposes that the resurge was dominated by coeval sediments and was likely a hydroplaning mudflow, thus prohibited from entraining sediments of the southern rim. Furthermore, significant portions of the resurge were intercepted by grabens of the extracrater terrain. This is evidenced by nearly identical lithology with the basal shear zone (L1) and exposures at the 'Welch' outcrop. Finally, higher dipping angles at the base of the resurge suggests that the structure of #0903 is partially syn-formational with the basal resurge.

Implications for Hydrocarbon Exploration

Unlike other well-studied marine impact structures (Gohn, et al. 2006, Ormö, et al. 2007) such as Chesapeake Bay (moderate, variable marine depth) and Lockne (deep marine), Wetumpka incorporates a finer lithology derived mostly from coeval depostion of Mooreville Chalk Ripups with a less aqueous hydrodynamic behavior. Based on the fine-grained character, poorly-sorted mudflow emplacement, and crystalline-rim, a impact crater analogous to Wetumpka would be favorable for a crater-filling breccia-megaslump reservoir due to the good sealing qualities of the capping resurge seal.

In summary, the following characteristics appear to be important, genetic controls on the character of impact craters analgous to Wetumpka:

1. Coeval deposition-lithology is mostly derived from seafloor ripups.

2. Shallow water depth:-Hydrodynamic behavior that trends toward high-density flows and poor sorting.

3. Obliquity of Impact-currently not fully understood control on ejecta patterns and water crater formation.

4. Position within a sequence stratigraphic framework- preservation potential of resurge is enhanced by position within the condensed section.

Acknowledgements:

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