Analysis of Compaction in the Niobrara Formation, Denver-Julesburg Basin, Colorado
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Introduction
The Upper Cretaceous Niobrara Formation in the Denver-Julesburg Basin is composed of alternating chalks and calccareous shales (Figure 1). Increased burial depth in the western part of the basin results in thermally mature oil and gas, but also poses the issue of decreased permeability and porosity due to post depositional diagenetic alterations.

This study sought to assess how compaction varies with respect to stratigraphic zone, facies, and facies components (e.g., grain types). Fifty four samples from two wells (referred to as the Timbro and the Aristocrat) in northeastern Colorado were analyzed in order to address these questions (Figure 2). By correlating the degree of compaction to lithologic attributes, we sought to identify the scale at which compaction can be categorized and determine the extent to which minor facies changes affect compaction profiles.

Methods
This study used peloids, which are grains of microcrystalline calcite (Figure 3) that are assumed to be round upon deposition, as a measure of compaction. Thin sections were prepared from core samples at an average spacing of two feet. Photomicrographs were taken at 40X magnification for each microfacies present in each slide. The area, perimeter, circularity, aspect ratio, roundness, solidity, Feret’s diameter, mean, and modal gray scale value were measured using Image J for fifty peloids in each photomicrograph.

Results
Of the variables measured, circularity was chosen as the proxy for extent of compaction because it showed the most variability, thus presumably was capturing the most variance in compaction (Figure 4).

Overall there is a large spread of peloid circularities within each well (Figure 5), and within each sample (Figure 6).

There is one dominant peloid size. There is also a positive skew due to a minor population of larger peloids (Figure 7).

Circularity shows some response to stratigraphic facies lithology (chalk vs. marl), but it appears to be very a minor influence (Figure 8).

Stratigraphic zones show little control on compaction. Though chalk zones contain samples with generally higher circularities and marl zones the samples with some of the lowest circularities, there is a broad range of circularities in every chalk and marl zone. This may reflect the fact that that most samples are chalk microfacies even when from marl zones.

The microfacies were categorized into seven groups on the basis of foraminifera abundance, chalk darkness, pelid color, and structure.

Microfacies
1. Foraminifera-rich light-colored chalk with dark pelids - bioturbated (in core)
2. Foraminifera-rich light-colored chalk with laminations of marl containing dark pelids - laminated
3. Foraminifera-bearing very light-colored chalk with light pelids - structureless
4. Foraminifera-poor light-colored chalk with laminations of marl containing dark pelids - laminated
5. Foraminifera-bearing light-colored chalk with dark pelids - light lamina
tions and some large burrows
6. Foraminifera-rich microlaminated darker chalk and marlier with dark pelids
7. Circle-laminated chalk

Figure 10: Microfacies 1, 2 and 4 show similar, low compaction. Microfacies 5, 6, and 7 show similar, high compaction. Microfacies 3 shows an intermediate level of compaction.

Conclusions
• Circularity is a proxy of compaction
• We observe that there is primarily one population of peloids. The positive skew also shows a minor population of larger peloids. From this we deduce that there is one primary organism present with minor input from one or more other organisms.
• Compaction within stratigraphic zone is highly varied because microfacies vary. Degree of compaction does not correlate to stratigraphic zone well.
• Compaction is not well categorized by the lithology of its corresponding stratigraphic zone. This is likely because within each zone there are many laminations of opposing lithologies within each zone.
• Compaction is better categorized by microfacies and pelid type than lithology (marl vs. chalk)
• Microfacies 1, 2 and 4 show similar, low compaction. Microfacies 5, 6, and 7 show similar, high compaction. Microfacies 3 shows an intermediate level of compaction. There does not appear to be any single variable that links these microfacies together.
• Darker peloids show higher amounts of compaction than lighter colored peloids.

Further work
The next step is to expand the sampling pool by sampling two more available cored wells in the area, the Gill Land Associates 2, and the Burbach 20-3H. Work should be done on finding a proxy which better estimates various aspects of color, not just gray scale values. Categorizing the samples in to microfacies by different variables might also create more insight into compaction correlations. More samples of the available core should also be made to correct the present bias for chalk samples. Chemical analysis of the samples would also provide additional insights into the present correlations and possibly show new relationships.

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Figure 2: A map of the Denver-Julesburg Basin and Niobrara formations inscribed with a range and township map of the two walls of interest: Aristocrat & Timbro. The Timbro Field is outlined in pink for reference.