An Assessment of Shock Metamorphism for Jeptha Knob, A Suspected Impact Crater in North-Central Kentucky

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This thesis titled
An Assessment of Shock Metamorphism for Jeptha Knob, A Suspected Impact Crater in North-Central Kentucky

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ABSTRACT

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An Assessment of Shock Metamorphism for Jeptha Knob, A Suspected Impact Crater in North-Central Kentucky

Director of Thesis: Keith Milam

Impact craters in carbonate rock account for ~30% of all impacts on Earth, yet little research has been conducted to study shock metamorphism on such targets. This study examined the petrography of carbonate rocks at Jeptha Knob, a 4.26 km diameter structure east of Shelbyville, KY, to investigate whether evidence of shock metamorphism is present and to determine peak pressures experienced by a previously postulated impact event. Petrographic observations and XRD analyses of calcite/dolomite have the potential to confirm shock metamorphism and constrain peak pressures in impact sites because certain petrographic features are correlated with increasing shock pressures. Specifically, XRD peaks in calcite/dolomite broaden and peak intensities decrease, mechanical twin density increases, and twin spacing decreases. Thin section petrography and XRD analysis of samples collected from the JK78-3 core show that the structure is highly deformed and provide evidence of these rocks experiencing pressures of > 4.6 GPa. The results collected from JK78-3 are consistent with that of an impact origin and provide insight into the development of other impact craters in carbonate rocks.
This paper is dedicated to my loving parents and wonderful brother. Without their support I don’t think I would have made it through graduate school. Love you guys.
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INTRODUCTION

The Earth’s dynamic geologic processes remove or bury impact craters making it difficult to both locate and identify them millions of years after the impact event. To date, there have been 184 impact craters identified and confirmed on the Earth’s surface (PASSC, 2013). Evidence of shock metamorphism is the key to determining whether or not a structure was formed by the impact of an asteroid or comet with the Earth’s surface (French, 1998; French and Koeberl, 2010). Impacts produce shock waves that can permanently deform rocks and minerals as they propagate through them (e.g. Bell et al., 1998; Burt et al., 2005; Bell, 2010; French and Koeberl, 2010). As a result, there are a number of features that are produced such as high pressure glasses, planar deformation features (PDF’s), and shatter cones, all of which have all been widely used in identifying or confirming impact events (Stöffler and Langenhorst, 1994; Grieve and Pilkington, 1996; Langenhorst, 2002; Langenhorst et al., 2002; French and Koeberl, 2010).

Shock features occur over a range of pressures and in a variety of minerals (Fig. 1). Quartz preserves shock features over a range of peak pressures (Table 1) (Stöffler and Langenhorst, 1994, French and Koeberl, 2010). The effects of shock on carbonates however, have received less attention (e.g. Bell, 1997; Skala and Jakes, 1999; Osinski and Spray, 2001; Skala, 2002; Langenhorst et al., 2002; Burt et al., 2005) despite their presence in ~30% of known terrestrial impacts (Kieffer and Simonds, 1980).
Figure 1: Pressure intervals which certain shock deformation effects form in quartz, olivine, graphite, and calcite (from Langenhorst, 2002).
Table 1

**Shock Effects on Mixed Powder Experiments on Calcite and Quartz. (after Bell, 2010)**

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<th>Shock Pressures (GPa)</th>
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<th>Quartz</th>
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<td>9.9</td>
<td>1-2 sets of twins with 10-50 μm spacing, Fractures on grain margins</td>
<td>Fractures on grain margins and intergranularly</td>
</tr>
<tr>
<td>13.8</td>
<td>1-2 sets of twins with 10-15 μm spacing, Some intergranular fractures</td>
<td>Incipient formation of PDFs, Fractures on grain margins</td>
</tr>
<tr>
<td>18.4</td>
<td>Twins more closely spaced, Twins kinked and curved, Intergranular fractures more prevalent</td>
<td>Multiple sets of PDFs, Mosaicism in some grains</td>
</tr>
<tr>
<td>24.3</td>
<td>Incipient recrystallization, Increasing twin density, Multiple closely spaced twin sets</td>
<td>Multiple sets of PDFs, Intergranular fractures</td>
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<td>30.1</td>
<td>Retains high birefringence, Grains densely twinned, Bimodel grain size distribution (&gt; 125 μm and &lt; 50 μm)</td>
<td>Isotropic, Bimodal grain size distribution (&gt; 125 μm and &lt; 50 μm)</td>
</tr>
<tr>
<td>40.7</td>
<td>Retains Birefringence, Twin domains &lt; 10 μm</td>
<td>Isotropic, Grains comminuting and rounding</td>
</tr>
<tr>
<td>47.1</td>
<td>Retains Biofringence, All grains &lt; 50 μm</td>
<td>All grains &lt; 50 μm</td>
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Unlike quartz, shock metamorphism in calcite does not produce PDFs, but results in an increase in the density of mechanical twins (Turner, 1953; Langenhost, 2002; Schedl, 2006; Bell, 2010). This phenomenon can also occur due to non-impact related processes (Turner, 1953; Barber and Wenk, 1979 (A); Burkhard, 1993), making interpretation of shock-induced twins somewhat equivocal. However, under low to moderate shock pressures (1MPa - 50 GPa) calcite develops three distinct sets of mechanical twins: \( e = \{0118 \} \), \( f = \{0112 \} \), and \( r = \{1014 \} \) (Turner, 1953; Turner and Weiss, 1963; Barber and Wenk, 1979 (A)), whereas dislocations dominate at higher pressures (Barber and Wenk, 1976; Langenhorst, 2002). Recent studies have shown that calcite may be stable up to pressures of 60 GPa (Martinez et al., 1995; Bell, 1997; Bell et al., 1998), but can display a variety of features over a large range of peak shock pressures in...
experiment (Table 1 and Bell, 2010). Dolomite, however, only displays one distinct twin set: $f' = \{0112\}$. The lack of $e$-twinning in dolomite is due to its $\{0118\}$ planes containing both Ca and Mg atoms, while the $f$-plan does not (Barber and Wenk, 1979 (B)). If twinning were to occur along the $e$-plane, the Ca and Mg cations would be in a closer-than-normal proximity (Barber and Wenk, 1979 (B)).

As increasing pressures are exerted upon a mineral, their X-ray diffraction peaks will begin to broaden and peak intensities will decrease as their crystal structures are progressively more affected by shock pressures (Fig. 2) (Martinez et al., 1995; Bell et al., 1998, Skala and Jakes, 1999, Skala, 2002). These effects were observed at the Ries Crater in Germany, where samples taken from varying distances from the center of the structure were to an un-shocked equivalent from the Malmain Solnhofen limestone (Skala, 2002). Peak broadening effects can vary depending on the distance from the pressure source (Vizgirda and Ahrens, 1980; Skala and Jakes, 1999). If no other known deformation has occurred within a given area, these broadening effects may be used as a possible shock barometer to infer peak shock pressures (Skala and Jakes, 1999; Skala, 2002; Burt et al., 2005). The Rietveld refinement method allows for crystal structure refinement by using the full width half-maximum (FWHM) of a broadened x-ray diffraction peak to find a best fit against a known crystal structure. The FWHM is determined through single-peak profile fitting by the equation of Caglioti et al. (1958): $(FWHM)^2 = Utan^2\theta + Vtan\theta + W$, were $U$, $V$, and $W$ are refined unit cell parameter values taken from the diffraction data which characterize the widths of the XRD peaks.
Figure 2: X-ray diffraction patterns of limestone samples (from Skala and Jakes 1999). A. Iceland spar representing an unshocked standard while the lower curve represents the location of quartz on the diffraction curve. B. Limestones from the Kara Crater exhibiting peak broadening and base area widening (intensity increases from bottom to top).

The advantage of the Rietveld refinement method is that it provides very reliable unit cell parameters and peak half widths. These unit cell dimensions can be used to determine if minerals (e.g. dolomite, Fig. 3) have experienced different levels of shock pressures (Skala and Jakes, 1999; Skala, 2002; Burt et al., 2005).
As described above, petrographic observations and XRD analyses of carbonate minerals can be used to assess shock metamorphism in suspected structures and to constrain peak pressures in impact craters confirmed by other means. This study examines the carbonate rock in one suspected impact crater, the Jeptha Knob structure, for evidence of shock metamorphism to determine if its formation resulted from an impact event and, if an impact origin is confirmed, to estimate peak shock pressures.

The Jeptha Knob Structure: A Suspected Impact Crater

The Jeptha Knob structure is an approximately 4.26 km diameter circular structure situated just east of Shelbyville, Kentucky (38.18°, -85.11°). Jeptha Knob is located in the Western Outer Bluegrass physiographic region of Kentucky. The structure is extensively brecciated and has concentric and radial faults, horsts and grabens, and anticline and syncline features (Cressman, 1981) (Fig. 4).
Structurally, Jeptha Knob consists of a central area of highly faulted and folded Ordovician aged units with the magnitude of deformation decreasing as one moves outward from the center of the structure. The central area is capped by a Lower Silurian fine-grained dolostone with an overlying soil and chert residuum from Middle Silurian formations (Cressman, 1981) (Fig. 5). The lower contact of the Middle Ordovician Clays Ferry Formation within the Jeptha Knob structure is ~137 m higher in elevation than it is adjacent to the structure (Cressman, 1981).
The origin of this anomalous structure has been debated for 125 years beginning with Linney (1887) who first proposed that Jeptha Knob was formed by a localized subsidence and subsequent sediment infilling. Bucher (1933) mapped the Jeptha Knob structure and postulated that it was formed by the upward force of gas from a deep rooted volcanic source. He claimed that this was one of 6 cryptovolcanic (a term that later was changed to cryptoexplosive) structures in the U.S., which included Serpent Mound in Adams County, Ohio and Wells Creek Basin in Stewart County, Tennessee (Bucher, 1933), both of which are now confirmed impact structures (Stearns et al., 1968; Baranoski et al., 2003).

Seeger (1968) was the first to discredit Bucher’s “cryptoexplosive” origin for the Jeptha Knob structure, suggesting that a hypervelocity impact could better explain its formation. He conducted gravity and magnetic studies of Jeptha Knob and determined that the basement rocks played no part in the development of the structure as would be required to produce a volcanic vent (Seeger, 1968). Seeger et al. (1985) conducted geochemical analyses of breccias from
Jeptha Knob and found elevated concentrations (0.108 ± 0.014 ppb) of iridium, suggestive of a potential meteorite component. These two studies concluded that the Jeptha Knob structure was most likely produced by hypervelocity impact.

Cressman (1981) mapped the surface geology and stratigraphy of Jeptha Knob and the surrounding area. He observed concentric and radial faults as well as the heterogeneous brecciation similar to that of Sierra Madera impact in Texas (Wilshire et al., 1972) and the Decaturville impact in Missouri (Offield and Pohn, 1977). He suggested that Jeptha Knob was most likely formed by an impact based on its circular form, lack of basement uplift, and localized brecciation (Cressman, 1981).

No clear evidence of shock metamorphism, such as: shatter cones, coesite, or PDFs, have been observed within the structure but the overall appearance, structure, and stratigraphy of the Jeptha Knob is consistent with formation by a hypervelocity impact of an asteroid or comet (Seeger, 1968; Cressman, 1981). This interpretation has not been previously fully confirmed due to previous lack of evidence of shock metamorphism at the structure.
PURPOSE

The purpose of this project was to use petrographic observations and XRD analyses of the carbonate sedimentary target rock at Jeptha Knob to answer the following questions:

1) Was the Jeptha Knob structure formed by a hypervelocity impact?

2) If the Jeptha Knob structure is of an impact origin, what were the peak pressures experienced during the impact event?
METHODS

Core Selections

Samples used in this study were collected from one of three cores that were drilled for mineral exploration within the Jeptha Knob structure by Ozark Mahoning in 1978. These cores are currently stored at the Kentucky Geological Survey Well Sample and Core Library in Lexington, KY. JK78-1 and JK78-3 were both drilled in the center of the structure, while JK78-2 was drilled on the northern flank of the knob (Fig. 4). JK78-3 was chosen for detailed analysis because of its proximity to the center of Jeptha Knob. If shock features are to be found within Jeptha Knob, the central area would have presumably experienced and recorded the highest shock pressures (Melosh, 1989; French and Koeberl, 2010). Thus, the highest probability of detecting shocked calcite or dolomite should be from this core. JK78-3 is a 5 cm diameter core that was drilled to a depth of 365 m (Fig. 6, 7, & 8) and contains discrete carbonate blocks and megablocks often separated by fault breccias. Preliminary observations of JK78-3 revealed rotated blocks and megablocks, faulting, intense brecciation, and slickensides within the core. Similar features were also observed in the nearby core JK78-1 (McCowan, 2012).
Figure 6: Stratigraphic column of core JK78-3. Total depth is 365 m. Core is comprised of alternating blocks and mega blocks of fine to medium-grained dolostone separated by breccia units. No core recovery from 0-3.66 m.
Figure 7: Stratigraphic columns of core JK78-3 from depth 0 - 183 m. Bedding dip angle of individual blocks and mega blocks is shown to the right of columns. UP/DOWN arrows show locations of slickenside.
Figure 8: Stratigraphic columns of core JK78-3 from depth 183 - 366 m. Bedding dip angle of individual blocks and mega blocks is shown to the right of columns. UP/DOWN arrows show locations of slickenside.
An additional core was chosen to provide samples that would serve as unshocked, undeformed analogs to those geologic units identified in JK78-3. Core C-204 was chosen as a comparison for JK78-3 due to its relative proximity to the Jeptha Knob (21 km SE), and because it assumed it is assumed to have been far enough from JF78-3 not to have been exposed to the shock waves of the potential impact event centered at Jeptha Knob. Core C-204 was drilled by Cominco American in 1970 for mineral exploration and is also currently stored at the Kentucky Geological Survey Well Sample and Core Library. Core C-204 is 687 m in length, 5 cm in diameter, and is composed of flat lying fine – medium grained limestone and dolostone beds (Fig. 9). This core shows no apparent signs of structural deformation.
Figure 9: Stratigraphic column of core C-204. Core is comprised of flat lying limestone and dolostone beds. Total depth is 687 m.
Sample Collection and Processing

A total of 65 samples were collected from cores C-204 and JK78-3: 18 from C-204 and 47 from JK78-3. Samples were chosen to assure that each of the different types of strata found within each column was represented in their entirety by sampling at the top, center, and bottom of any given geologic unit. Rocks in JK78-3 are significantly deformed. The core consists of megablocks with sedimentary bedding of varying orientations separated by faults, some of which contain fault breccias (Figs. 6, 7, & 8). Megablocks are internally deformed as evidenced by imbricated microfaults (most of which are normal). All megablocks appeared to represent single geologic units. Samples were collected more frequently from megablocks that displayed structural deformation because these locations were thought to be the location of more intense deformation. Samples were collected more frequently from thicker fault breccias.

Samples were observed and described in hand specimen and then processed into thin sections. The remaining material from each sample was processed for X-ray diffraction analysis. Each sample was cut using a Hillquist Trim Saw into thin slabs ~0.25 – 0.5 cm thick. This was done in order to facilitate the crushing of the samples into the appropriate size for use of a mortar and pestle. The material was then pulverized to a diameter of 20-50 μm using a ceramic mortar and pestle. The method was chosen in order to minimize any peak broadening that might result by the use of a pulverizer (Skala, 2002). In order to verify that this sample preparation technique did not skew the test results, a sample of micritic limestone was cut into three different thicknesses and widths and then pulverized in the ceramic mortar and pestle. All of these samples were then analyzed through the X-ray diffractometer to verify that the sample preparation process did not cause any peak broadening. None was detected.
Petrography

Thin sections were observed using an Olympus CX31 microscope using polarized and cross-polarized transmitted light. Photomicrographs were collected using a Motic BA300Pol microscope with a Motocam1000 1.3M pixel USB2.0 camera. Individual minerals were identified by their optical properties. Classification of carbonate rocks was based on the abundance of carbonate grains and the relative abundance of micrite and sparry calcite, as well as the abundance and type of allochems present within each sample (Folk, 1959; Dunham, 1962).

All bedding orientations and structural features including normal or reverse faults, fractures, and bedding displacement were documented and/or measured. All of the faults and fractures observed within a given grain were observed to determine their relationship with the surrounding mineral grains. This was done in order to determine whether mineral grains were being cut or displaced by the faulting and also to identify any evidence of secondary precipitation of mineral growth within microfaults. Twinning in carbonates was characterized when possible to include twinning intensity (# of twins per grain), spacing (spacing between each twin), and width of each twin.

X-Ray Diffraction and Rietveld Analysis

Samples were analyzed with a Rigaku Mini Flex II X-Ray Diffractometer at Ohio University. Data were collected over a 2θ range of 20°-120°, to insure that all of the major and minor peaks of both calcite and dolomite were collected, along with a measurement interval or step width of 0.02°. Minerals in each sample were identified manually by comparison of study spectra to those from known standards from the International Center for Diffraction Data (ICDD) database (PDF-2 release 2009). This was followed by automated peak fitting analysis using PDXL software. This analysis also utilized standard spectra from the ICDD database to produce a best fit spectrum to each spectrum from this study.
All XRD data collected from core C-204 and core JK78-3 were analyzed with the PDXL software program that was used to conduct the Rietveld peak refinement. Rietveld analysis is a technique for the characterization of a crystalline material by using the height, width, and position of the measured profile peaks of x-ray diffraction pattern of a powdered sample. The Rietveld method uses a least squares approach to refine a standard powder profile until it matches a measured profile. This is done by minimizing the sum of the squared residual, the residual being the difference between an observed value and the best fitted value of a model. The equation used to perform the least squares actions is:

\[ S_y = \sum_i w_i (y_i - y_{ci})^2, \]

where \( w_i = 1/y_i \) which is based on the counting statistics, \( y_i \) is the observed intensity at the \( i^{th} \) step, and \( y_{ci} \) is the calculated intensity at the \( i^{th} \) step, and the sum are the overall data points (Young, R. A., 1993). This calculated intensity is determined as such:

\[ y_{ci} = s \sum_H L M_H [F_H]^2 \phi(2\Theta_i - 2\Theta_H)P_H A + Y_{bi}, \]

where \( s \) is the overall scale factor, \( H \) represents the Miller indices (\( h, k, l \)) for the Bragg reflections, \( L \) contains the Lorentz and polarized factors, \( M_H \) is the Multiplicity, \( F_H \) is the structure factor for the \( H^{th} \) Bragg reflection, \( \phi(2\Theta_i - 2\Theta_H) \) is a profile function, where \( 2\Theta_i \) is corrected for the \( 2\Theta \) zero error, \( P_H \) is a preferred absorption factor, \( A \) is an absorption factor based on the instrument – a constant, and \( Y_{bi} \) in a background intensity factor (Young, R. A., 1993). The Bragg reflections, \( F_H \), contained in the added sum at each point of the powder pattern are determined from a sorted list of possible reflections and their profile widths at \( 2\Theta_i \). This structure facture contains the structural information:

\[ F_H = \sum f_jg_j \exp -2\pi i(hx_j + ky_j + lZ_j) \exp (-B_j sin^2 \Theta/\lambda^2), \]

where \( f_j \) is the scattering factor of atom \( j \), \( g_j \) is the occupancy factor, \( h, k, and l \) are Miller indices, \( x_j, y_j, \) and \( z_j \) are the fractional coordinates, and \( B_j \) is the temperature factor coefficient (Young, R. A., 1993). The least squares minimization procedure leads to a set of normal equations that involve derivatives of all the calculated intensities, \( y_{ci} \), with respect to each adjustable parameter and are
able to be solved by inversion of a normal matrix with the variable $M_{jk}$, $M_{jk} = - \sum_i 2w_i \left[ (y_i - y_{ci}) \frac{\partial^2 y_{ci}}{\partial x_j \partial x_k} - \left( \frac{\partial y_{ci}}{\partial x_j} \right) \left( \frac{\partial y_{ci}}{\partial x_k} \right) \right]$, where $w_i$ is $1/y_i$, $y_i$ is the observed intensity, $y_{ci}$ is the calculated intensity, and where $x_j$ and $x_k$ are adjustable parameters (Young, R. A., 1993). This leads to created and refined $m$ by $m$ matrix, with $m$ being the number of parameters being refined. Due to the non-linear function of the residual, the solution of this matrix must be found with an iterative procedure, a mathematical procedure that generates a sequence of improving approximate solutions, where the shifts are expressed as: $\Delta x_k = \Sigma M^{-1}_{jk} \frac{\partial s_y}{\partial x_k}$. These calculated shifts are applied to the initial parameters to produce an improved model and then the entire procedure is repeated until a match is found between the standard powder profile and the measured profile (Young, R. A., 1993).

For Rietveld analysis, PDXL software uses stored powder diffraction files to plot against experimental data. Every powder diffraction file is assigned a Quality Marker, or QM. These QM’s indicate the quality of the diffraction data stored in the retrieved data. For the PDXL software to perform Rietveld analysis, only powder diffraction files that have been classified with the highest quality mark; a Star rating, or S rating, can be used for the analysis due to the parameters of the PDXL program. For this study three standards were used for the comparison of the measured XRD patterns from cores C-204 and JK78-3; Dolomite (8): 01-071-1662, Calcite (43): 01-072-1651, and Quartz (28): 01-070-7344. These standards were chosen due to their high quality mark of S-rating, and because their major and minor peaks best matched the collected spectra. Once standards were chosen, Rietveld analysis was conducted by the PDXL software where FWHM were calculated automatically for all XRD spectra from C-204 and JK78-3 samples. FWHM and 2$\Theta$ were then saved for comparison analysis between C-204 and JK78-3.
and comparison analysis between the FWHM and $2\Theta$ calculated from Skala et al. (1999) and each individual core.
RESULTS

Analog Strata to JK78-3: Core C-204

Hand Sample and Thin Section Descriptions

Please refer to Appendix A for further information on core C-204. Core C-204 is a 687 m long, 5 cm diameter core comprised of flat lying beds of fine to medium-grained limestone and fine to coarse-grained dolostone (Fig. 9). There are no apparent signs of structural deformation except for a breccia layer observed at 250.85 - 251.46 m of depth. From 687 – 251.46 m depth the core is comprised of a vuggy, textured, flat-lying, medium to course-grained, light olive, and pale green crystalline dolostone (Fig. 10) that can be classified as a dismicrite.
Figure 10: Photo of core C-204 from 679.4-680.92 m depth. Core is 5.08 cm wide. A. Coarse grained vuggy textured light olive gray and pale green dolostone. B. Highly vuggy textured sample of dolostone.

Thin horizontal layers, ~1 mm thick, of course to medium-grained dark colored rhombohedral dolomite grains are present throughout this interval of core (Appendix A: Sample 18).

From 251.46 – 234.39 m depth the core is composes alternating layers of horizontally bedded light-medium gray fine to medium - grained crystalline dolostone and a medium - dark olive gray fine-grained dolomitic lime mudstone with thin laminations of shale (Appendix A: Sample 17). A matrix supported, monolithic breccia layer was observed at 250.85 - 251.46 m of depth. This breccia consists of angular to sub angular clasts, ~ 0.5 cm in size, of fine-grained
dolostone and limestone. This breccia layer is regionally extensive and is formed from a paleokarst situation.

From 234.39 – 109.73 m depth the core is comprised of a horizontally bedded, highly bioturbated, medium – dark olive gray, fine- to medium-grained lime mudstone with thin lenses of brachiopodal lime mudstone (Fig. 11). This interval is classified as a fossiliferous dismicrite with thin lenses of sparry biodismicrite. The matrix in this interval is comprised of semi-rhombohedral grains of calcite, with thin horizontal to sub-horizontal laminations of shale throughout (Appendix A: Samples 9 – 16).

*Figure 11:* Photo of core C-204 from 110.03 – 113.08 m depth. Core is 5.08 cm wide. Light olive gray limestone and dolostone unit, contains a high amount of laminated shale beds.
From 109.73 – 99 m depth the core is comprised of flat-lying pale orange fine – medium grained dolomitic lime mudstone with abundant horizontal burrows filled with a dark olive lime mudstone (Fig. 12) (Appendix A: Sample 6-8). This interval was classified as a dismicrite.

**Figure 12**: Photo of core C-204 taken from 102.11 m depth. Core is 5.08 cm wide. A fine grained limestone and dolostone unit comprised of dolomite filled semi-horizontal and semi-vertical burrows.

From 99 – 66.14 m depth the core is comprised of a flat lying light gray fine to medium-grained ostracodal lime mudstone (Fig. 13), or a biodismicrite (Appendix A: Samples 2 -5).
Figure 13: Photos of core C-204. Scale bar is in centimeters. A. Brachiopod and ostracod fossils found at a depth of 81.48 m (depth in pictures is incorrect). B. Vertical tubular burrows infilled with calcite/dolomite.

Ostracod shells and brachiopod valves are more common within the first 10 meters of this interval. Thin horizontal laminations of medium – dark olive shale are present. Thin vertical burrows are present throughout this entire interval of core; burrows are filled with either calcite or dolomite. From 69.49 – 69.8 m depth (Fig. 14. A), the core is comprised of a friable 30.48 cm thick dark olive bentonite. Two bentonite layers were observed at depths of 70.41 m (Fig. 15)
and 74.98 m (Fig. 14 B), both just a few centimeters in thickness. From 66.14 – 65.74 m depth the core is one again comprised of a highly friable dark olive bentonite layer roughly 40.6 cm thick.

*Figure 14:* Photos of bentonite layers within core C-204. The core is 5.08 cm wide. A. 10.5cm thick layer at 69-70 m depth. B. 15.25cm thick layer found at 75.13 m depth.
Figure 15: Photo of core C-204; depth interval: 69.49 – 72.54 m. The core is 5.08 cm wide. A light olive gray, fine grained limestone.
From 65.74 – 62.48 m depth the core is comprised of flat, irregularly-bedded, sandy, light – medium gray brachiopodal bryozoan lime mudstone/ fossiliferous biomicrite (Appendix A: Sample 1). Bryozoan and brachiopod fossils were observed throughout this interval.

From 62.48 – 53.04 m depth the core is comprised of flat-lying, light orangish gray, fine- to medium-grained brachiopodal lime mudstone with thin layers of shale. Brachiopod valves were seldom observed throughout upper and lower 0.91 – 1.22 m of this interval. These closely packed brachiopod valves were observed parallel to horizontal shale layers within the middle (~ 55 – 58 m depth) of the core.

From 53.04 – 14.94 m depth the core is comprised of flat, interbedded layers of a poorly sorted, light – medium gray, medium- to course-grained, bryozoan- and brachiopod-rich, lime mudstone with abundant thin lenses of shale. This interval is highly bioturbated with numerous bryozoan and brachiopod fossils present.

From 14.94 – 6.1 m depth the core is comprised of flat interbedded layers of a light – medium olive gray, fine- to medium-grained, lime mudstone but transitions to a brachiopod and bryozoan-rich lime mudstone in the lower 1.22 m. Multiple horizontal lenses of medium to dark olive-colored shale are common throughout this entire interval. Bryozoan and brachiopod fossils were scarcely observed throughout this interval of core except within the lower 1.22 m of this interval.

From 0 – 6.1 m depth of core C-204 no core is present. It was presumably not recovered during core extraction.

Thin Section Analysis

Please refer to Appendix A for further information about core C-204. The thin sections collected from C-204 are comprised of both calcareous and dolomitic micritic sized grains. Of
the 18 samples collected, 7 contain evidence of twins (Appendix A). The twins that were observed are similar to those of a tectonic origin and not of an impact origin.

*X-Ray Diffraction and Rietveld Analysis*

Please refer to Appendix A for further information about core C-204. X-ray diffraction analyses confirmed that calcite and dolomite are the dominant minerals in core C-204 with lesser amounts of quartz (for example diffraction spectra, see Figs. 16.A, 17.A, & 18.A).
Figure 16: XRD Spectra of the suspected Tyron formation within cores C-204 and JK78-3. A. XRD spectra of suspected C-204 samples of the Tyron formation. B. XRD spectra of suspected JK78-3 samples of the Tyron formation. C = Calcite. D = Dolomite, Q = Quartz.
**Figure 17:** XRD Spectra of the suspected Oregon formation within cores C-204 and JK78-3. A. XRD spectra of suspected C-204 samples of the Oregon formation. B. XRD spectra of suspected JK78-3 samples of the Oregon formation. C = Calcite. D = Dolomite, Q = Quartz.
Figure 18: XRD Spectra of the suspected Camp Nelson Formation within cores C-204 and JK78-3. A. XRD spectra of suspected C-204 samples of the Camp Nelson Formation. B. XRD spectra of suspected JK78-3 samples of the Oregon formation. C = Calcite. D = Dolomite, Q = Quartz.
More specifically, the upper 234 m of C-204 is dominated by calcite, while the remaining 452.6 m is dominated by dolomite. FWHM values at the full range of 2θ values (20-120°) are shown in Figures 19 and 20.

Figure 19: FWHM vs. 2θ of C-204 samples: 1-10(C) plotted with a calcite and dolomite standard.
Figure 20: FWHM vs. 2θ of C-204 samples: 10(D) - 18 plotted against calcite and dolomite standards.

FWHM values were calculated during the Rietveld analysis of the spectra from C-204. A total of 13 out of the 18 total samples collected displayed evidence of peak broadening. Skala and Jakes (1999) only experimentally shocked dolomite samples and did not use calcite in their experiments. Because of this, the spectra collected from C-204 samples are plotted against a calcite standard collected from Taos, New Mexico (from Ohio University collection) (Fig(s). 19 and 20). Samples that are predominantly dolomite (Sample(s) 6, 7, 17, and 18) may be viewed and compared within Appendix A.
Results for Core JK78-3

*Hand Sample and Thin Section Descriptions*

Please refer to Appendix B for further information about core JK78-3. JK78-3 is a 365 m long, 5 cm diameter core comprised of highly-deformed, fine- to medium-grained dolostone blocks and megablocks (Fig(s) 6, 7, and 8) separated by discrete faults. Slickensides are ubiquitous throughout (Fig. 21).

*Figure 21:* Photos of core JK78-3 from 26.82 – 29.87 m depth. A. Photo of box 9 at 26.82 – 29.87 m depth. Red box indicated location of photo (B). Yellow box indicates location of photo (C). B. Photo of fractures and brecciation from box 9. Red lines indicate location and direction of slickenside. C. Photo of slickenside from box 9. Slickenside is located on upper portion of yellow box in photo (A).

Clast- and matrix-supported monolithic and polymictic breccia occur between and within many megablocks and comprise approximately half the total thickness of the core (Fig(s) 21, 22, 23, and 24).
Figure 22: Photos of core JK78-3. Core is 5.08 cm wide. A. Photo of box 25 at 74.07 – 77.42 m depth. B. Photo of monolithic breccia. Clast size ~10.16 – 15.24 cm.
Figure 23: Photo of core JK78-3 from 21.34 – 24.08 m depth. Core is 5.08 cm wide. A. Box 7 of core JK78-3 at 21.34 – 24.08 m of depth. Red box indicates location of photos (B). Slickensides present at upper portion of sample. B. Sample of monolithic breccia.
Material comprising these breccias appears to be locally derived from adjacent megablocks. Individual megablocks are internally deformed by micro- and macro-scale fractures and faults (Fig(s). 21, 24, and 25).
Figure 25: Photos of core JK78-3 from 59.13-61.87 m depth. Core is 5.08 cm wide. A. Photo of box 20 at depth interval of 59.13 – 61.87 m, Tyrone Formation. Red box indicates location of photo (B). B. Photo of displacement within core at 60.66 m depth. Yellow line indicates location of displacement.

Megablocks

Please refer to Appendix B for further information about core JK78-3. At intermittent intervals between 365.15m and 16.76 m depth (Figs. 6, 7, and 8) the core is comprised of megablocks of a highly bioturbated, light – medium olive gray, fine- to medium-grained, dolomitic mudstone/dismicrite with thin lenses of brachiopodal, dolomitic mudstones/fossiliferous dismicrite (Appendix B: Samples 5, 17 – 20, 22 – 24, 27 – 31, 35 – 38, and 43 – 47). Bedding attitudes in these megablocks range 32-90º from horizontal (Fig. 6, 7, and
8). Structural deformation in the form of micro-faulting was observed in said megablocks with displacements ranging from a few mm to a few cm. Pyrite was observed in veins between 107 – 107.9 and 112.78 – 115.82 m in depth (Fig. 26).

![Figure 26: Photo of core JK78-3 from 112.78 – 115.82 m depth. Red box indicates the location of figure (B). The yellow box indicates the location of figure (C). (B) Photo of translucent rhombohedral dolomite minerals ranging from 3 – 8 mm in length and semi-cubic to cubic pyrite minerals. (C) Photo of translucent semi-rhombohedral dolomite minerals ranging from 5 – 12 mm in length, full length of the largest minerals could not be measured due to drill bit damage during coring.]

At discrete intervals from 343.51 -3.66 m depth (Figs. 6, 7, and 8) the core is also comprised of megablocks of a pale orange, fine-grained, dolomitic mudstone/dismicrite (Fig. 25; Appendix B: Samples 1, 2, 7 – 9, 16, 21, 32 – 34, 41, and 42). Megablock strata dip 32-89° (Fig. 7 and 8). Faulting and micro-faulting are very prominent within these stratigraphic intervals with displacements ranging from a few mm to a few cm in length. Secondary pyrite and dolomite was
also observed at 14 m and between 98.76 – 101.50 m, 102.11 – 102.72 m completely filling cracks and vugs.

At specific intervals from the depth of 331.01 m up to 12.50 m depth the core consists of megablocks of a light gray fine to medium-grained dolomitic mudstone/dismicrite (Fig. 6, 7, and 8) with a few thin lenses of brachiopodal dolomitic mudstone throughout (Fig. 25); Appendix B: Samples 3, 4, 13, 14, 26, 39, and 40). Extensive micro-faulting has been observed throughout these intervals of core with displacements ranging from several millimeters to 1.5 cm. Between 61.87-63.7 m, pyrite and dolomite were observed as secondary precipitates. Bedding varies from 90-35° from horizontal (Fig. 7 and 8).

**Fault Breccias**

Please refer to Appendix B for further information about core JK78-3. Monolithic and polymictic breccias were observed in the upper 169.16 m of JK78-3 (Figs. 6 and 7). Breccias are comprised of angular fragments of the adjacent megablocks with clast sizes ranging from a few millimeters to 10 cm (Fig. 22, 23, and 24; Appendix B: Samples 6, 10 – 12, and 25). Both breccia types ranged from clast- to matrix-supported at varying intervals. Thin breccias were observed between almost every megablock in JK78-3.

**Thin Section Analysis**

Please refer to Appendix B for further information about core JK78-3. All of the thin sections collected from core JK78-3 are comprised of micritic dolomite. No evidence of twins was found within any of the samples collected. Of the 47 samples, 21 contain normal/reverse micro faults (mfs) and/or micro fractures (mfrs) (Table 2). These mfs and mfrs occur in megablocks and are displaced between 0.25 – 25 mm. (Table 2). The frequency of these mfs and mfrs was not dependent on the location of the megablock itself, samples collected from certain
megablocks contained no mfs or mfrs while others contained as many as 6 normal/reverse mfs (Table 2).

Table 2

Degree of Microfaults and Microfractures within JK78-3 Samples

<table>
<thead>
<tr>
<th>Smp #</th>
<th>Depth (m)</th>
<th># of mfs/mfrs</th>
<th>Displacement (mm)</th>
<th>mfs vs. mfrs</th>
<th>normal vs. reverse fault</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.54 – 5.61</td>
<td>~5 – 6</td>
<td>~60 – 65 (40)</td>
<td>mfs</td>
<td>normal</td>
</tr>
<tr>
<td>2</td>
<td>10.07 – 11.05</td>
<td>~3 - 4</td>
<td>1 mm</td>
<td>mfs</td>
<td>normal</td>
</tr>
<tr>
<td>7</td>
<td>25.81 – 25.88</td>
<td>1</td>
<td>-----</td>
<td>mfs</td>
<td>normal</td>
</tr>
<tr>
<td>8</td>
<td>28.04 – 28.12</td>
<td>~6 – 7</td>
<td>1 mm</td>
<td>mfs</td>
<td>normal</td>
</tr>
<tr>
<td>14</td>
<td>62.41 – 62.48</td>
<td>~2 – 3</td>
<td>~60 – 120 (40)</td>
<td>mfs</td>
<td>-----</td>
</tr>
<tr>
<td>16</td>
<td>72.95 – 73.03</td>
<td>1</td>
<td>~5 -6 mm</td>
<td>mfs</td>
<td>normal</td>
</tr>
<tr>
<td>19</td>
<td>97.61 – 97.69</td>
<td>1</td>
<td>3 mm</td>
<td>mfs</td>
<td>normal</td>
</tr>
<tr>
<td>20</td>
<td>100.18 – 100.23</td>
<td>1/1</td>
<td>0.75 – 1 mm</td>
<td>mfs/mfrs</td>
<td>normal</td>
</tr>
<tr>
<td>21</td>
<td>111.40 – 111.48</td>
<td>2 – 3</td>
<td>5 mm</td>
<td>mfs</td>
<td>reverse</td>
</tr>
<tr>
<td>22</td>
<td>134.65 – 134.70</td>
<td>1</td>
<td>2 – 3 mm</td>
<td>mfs</td>
<td>-----</td>
</tr>
<tr>
<td>24</td>
<td>152.91 – 152.98</td>
<td>1</td>
<td>1 mm</td>
<td>mfs</td>
<td>normal</td>
</tr>
<tr>
<td>29</td>
<td>194.16 – 194.23</td>
<td>1</td>
<td>~1 -2 mm</td>
<td>mfs</td>
<td>-----</td>
</tr>
<tr>
<td>31</td>
<td>218.19 – 218.24</td>
<td>1</td>
<td>90 (40)</td>
<td>mfs</td>
<td>normal</td>
</tr>
<tr>
<td>32</td>
<td>231.04 – 231.12</td>
<td>2 – 3</td>
<td>0.25 mm</td>
<td>mfs</td>
<td>normal</td>
</tr>
<tr>
<td>34</td>
<td>253.21 – 253.29</td>
<td>3 – 4</td>
<td>24 (40)</td>
<td>mfs</td>
<td>normal/reverse</td>
</tr>
<tr>
<td>36</td>
<td>282.75 – 282.85</td>
<td>1</td>
<td>25 – 30 (40)</td>
<td>mfs</td>
<td>normal</td>
</tr>
<tr>
<td>38</td>
<td>315.06 – 315.11</td>
<td>1</td>
<td>15 (40)</td>
<td>mfs</td>
<td>normal</td>
</tr>
<tr>
<td>39</td>
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<td>25 mm</td>
<td>mfs</td>
<td>normal</td>
</tr>
<tr>
<td>41</td>
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<td>1</td>
<td>1 mm</td>
<td>mfs</td>
<td>normal</td>
</tr>
<tr>
<td>42</td>
<td>341.35 – 341.38</td>
<td>1</td>
<td>-----</td>
<td>mfs</td>
<td>-----</td>
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<tr>
<td>43</td>
<td>343.99 – 344.09</td>
<td>1</td>
<td>0.25 – 0.5 mm</td>
<td>mfs</td>
<td>-----</td>
</tr>
</tbody>
</table>

X-Ray Diffraction and Rietveld Analysis

Please refer to Appendix B for further information about core JK78-3. Analysis of X-ray diffraction spectra from JK78-3 indicate that dolomite is the major phase for the entire core and with only very minor amounts of quartz detected (Fig. 16.B, 17.B, and 18.B). This stands in contrast to the compositional variability (calcite vs. dolomite) between similar units of C-204 (please see below).
FWHM values calculated for Rietveld-refined spectra of JK78-3, when plotted against known experimentally-shocked dolomite values (Skala et al., 1999), demonstrates that strata in JK78-3 have been exposed to peak pressures ranging from ambient conditions to values consistent with 17 GPa (Appendix B). Of the 47 samples collected, 34 appear to be unshocked, while 8 samples were exposed to pressures between 0-4.6 GPa (Fig. 27; Appendix B: Sample(s): 31, 36, 39, 40, 41, 42, 43, and 44(D)). Spectra from samples 33, 34, 35 and 47 has peak broadening consistent with the 4.6 GPa experimentally shocked dolomite, while sample 32 experienced pressures between 4.6 and 17 GPa (Fig. 28; Table 3; Appendix B).

*Figure 27: FWHM vs. 2θ of JK78-3 samples that plot between 0 > 4.6 GPa against Skala et al. (1999).*
Figure 28: FWHM vs. $2\Theta$ of JK78-3 samples that plot between 4.6 > 17 GPa against Skala et al. (1999).
Table 3

*Samples from Core JK78-3 That Express High Levels of Shock Pressure.*

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Depth (m)</th>
<th>GPA Range</th>
</tr>
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<tbody>
<tr>
<td>31</td>
<td>218.19-218.24</td>
<td>0 - 4.6</td>
</tr>
<tr>
<td>32</td>
<td>231.04-231.12</td>
<td>4.6 - 17</td>
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<tr>
<td>33</td>
<td>249.73-249.78</td>
<td>4.6</td>
</tr>
<tr>
<td>34</td>
<td>253.21-253.29</td>
<td>4.6</td>
</tr>
<tr>
<td>35</td>
<td>258.45-258.47</td>
<td>4.6</td>
</tr>
<tr>
<td>36</td>
<td>282.75-282.83</td>
<td>0 - 4.6</td>
</tr>
<tr>
<td>39</td>
<td>321.56-321.64</td>
<td>0 - 4.6</td>
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<td>40</td>
<td>327.3-327.36</td>
<td>0 - 4.6</td>
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<td>41</td>
<td>335.59-335.66</td>
<td>0 - 4.6</td>
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<td>341.35-341.38</td>
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<td>343.99-344.09</td>
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<td>44</td>
<td>345.54-345.62</td>
<td>0 - 4.6</td>
</tr>
<tr>
<td>47</td>
<td>358.85-358.93</td>
<td>4.6</td>
</tr>
</tbody>
</table>
DISCUSSION

Comparisons between Core C-204 and Core JK78-3

A visual comparison between cores C-204 to core JK78-3 reveals many differences both structurally and mineralogically although the majority of geologic units within both cores are the same (dominated by the High Bridge Group). Geologic units within core C-204 (Figure 9) are horizontally bedded, with no signs of any structural deformation excluding the breccia layer separating the Knox Group from the Wells Creek Dolomite. In contrast, strata in core JK78-3 are extensively brecciated, fractured, and faulted. Strata in JK78-3 (as exposed in megablocks) have been displaced from their normal stratigraphic positions.

Unit Identification

Core C-204

Hand specimen descriptions, thin section observations, and XRD analyses have been used to characterize and identify geologic units present within each core. Observations have demonstrated that C-204 contains geologic units that are analogous to those present in the megablocks of JK78-3. Figures 6-8 show my interpretation of the units in both cores.

The Knox Group was identified at the base (687-251.46 m) of core C-204 (Fig. 9 & 10), because of similarities, such as a highly vuggy light tannish-gray medium to coarse-grained dolostone, to textures in the Knox Group as described by Gooding (1992). From 251.46 – 234.39 m, the Wells Creek Dolomite was identified by the rubble breccia zone at 251.46 – 250.85 m depth, roughly 61 cm thick, consisting of fine-grained crystalline dolomite and limestone. This is a well-known stratigraphic marker for the contact between the Knox Group and the Wells Creek Dolomite (Gooding, 1992). The High Bridge Group was identified between 234.39 – 66.14 m (Fig. 9, 11, 12, & 13). Based on physical and mineralogical characteristics identified by Cressman (1973) and Cressman and Noger (1976), the Camp Nelson Formation was identified
from 234.39 – 109.73 m depth (Fig. 11), the Oregon Formation was identified from 109.73 – 99 m depth (Fig. 12), and the Tyrone Formation was identified from 99 – 66.14 m depth (Fig. 13). The Mud Cave and Pencil Cave Bentonite layers were also identified within the Tyrone Formation (Fig. 14). The Pencil Cave Bentonite occurs at 69.49 – 69.7 m depth and the Mud Cave Bentonite occurs at the contact between the Tyrone and the Curdsville Member of the Lexington Limestone, 66.14 – 65.74 m depth (Cressman and Noger, 1972). The remaining 60 m of core is comprised of members of the Lexington Limestone Formation (Fig. 9) that were identified based on the physical and mineralogical descriptions of Cressman (1973). The Curdsville Limestone Member was identified from 65.74 – 62.48 m depth. The Curdsville Member was overlain by the Logana Member of the Lexington Limestone, which was observed from 62.48 – 53.04 m depth. Following the Logana Member, the Grier Limestone appears from 53.04 – 14.94 m depth and was identified based on the very poor sorting of the beds due to intense bioturbation as well as the numerous brachiopods and bryozoans present as described in Cressman (1973). The last 14.94 – 6.1 m depth of C-204 contains the Brannon Member of the Lexington Limestone and was identified due to the sparseness of fossils throughout the interval as well as the numerous beds of dark shale interbedded into the finely grained mudstone (Cressman, 1973).

Core JK78-3

The Camp Nelson Formation was identified from the base of the core, 365.15 m to 343.51 m depth, and was observed at varying intervals up to 18.90 – 16.76 m depth (Fig(s). 6, 7, and 8). This unit was identified based off of similar burrowing features and similar coloring of the unit observed in core C-204, both of these units were dominantly micrite with a pale olive gray coloring (Cressman and Noger, 1972). The Oregon Formation was identified from 343.51 – 331.01 m depth and observed at varying intervals up to the depth of 12.50 – 3.66 m (Fig(s). 6 and
These units were identified based on the pale orange micrite and identical burrow structures with a olive brown infill noted elsewhere in the Oregon Formation (Cressman and Noger, 1972) and observed in core C-204 (Fig. 13). Finally, the unit observed at 331.01 – 317.60 m depth and at varying intervals up to the depth of 16.15 – 12.50 m (Fig(s). 6 and 27) show identical micritic sized pale olive – yellowish olive gray dolomite grains observed in the Tyrone Limestone (Cressman and Noger, 1972) at 99 m to 66.14 m depth seen within core C-204 (Fig. 12).

**Structural Geology**

Units in JK78-3 have been highly fractured and faulted. Notably, strata of the High Bridge Group in core JK78-3 were significantly more deformed than those of C-204. Massive megablocks comprised of High Bridge Group strata were displaced several hundred meters from their original stratigraphic positions (McCowan, 2012) (when compared to positions outside of the Jeptha Knob area) and tilted as much as 90° from their original horizontal positions. Numerous slickensides and fault breccias (Fig(s). 6-8) were observed throughout core JK78-3, further indicating extensive fracturing and faulting (Fig. 7 and 8) that did not occur outside of the structure (21 km away at C-204). Thin section observations of samples from core C-204 show no evidence of micro-faults or micro-fractures along the entire length of core, while 21 out of 47 samples from core JK78-3 contain normal/reverse micro faults (mfs) and/or micro fractures (mfrs) (Table 2). These mfs and mfrs occur in megablocks and are displaced between 0.25 – 25 mm. (Table 2). The frequency of these mfs and mfrs was not dependent on the location of the megablock itself, samples collected from certain megablocks contained no mfs or mfrs while others contained as many as 6 normal/reverse mfs (Table 2).
Comparison between X-Ray Diffraction Data Collected from Cores C-204 and JK78-3

X-Ray Diffraction

The entire length of JK78-3 has been completely dolomitized and none of the corresponding units in both JK78-3 and C-204, excluding the Oregon Formation, shares any similar mineralogical characteristics (Fig. 16 and 18). Evidence of peak broadening was recovered via Rietveld analysis of the XRD spectrum for 13 samples of the 18 samples analyzed from C-204 and 13 of the 47 samples analyzed from JK78-3.

Rietveld Analysis

Rietveld analysis of the samples collected from core C-204 recovered evidence of peak broadening. However, these spectra cannot be compared to the spectra collected from Skala and Jakes (1999) because they only used pure dolomite samples for their calibration while the samples collected from C-204 were dominated by calcite, with some being a mixture of both calcite and dolomite. It is clear that a majority of the samples collected from C-204 have some evidence of peak broadening but it is unclear as to what pressure was exerted upon them to produce this broadening effect because there is currently no experimental data on the shock effects in a mixed powder of both calcite and dolomite.

It is possible that the impact event that produced the Jeptha Knob structure may have produced the broadening observed within core C-204. During the excavation stage of the Jeptha Knob’s formation, the shock wave that was produced during the contact/compression stage would have continued to radially propagate outward from the contact point (Melosh, 1989; French, 1998). This shock wave would have continued to propagate through the surrounding rock units until it finally dissipated, possibly producing the peak broadening in C-204 samples. Given the overall size of the preserved Jeptha Knob structure, roughly 4.26 km in diameter, an estimation of the craters diameter can be made based on the morphometric relationship of \( D_{cp} = 0.23D \) (Pike,
1977), where $D_{cp}$ is the diameter of the central peak and $D$ is the diameter of the crater. When applying the 4.26 km diameter of the central peak for Jeptha Knob an overall diameter of 18.52 km, radius of 9.26 km, is calculated. The location of C-204 is roughly 21 km east, roughly 11.74 km east/south east, from the distal edge of the proposed Jeptha Knob crater. It is unlikely that the shock wave produced during the impact event propagated an additional 11.74 km past the proposed crater rim. It is possible, however, that the remains of the Jeptha Knob structure is only a portion of the total diameter of the original central peak. Using the equation: $D_{cp} = 0.23D$ (Pike, 1977) the overall size of the original central peak would have to be roughly 9.66 km in diameter (double the size of the uplifted area) for the 21 km distance from C-204 to be reached.

Impact is not the only potential cause for peak broadening. A recent study by Huson et al. (2009) has shown through X-ray diffraction and Rietveld analysis that tectonically deformed calcite samples will show similar XRD broadening patterns and Rietveld FWHM curves to mildly shocked calcite samples, between 3 – 10 GPa. Huson et al. (2009) collected samples from the crater rim and central uplift of the eroded Sierra Madera complex crater in Fort Stockton, Texas. Huson et al. (2009) found that the FWHM curves of the calcite-rich tectonically disturbed Mission Canyon Formation samples overlap calcite-rich samples collected from the crater rim of the Sierra Madera impact structure. It should be noted that the Mission Canyon Formation was never exposed to intense forces associated with a convergent boundary. This unexpected relationship means that comparison between mildly shocked samples and samples that have experienced tectonic processes may not always be able to be distinguished through XRD with Rietveld refinement processes.

The peak broadening observed in 13 out of 18 samples collected from core C-204 could be the result of this proximity to the Appalachian Mountains. Also, throughout the region are numerous surface and subsurface faults; the Kentucky River Fault System, the Irvine – Paint Creek Fault System, and Rockcastle River Fault System. With the Kentucky River Fault system
occurring only 38.77 km away from location of C-204. It is possible that due to tectonic activity within the region the evidence of peak broadening could be the result of this tectonic activity.

The results of the Rietveld analysis of samples collected from JK78-3 show that the Jeptha Knob structure is the result of hypervelocity impact. A few samples show signs of experiencing high levels of shock pressures; however the majority of FWHM values are consistent with rocks that have only experienced relative ambient pressure conditions (Table 3). Of the 47 samples collected, 13 samples showed evidence of peak broadening (Sample(s): 31, 32, 33, 34, 35, 36, 39, 40, 41, 42, 43, 44(D), and 47). For this core, sample 44 contains both a dolomite peak as well as a calcite peak. (For the remainder of this paper either a D, for dolomite, or a C, for calcite will be placed after a samples number and used to distinguish which spectra of sample will be used) Of the 13 JK78-3 samples, 8 of these showed evidence of experiencing shock pressures between $0 > x < 4.6$ GPa (Sample(s): 31, 36, 39, 40, 41, 42, 43, and 44), samples: 32, 33, 34, 35, and 47 plot perfectly along the 4.6 GPa plot, and sample 32 plots above the 4.6 GPa plot but under the 17 GPa plot of the experimentally shocked dolomite samples from Skala and Jakes (1999).

This uneven distribution of shock metamorphism is not uncommon. Burt et al. (2005) found, through X-ray diffraction and Rietveld analysis, that the Meteor Crater in Arizona experienced heterogeneous shock wave propagation during crater formation. Overall, samples collected from the outer rim of the structure expressed higher shock metamorphic effects than those collected from the center of the structure. This heterogeneity in shock wave propagation may be the case at Jeptha Knob.

Dolomitization and the Jeptha Knob Structure

When comparing samples collected from core JK78-3 to those from equivalent units in C-204, it is apparent that the Jeptha Knob structure has experienced extensive
dolomitization/mineralization. The area surrounding the Jeptha Knob structure and at the surface within the structure, however, does not seem to have been affected (Cressman, 1975; Black et al., 1981; Cressman, 1985). The timing of dolomitization has important implications for the detection of peak broadening at Jeptha Knob. Dolomitization prior to impact would provide the necessary dolostones that served as target rocks for the impact event and thus peak broadening would appear in these shocked dolomites. Post-impact dolomitization holds the potential for erasing an impact signature through recrystallization of shocked target rocks following impact.

Seeger (1968) found and classified two distinct types of (autochthonous monomict and allochthonous polymict) breccias with both Ordovician and Silurian-aged fragments and matrix in the central portion of the Jeptha Knob structure. These breccias consist of angular rock fragments of the Clays Ferry Formation held together by a recrystallized dolomitic Silurian matrix. Seeger (1968) claimed that the formation was brecciated as a unit, mostly likely very shortly after the rock units were fractured and the breccia was formed, and then recrystallized into dolomite. Such breccias were interpreted to have formed rapidly after the structures formation.

The allochthonous/polymict breccias are further classified into three categories: 1) sedimentary breccias, 2) flow breccias, and 3) breccias within grabens (Seeger, 1968). The sedimentary breccias are primarily composed of closely packed very angular and extremely variably-sized Ordovician aged fragments with a fine-grained Silurian aged dolomitic matrix. Evidence from thin section petrography showed that dolomitization did not fully penetrate this breccia type with the dolomitization not entering the boundaries of the fragments (Seeger, 1968). The flow breccias are comprised of the same material as the sedimentary breccias but the fragments are more widely dispersed in the dolomitic matrix. Dolomitization was observed to have occurred at clast exteriors. Finally, the third type of breccia consists of very well rounded Ordovician limestone with a fine grained dolomite and fragmented shell matrix. Seeger (1968)
interpreted these breccias to have formed after the structures formation, after a period of mechanical weathering rounded out the limestone fragments.

Fragments described within these breccias are similar in age to the units found within JK78-3. Some however, have not been entirely dolomitized. If the dolomitization of the structure had been post event, breccias would have also been more thoroughly dolomitized due to the numerous pathways, via faults and fractures, that would have allowed high Mg-rich waters to move more readily throughout the structure and the surrounding areas to completely dolomitize formations present as clasts in these breccias. Geologic units younger than those in the High Bridge Group were not extensively dolomitized (Milam, 2014).

Dolomitization and related mineralization seemed to be regional in extent and similarly confined to the Lower -Middle Ordovician strata in the region and well away from Jeptha Knob (Jolly and Heyl, 1964). This event precipitated minerals within faults systems and fractures during the formation of the Cincinnati Arch (Jolly and Heyl, 1964), which likely occurred during the Middle to Late Ordovician (Borella and Osborne, 1978). Had mineralization event occurred post event, fractures, faults, and breccia zones would be key pathways for this mineralization to occur at Jeptha Knob. However, no faults and fractures found within core JK78-3 contained evidence of this. Such mineralization would have erased at least some (if not most) evidence of shock metamorphism. This, however, is not the case because 13 samples collected from core JK78-3 contain evidence of shock pressures reaching levels greater than 4.6 GPa. Considering this it is clear that dolomitization occurred prior to the structures formation.

Dolomitization could also have occurred multiple times after the formation of the structure. These pre dolomitization events could have further erased any evidence of peak broadening within the JK78-3 samples.
Origin of the Jeptha Knob Structure

The style of structural deformation expressed in the Jeptha Knob structure, as well as evidence of the intense levels of pressure found within samples from the Jeptha Knob Structure, are similar to that which has been observed in other known complex impact craters (Reiff, 1977; Roddy, 1968; Roddy, 1979; Baranoski et al., 2003; Kenkmann et al., 2005).

Such structural features include extensive brecciation, anticlines, synclines, concentric and radial faults, and horsts and grabens (Fig. 4) (Baranoski et al., 2003, Kenkmann et al., 2005, French and Koeberl, 2010). The concentric and radial faulting and folding is similar to that seen at the Flynn Creek impact structure (Roddy, 1968) and the Serpent Mound impact structure (Baranoski et al., 2003). The style of the normal/reverse micro faulting, the frequency of micro faulting and micro fracturing, and the range of displacements observed within core JK78-3 samples are similar to those observed in other impact craters (Milam, 2002; Milam, 2006). At both the Middlesboro and Flynn Creek impact craters, fms from the central uplift of the craters displayed similar frequencies of faulting, style of faulting, and share the same ranges of displacements, < 3.9 mm displacement at Middlesboro and 0.5 – 20 mm at Flynn Creek, as those observed within Jeptha Knob, 0.5 – 25 mm (Table 3).

The evidence of intense levels of shock that was found within 13 of the 47 JK78-3 samples, ranging as high as 4.6 GPa but below 17 GPa, collected from the Jeptha Knob structure is similar to experimentally shocked dolomite samples from Skala and Jakes (1999) as well as the levels of shock found within samples collected from the Ries crater is Germany (Skala, 2002). Such pressures can only be produced at the surface by hypervelocity impact or by a tectonic event.
SUMMARY

The formation of the Jeptha Knob complex crater just east of Shelbyville, Kentucky, occurred after the dolomitization of the High Bridge Group members within the area, but either before or during the deposition of the flat lying Early Silurian units found capping the structure. This is the case due to the absence of mineralization within possible pathways, such as the many fractures, faults, and breccia zones found throughout the core JK78-3. During the formation of Jeptha Knob, the Middle Ordovician aged High Bridge Group members were extensively brecciated and multiple megablocks of these units were rotated to the near vertical and uplifted several meters above their normal plane of deposition. The intense shock wave that propagated throughout the structure did not affect the units in a homogeneous fashion; rather these shock waves produced a heterogenetic non-uniform distribution of shock within the structure. This is clear from the non-uniform distribution of shock levels expressed from the samples collected from core JK78-3 (Fig(s). 27 and 28).

The evidence found within Jeptha Knob is consistent with other known impacts found on Earth and could make Jeptha Knob the 2nd impact in the state of Kentucky. This identification serves to fill in one of many gaps in our knowledge of the impact cratering record for planet Earth.
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Scherrer, P. and Gottingen, N., 1918, Elements of X-Ray Diffraction: p. 98


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APPENDIX A: ALL RAW DATA FOR CORE C-204

C-204 Sample #1: Depth: 65.25 m - 65.30 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
</table>

Member: Formation/Group (Age) | Curdsville Limestone: Lexington Limestone (Middle Ordovician: 470-458)

Hand Sample Description | Brachiopodal lime mudstone, dry appearance: pale olive (10Y 7/4), wet appearance: olive gray (5Y 3/2), fine grained, thin horizontal shale shales common throughout length of sample, shale: grayish olive green (5GY 3/2), small inclusions of spar calcite, 0.75cm long brachiopod fossil present in middle of sample

Thin Section Description: | Fossiliferous biomicrite, matrix of sample is comprised of micrite cement – sub-rounded to sub-angular grains of calcite and quartz are present throughout matrix, grains are not in contact with each other, horizontal layers of calcite and quartz grains are present from the top of the sample to the bottom of the sample – abundance of grains is much higher than the surrounding matrix but the grain size is the same; opaque grains (Op) common throughout sample but are more common within the thin layers of calcite and quartz – shape of grains are semi cubic to semi triangular, large brachiopod fossil present within middle of sample (Br)

Twinning Measurements: | No secondary twinning was observed within grains
C-204 Sample #1 Depth: 65.25 m - 65.30 m: Continued

X-Ray Diffraction Profile:

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FWHM vs. 2θ:

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- Smp 1-D
C-204 Sample #1: Depth: 65.25 m - 65.30 m: Continued

Rietveld Comparison:

![Graph showing Rietveld comparison with intensity on the y-axis and 2-theta on the x-axis. The graph compares two sets of data, with one set generally above the other, indicating a comparison between experimental and calculated data.](image-url)
C-204 Sample # 2: Depth: 68.37 m - 68.42 m

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<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
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**Member: Formation/Group (Age)**  
Tyrone Limestone: High Bridge Group (Middle Ordovician: 470-458)

**Hand Sample Description:**  
Brachiopodal lime mudstone, wet appearance: light olive gray (5Y 5/2), dry appearance: yellowish gray (5Y 7/2), brachiopod fossil in low section of sample: roughly 0.5 cm in length, matrix of sample is composed of micrite

**Thin Section Description:**  
Packed biomicrite, matrix is comprised of an abundance of peloids (Pe) and forams with micritic mud, calcite and quartz grains are common throughout sample – grains are angular to sub-rounded, some quartz grains experience undulose extinction, small opaque grains (Op) throughout sample – shape is cubic to rectangular; semi opaque grains are common throughout sample as well as completely opaque grains – a rusty color when in PPL but opaque in XPL, many grains appear to be the remnants of skeletal grains; large brachiopod valve at base of sample, ostracod shells (Os) common throughout sample

**Twinning Measurements:**  
No secondary twinning was observed within grains
C-204 Sample # 2: Depth: 68.37 m - 68.42 m: Continued

X-Ray Diffraction Profile:

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</table>
C-204 Sample # 2: Depth: 68.37 m - 68.42 m: Continued

Rietveld Comparison:
C-204 Sample # 3: Depth: 71.55 m - 71.60 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Hand Sample Image" /></td>
<td><img src="image2" alt="Thin Section Image" /></td>
<td><img src="image3" alt="PPL Image" /></td>
<td><img src="image4" alt="XPL Image" /></td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**

<table>
<thead>
<tr>
<th>Tyrone Limestone: High Bridge Group (Middle Ordovician: 470-458)</th>
</tr>
</thead>
</table>

**Hand Sample Description:**

Ostracodal brachiopodal wackestone, dry appearance: yellowish gray (5Y 7/2), wet appearance: dusky yellow (5Y 6/4), replaced brachiopod and ostracod fossils with spar: common throughout sample, matrix of sample is composed of micrite

**Thin Section Description:**

Spars biodismicrite, matrix of sample is comprised of micrite, rhombohedral calcite grains are scattered throughout matrix – grains are not in contact with each other, ostracod shells (Os) and possibly brachiopod shells are common throughout sample – majority of larger shells are replaced with secondary calcite while smaller shells are not; opaque grains are uncommon in sample – shape is semi cube to semi triangular, spar calcite is common throughout sample filling voids and replacing fossils – calcite grains contain twinning

**Twinning Measurements:**

| Intensity: 1:6(400x), 2:4(100x), 3:1(100x), 4:1(100x), 5:4(100x) |
| Spacing: 1:1:7.5µm, 1:2:35µm, 1:3:35µm, 2:1:40µm, 2:2:140µm, 2:3:120µm |
| 1:4:615µm, 1:5:70µm, 3:30µm, 4:30µm, 5:1:6:2:5µm, 2:1:4:20µm, 3:30µm, 4:30µm, 5:1:4:10µm |
| Widths: 1:3:35µm, 2:1:40µm, 2:2:140µm, 2:3:120µm |
| Widths: 1:3:35µm, 2:1:40µm, 2:2:140µm, 2:3:120µm |
| Widths: 1:3:35µm, 2:1:40µm, 2:2:140µm, 2:3:120µm |
| Widths: 1:3:35µm, 2:1:40µm, 2:2:140µm, 2:3:120µm |
| Widths: 1:3:35µm, 2:1:40µm, 2:2:140µm, 2:3:120µm |
| Widths: 1:3:35µm, 2:1:40µm, 2:2:140µm, 2:3:120µm |
C-204 Sample # 3: Depth: 71.55 m - 71.60 m: Continued

X-Ray Diffraction Profile:

<table>
<thead>
<tr>
<th>2θ</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
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FWHM vs. 2θ:

<table>
<thead>
<tr>
<th>2θ</th>
<th>FWHM</th>
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<tbody>
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<tr>
<td>120</td>
<td>1.0</td>
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</table>
C-204 Sample #3: Depth: 71.55 m - 71.60 m: Continued

Rietveld Comparison:

[Graph showing X-ray diffraction data with intensity on the y-axis and 2-theta on the x-axis. Peaks at various 2-theta values, intensity ranging from 0 to 1.5e+004 cps.]
C-204 Sample # 4: Depth: 82.17 m - 82.22 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
</table>

Member: Formation/Group (Age) | Tyrone Limestone: High Bridge Group (Middle Ordovician: 470-458) |
Hand Sample Description: | Ostracodal lime mudstone, dry appearance: pale greenish yellow (10Y8/2), wet appearance: pale olive (10Y6/2), spar replacement of fossils, thin horizontal layers of shale are common along the bottom edge of sample, fossils are seen within sample: possible ostracod shells or brachiopod valves |
Thin Section Description: | Packed biodismicrite, matrix is composed of micrite, rhombohedral calcite grains are scattered throughout sample, semi horizontal layers of muddy rhombohedral calcite grains are present at the top and bottom of sample – opaque grains tend to appear more often within these layers, two possible stylolite layers are present at the middle and top of sample, bryozoan fossils, ostracod shells (Os), and brachiopod fossils present within sample, spar calcite is present filling cracks and voids – few grains display twinning features |
Twinning Measurements: | Intensity: 1:2 (100x) |
| | Spacing: 1:50µm |
| | Widths: 1:1-2:10µm |
C-204 Sample # 4: Depth: 82.17 m - 82.22 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2ϴ:
C-204 Sample #4: Depth: 82.17 m - 82.22 m: Continued

Rietveld Comparison:

![Graph showing Rietveld comparison with intensity (cps) on the y-axis and 2-theta (deg) on the x-axis. The graph displays various peaks and valleys indicating the comparison of the data.](image)
**C-204 Sample # 5: Depth: 91.84 m - 91.9 m**

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image 1]</td>
<td>![Thin Section Image 2]</td>
<td>![Thin Section Image 3]</td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**
Tyrone Limestone: High Bridge Group (Middle Ordovician: 470-458)

**Hand Sample Description:**
Brachiopodal lime mudstone, dry appearance: yellowish gray (5Y 7/2), wet appearance: dusky yellow (5Y 6/4), spar calcite replacement of brachiopod fossils, thin horizontal layer seen across middle of sample, matrix of sample is comprised of micritic

**Thin Section Description:**
Spars biodismicrite, matrix is comprised of micrite with rhombohedral calcite crystals scattered throughout – calcite grains are not in contact, stylolite layer present across middle of sample – rusty color in PPL; spar calcite is present throughout sample – few grains display twinning; ostracod fossils present within sample, opaque grains (Op) present within sample – cubic in shape

**Twinning Measurements:**
<table>
<thead>
<tr>
<th>Intensity:</th>
<th>1:1(400x), 2: 2(400x), 3:3(400x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spacing:</td>
<td>1:1:95µm</td>
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<tr>
<td></td>
<td>2:1:45µm</td>
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<tr>
<td></td>
<td>3:1:17.5µm, 3:2:42.5µm</td>
</tr>
<tr>
<td>Widths:</td>
<td>1:2.5µm, 2:1-2:5µm, 3:1-3:2.5µm</td>
</tr>
</tbody>
</table>
C-204 Sample # 5: Depth: 91.84 m - 91.9 m: Continued

X-Ray Diffraction Profile:

<table>
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<tr>
<th>2θ</th>
<th>Intensity</th>
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</thead>
<tbody>
<tr>
<td>20</td>
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<tr>
<td>22.86</td>
<td>16000</td>
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<td>25.72</td>
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<td>114.38</td>
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<tr>
<td>117.24</td>
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</tr>
</tbody>
</table>

FWHM vs. 2θ:

- Smp 5-C
- Smp 5-D
Rietveld Comparison:

Intensity (cps)

2-theta (deg)

Intensity (cps)
C-204 Sample # 6: Depth: 100.23 m - 100.28 m

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Oregon Formation: High Bridge Group (Middle Ordovician: 470-458)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Lime mudstone, dry appearance: very pale orange (10YR 8/2), wet appearance: moderate olive brown (5Y 4/4), highly mottled, burrow infill is olive gray (5Y 3/2), sample is heavily bioturbated</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Micrite, sample is composed of micrite, areas of sample are darker in color than surrounding matrix and appear in random locations of sample – burrows, areas that are darker tend to have a slightly higher amount of opaque minerals than surrounding, opaque grains are cubic to spherical in shape</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>
C-204 Sample # 6: Depth: 100.23 m - 100.28 m: Continued

**X-Ray Diffraction Profile:**

![X-ray diffraction profile graph]

**FWHM vs. 2θ:**

![FWHM vs. 2θ graph]
C-204 Sample # 6: Depth: 100.23 m - 100.28 m: Continued

Rietveld Comparison:
C-204 Sample # 7: Depth: 101.96 m – 102 m

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Oregon Formation: High Bridge Group (Middle Ordovician: 470-458)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Lime mudstone, Dry: very pale orange (10YR 8/2), Wet: moderate olive brown (5y 4/4), fine grained, burrowed, vertical stylolite layer present at middle of sample, matrix of sample is comprised of micrite</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, matrix of sample is composed of micrite, vertical stylolite layer (Sty) present through entire middle of sample, a patchy vertical layer of larger calcite grains is seen through the middle of the previous stylolite layer, opaque grains are observed throughout sample – shape is cubic</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>
C-204 Sample # 7: Depth: 101.96 m – 102 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2θ:
C-204 Sample # 7: Depth: 101.96 m – 102 m: Continued

Rietveld Comparison:

![Rietveld Comparison Graph]

Intensity (cps) vs. 2-theta (deg) graph showing the comparison of experimental and simulated diffraction patterns.
<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image]</td>
<td>![PPL Image]</td>
<td>![XPL Image]</td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**

Oregon Formation: High Bridge Group (Middle Ordovician: 470-458)

**Hand Sample Description:**
Lime mudstone, dry appearance: pale green (5G 7/2), wet appearance: pale greenish yellow (10Y 8/2), small zones of spar within sample, matrix of sample is comprised of micrite, thin horizontal layers are seen across sample - more common towards the top of sample

**Thin Section Description:**
Dismicrite, matrix is composed of micrite, few calcite and opaque grains scattered throughout sample – opaques are cubic in shape; spare calcite (Ca) is common throughout sample appearing as thin horizontal layers or as secondary formation within a vug, many calcite grains display secondary twinning

**Twinning Measurements:**

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<tr>
<th>Intensity:</th>
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<tbody>
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<td>Spacing:</td>
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</tr>
<tr>
<td>Widths:</td>
<td>1:1-12:10µm</td>
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</tbody>
</table>
C-204 Sample # 8: Depth: 104.55 m - 104.60 m: Continued

X-Ray Diffraction Profile:

<table>
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<tr>
<th>2θ</th>
<th>Intensity</th>
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<tbody>
<tr>
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FWHM vs. 2θ:

<table>
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<tr>
<th>2θ</th>
<th>FWHM</th>
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</table>
C-204 Sample # 8: Depth: 104.55 m - 104.60 m: Continued

Rietveld Comparison:

![Graph showing Rietveld Comparison](image-url)
C-204 Sample # 9: Depth: 117.55 m - 117.60 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
</table>

**Member: Formation/Group (Age)**
Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 470-458)

**Hand Sample Description:**
Brachiopodal lime mudstone, Dry: light olive gray (5Y 5/2) – pale greenish yellow (10Y 7/4), brachiopod valves: ~0.5cm, matrix of sample appears to be highly bioturbated - fossil fragments could indicate areas of bioturbation

**Thin Section Description:**
Spars biomicrite, sample is composed of two different units - unit one is comprised of semi rhombohedral calcite grains while unit two is composed of micrite, both units comprise ~50% each of the sample, unit two is the cause of bioturbation - brachiopod (Br), ostracod, and bryozoan fossils are present only within unit two, two thin horizontal layers of a muddy matrix cross the lower section of the sample – cubic opaque grains (Op) are common within these layers and are positioned parallel to the bedding

**Twinning Measurements:**
No secondary twinning was observed within grains
C-204 Sample # 9: Depth: 117.55 m - 117.60 m: Continued

X-Ray Diffraction Profile:

<table>
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<th>2θ</th>
<th>Intensity</th>
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<td>114.38</td>
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FWHM vs. 2θ:

FWHM

<table>
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<th>FWHM</th>
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<tr>
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Smp 9-C

Smp 9-D
C-204 Sample # 9: Depth: 117.55 m - 117.60 m: Continued

Rietveld Comparison:
C-204 Sample # 10: Depth: 129.34 m - 129.39 m

<table>
<thead>
<tr>
<th>Hand Sample Description:</th>
<th>Brachiopodal lime mudstone, dry appearance: yellowish gray (5Y 7/2), wet appearance: light olive gray (5Y 5/2), small brachiopod fragments seen within sample, matrix of sample is micritic and appears to be highly bioturbated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin Section Description:</td>
<td>Spars biodismicrite, sample is composed of two different units - unit one is comprised of semi rhombohedral calcite grains while unit two is composed of micrite, unit two comprises 70-80% of the total sample, unit two is the cause of bioturbation - brachiopod, ostracod, gastropod, and bryozoan fossils are present only within unit two, opaque grains are common throughout entire sample but tend to accumulate in greater quantities within unit one – shape of grains is cubic to semi cubic, few areas of sparry calcite present</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 470-458)</th>
</tr>
</thead>
</table>

| Scanned Image of Hand Sample | Scanned Image of Thin Section | Thin Section Photomicrograph PPL (40x) | Thin Section Photomicrograph XPL (40x) |
C-204 Sample # 10: Depth: 129.34 m - 129.39 m: Continued

X-Ray Diffraction Profile:

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<tr>
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<th>Intensity</th>
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<tr>
<td>22.86</td>
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<tr>
<td>25.72</td>
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<td>16000</td>
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FWHM vs. 2Θ:

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<th>FWHM</th>
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<tbody>
<tr>
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<td>80</td>
<td>0.4</td>
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<td>100</td>
<td>0.5</td>
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</tbody>
</table>

- Smp 10-C
- Smp 10-D
C-204 Sample # 10: Depth: 129.34 m - 129.39 m: Continued

Rietveld Comparison:
C-204 Sample # 11: Depth: 144.98 m - 145.03 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**
Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 470-458)

**Hand Sample Description:**
Lime mudstone, wet appearance: light olive gray (5Y 5/2), dry appearance: yellowish gray (5Y 7/2), small layer of spar in bottom lift of sample, semi horizontal layers of shale across lower left corner of sample: grayish olive green (5GY 3/2), matrix of sample is comprised of micrite

**Thin Section Description:**
Fossiliferous dismicrite, sample is composed of two different units - unit one is composed of micrite while unit two is comprised of semi rhombohedral calcite grains, opaque grains are uncommon within unit one but are very common within unit two – shape of grains is semi cubic to semi triangular, opaque grains (Op) form thin layers parallel with bedding and small blotches; stylolite layer across middle of sample, spar calcite found filling crack in lower right corner

**Twinning Measurements:**
No secondary twinning was observed within grains
C-204 Sample # 11: Depth: 144.98 m - 145.03 m: Continued

### X-Ray Diffraction Profile:

<table>
<thead>
<tr>
<th>2θ</th>
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</tbody>
</table>

### FWHM vs. 2θ:

- **Smp 11-C**
- **Smp 11-D**
C-204 Sample # 11: Depth: 144.98 m - 145.03 m: Continued

Rietveld Comparison:
**C-204 Sample # 12: Depth: 157.20 m - 157.25 m**

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image 1]</td>
<td>![Thin Section Image 2]</td>
<td>![Thin Section Image 3]</td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age):** Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 470-458)

**Hand Sample Description:** Peloidal brachiopodal lime mudstone, wet appearance: dusky yellow (5Y 7/2) – light olive gray (5Y 5/2), dry appearance: yellowish gray (5Y 7/2), thin horizontal layers of shale through entire length of sample, peloids and brachiopod fossils are seen scattered through sample.

**Thin Section Description:** Packed biodismicrite, matrix is comprised primarily of micrite, thin rusty colored horizontal layers of semi rhombohedral calcite grains present throughout entire length of sample, ostracod and bryozoan fossils present throughout entire sample, opaque grains present within thin layers of calcite – cubic to angular in shape, spar calcite found filling void under ostracod shell – calcite grain displays secondary twinning.

**Twinning Measurements:**

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<th>Intensity</th>
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<tr>
<td>Widths</td>
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</table>
C-204 Sample # 12: Depth: 157.20 m - 157.25 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2θ:

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<tr>
<th>2θ</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
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<tr>
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<tr>
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<td>28.58</td>
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<table>
<thead>
<tr>
<th>2θ</th>
<th>FWHM</th>
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<tbody>
<tr>
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Smp 12-C
Smp 12-D
C-204 Sample # 12: Depth: 157.20 m - 157.25 m: Continued

Rietveld Comparison:
C-204 Sample # 13: Depth: 171.48 m - 171.53 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
</table>

**Member: Formation/Group (Age)**
Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 470-458)

**Hand Sample Description:**
Lime mudstone, wet appearance: grayish olive (10Y 4/2), dry appearance: pale olive (10Y 6/2), three horizontal shale layers seen through sample - 1-3 mm thick, color: dusky green (5G 3/2), matrix is comprised of micrite

**Thin Section Description:**
Fossiliferous dismicrite, matrix is comprised of micrite, few horizontal layers of semi rhombohedral calcite grains are present within the sample – outer edges are a rusty color, sparry calcite is found filling cracks within sample – secondary twinning is seen within few grains, opaque grains are uncommon within micrite but are more common within calcite layers, ostracod shells are very common within micrite

**Twinning Measurements:**

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<tr>
<th>Intensity:</th>
<th>1:5(400x), 2:3(400x)</th>
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C-204 Sample # 13: Depth: 171.48 m - 171.53 m: Continued

X-Ray Diffraction Profile:

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<th>Intensity</th>
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FWHM vs. 2θ:

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<tr>
<th>2θ</th>
<th>FWHM</th>
</tr>
</thead>
<tbody>
<tr>
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</table>
C-204 Sample # 13: Depth: 171.48 m - 171.53 m: Continued
### C-204 Sample # 14: Depth: 199.11 m - 199.16 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
</table>

**Member: Formation/Group (Age)**

Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 470–458)

**Hand Sample Description:**

Lime mudstone, wet appearance: light olive (10Y 5/4) – pale greenish yellow (10Y 8/2), semi horizontal muddy layer seen through middle of sample, matrix of sample is micrite, sample appears to be highly bioturbated

**Thin Section Description:**

Fossiliferous dismicrite, sample is composed of two different units - unit one is composed of micrite while unit two is comprised of semi rhombohedral calcite grains, unit one comprises majority of the sample, horizontal stylolite layer seen across middle of sample – a rusty color in PPL

**Twinning Measurements:**

No secondary twinning was observed within grains
C-204 Sample # 14: Depth: 199.11 m - 199.16 m: Continued

X-Ray Diffraction Profile:

<table>
<thead>
<tr>
<th>2θ</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
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<tr>
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<td>114.38</td>
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FWHM vs. 2θ:

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<th>FWHM</th>
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<tbody>
<tr>
<td>20</td>
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</tr>
<tr>
<td>40</td>
<td>0.2</td>
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<tr>
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<td>100</td>
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<tr>
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</table>

- Smp 14-C
- Smp 14-D
C-204 Sample # 14: Depth: 199.11 m - 199.16 m: Continued

Rietveld Comparison:
C-204 Sample # 15: Depth: 213.26 m - 213.31 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image]</td>
<td>![PPL Photomicrograph Image]</td>
<td>![XPL Photomicrograph Image]</td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**  
Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 470-458)

**Hand Sample Description:**  
Lime mudstone, wet appearance: light olive gray (5Y 5/2), dry appearance: pale olive (10Y 6/2), matrix of sample is comprised of micrite, semi horizontal layer seen through top of sample, zones of spar calcite present in lower end of sample

**Thin Section Description:**  
Fossiliferous dismicrite, matrix of sample is comprised of micrite, sparry calcite is seen filling cracks and voids within sample – secondary twinning is seen within grains, few ostracod shells found, opaque grains are uncommon within sample – cubic in shape, few thin semi horizontal layers of semi rhombohedral calcite grains throughout sample

**Twinning Measurements:**

<table>
<thead>
<tr>
<th>Intensity:</th>
<th>1:4(100x), 2:4(100x), 3:17(100x), 4:6(100x), 5:3(100x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spacing:</td>
<td>1:1:50μm, 1:2:100μm, 1:3:90μm</td>
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<tr>
<td></td>
<td>2:1:400μm, 2:2:200μm, 2:3:120μm</td>
</tr>
<tr>
<td></td>
<td>3:17:100μm, 5:1:230μm, 5:2:100μm</td>
</tr>
</tbody>
</table>
C-204 Sample # 15: Depth: 213.26 m - 213.31 m: Continued

X-Ray Diffraction Profile:

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<tr>
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<td>28.58</td>
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<td>31.44</td>
<td>10000</td>
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<td>42.88</td>
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<tr>
<td>45.74</td>
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FWHM vs. 2θ:

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<tr>
<th>2θ</th>
<th>FWHM</th>
</tr>
</thead>
<tbody>
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</table>
C-204 Sample # 15: Depth: 213.26 m - 213.31 m: Continued

Rietveld Comparison:

```
Intensity (cps)

2-theta (deg)

Intensity (cps)
```

```
0.0e+000
5.0e+003
1.0e+004
1.5e+004
20 40 60 80 100 120

-2000
-1000
0
1000
2000

20 40 60 80 100 120

2-theta (deg)

Intensity (cps)
```
C-204 Sample # 16: Depth: 228.45 m - 228.52 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 470-458)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Lime mudstone, wet appearance: greyish olive (10Y 4/2), dry appearance: dusky yellow green (5GY 5/2), sample appears to be highly bioturbated, matrix of sample is comprised of micrite</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, matrix of sample is comprised of micrite, few rounded quartz grains seen throughout sample, few areas of sparry calcite, opaque grains uncommon throughout sample – cubic in shape</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>
C-204 Sample # 16: Depth: 228.45 m - 228.52 m: Continued

X-Ray Diffraction Profile:

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<th>Intensity</th>
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<tbody>
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<td>25.72</td>
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</table>

FWHM vs. 2Ө:

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<th>2Ө</th>
<th>FWHM</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
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<td>100</td>
<td>0.5</td>
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</tbody>
</table>

- Smp 16-C
- Smp 16-D
C-204 Sample # 16: Depth: 228.45 m - 228.52 m: Continued

Rietveld Comparison:
C-204 Sample # 17: Depth: 238.20 m - 238.25 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Wells Creek Dolomite: (Middle Ordovician: 470-458)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Dolomitic lime mudstone, wet appearance: light olive gray (5Y 5/2), dry appearance: yellowish gray (5Y7/2), matrix of sample seems to be all micrite, certain splotchy areas of sample have a darker color - possibly burrows</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, matrix of sample is a semi rhombohedral dolomite, vertical layers of dolomite seen through middle of sample, opaque grains seen throughout sample – shape is spherical to cubic, few rounded to sub rounded quartz grains throughout sample</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>
C-204 Sample # 17: Depth: 238.20 m - 238.25 m: Continued

X-Ray Diffraction Profile:

<table>
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<tr>
<td>30</td>
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FWHM vs. 2θ:

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<tr>
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<th>FWHM</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

Graphs showing the intensity and FWHM values for different angles.
C-204 Sample # 17: Depth: 238.20 m - 238.25 m: Continued

Rietveld Comparison:
C-204 Sample # 18: Depth: 265.48 m - 265.53 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image]</td>
<td>![Polarized Light Image]</td>
<td>![Crossed Polars Image]</td>
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</tbody>
</table>

### Member: Formation/Group (Age)
Knox Group: (Middle Ordovician: 485-470)

### Hand Sample Description:
Crystalline dolomitic, wet appearance: pale green (5G 7/2), horizontal darker thin layers seen crossing bottom of sample, matrix is comprised of dolomite grains

### Thin Section Description:
Dismicrite, matrix is composed of semi rhombohedral dolomite grains, horizontal layer or larger dolomite grains in middle of sample

### Twinning Measurements:
No secondary twinning was observed within grains
C-204 Sample # 18: Depth: 265.48 m - 265.53 m: Continued

X-Ray Diffraction Profile:

<table>
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<tr>
<th>2θ</th>
<th>Intensity</th>
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<td>45000</td>
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</table>

FWHM vs. 2θ:

<table>
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<tr>
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<th>FWHM</th>
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<tbody>
<tr>
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</table>
C-204 Sample # 18: Depth: 265.48 m - 265.53 m: Continued

Rietveld Comparison:
APPENDIX B: ALL RAW DATA FOR CORE JK78-3

JK78-3 Sample # 1: Depth: 5.54 m - 5.61 m

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Oregon Dolomite: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Dolomitic mudstone, dry appearance: dusky yellow (5Y 6/4) – dusky yellow green (5GY 5/2), wet appearance: olive gray (5Y 3/2) – pale greenish yellow (10Y 7/4), reacts slightly to HCl, multiple (~5 - 6) normal microfaults may be present:~1mm, matrix of sample is micritic, bedding of sample appears to be near vertical - dark colored layers common through sample indicate orientation, multiple fractures are seen within sample</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, sample has vertical veins of slightly rhombohedral dolomite grains cutting entire length of sample, bedding appears to be near vertical, displacement of vertical dark bands: ~60-65 ticks (40x), possible halos around faulting, opaque grains (Op) with cubic and slightly euhedral habits present throughout sample but are more common within darker units, darker units are a rusty brown color which tend to contain opaque smudges and grains</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>
JK78-3 Sample # 1: Depth: 5.54 m - 5.6 m: Continued

X-Ray Diffraction Profile:

![X-Ray Diffraction Profile Graph](image)

FWHM vs. 2Θ:

![FWHM vs. 2Θ Graph](image)
JK78-3 Sample # 1: Depth: 5.54 m - 5.6 m: Continued

Rietveld Comparison:
JK78-3 Sample # 2: Depth: 10.97 m - 11.05 m

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Oregon Dolomite: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Dolomitic mudstone, dry appearance: dusky yellow (5Y 6/4), wet appearance: moderate olive brown (5Y 4/4), multiple (~3 - 4) normal microfault: displacement ~1mm, swirly olive gray or grayish olive green layers common throughout, reacts slightly to HCL, multiple fractures are seen throughout the core</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, rhombohedral like dolomite crystals comprise the matrix of sample, opaque grains are present throughout sample – habit tends to be slightly cubic to angular, rounded – sub-rounded quartz grains are uncommon with</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>
JK78-3 Sample # 2: Depth: 10.97 m - 11.05 m: Continued

X-Ray Diffraction Profile:

FWHM vs. $2\theta$:

![Graph showing FWHM vs. $2\theta$ for different pressures: Smp 2, Amb, 4.6 GPa, 17 GPa, 26 GPa, 29.8 GPa.]
JK78-3 Sample # 2: Depth: 10.97 m - 11.05 m: Continued
**JK78-3 Sample # 3: Depth: 13.41 m - 13.49 m**

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Tyrone Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Dolomitic mudstone, wet appearance: light olive (10Y5/4), dry appearance: yellowish gray (5Y 7/2), HCl slightly reacts, matrix of sample is comprised of micrite, blotchy areas of a slightly more tan lithology are scattered throughout the sample</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, rhombohedral dolomite grains comprise entire matrix of sample, opaque grains are present at higher magnification – grains display a cubic and slightly triangular habit, large dolomite (Do) grains along fracture on right side of sample</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>


JK78-3 Sample # 3: Depth: 13.41 m - 13.49 m: Continued

X-Ray Diffraction Profile:

![X-Ray Diffraction Profile](image)

FWHM vs. 2Θ:

![FWHM vs. 2Θ](image)
JK78-3 Sample # 3: Depth: 13.41 m - 13.49 m: Continued

Rietveld Comparison:
JK78-3 Sample # 4: Depth: 15.84 m - 15.93 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**
Tyrone Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**
Dolomitic mudstone, dry appearance: yellowish gray (5Y 7/2), wet appearance: light olive gray (5Y 5/2), small vugs present, matrix of sample is comprised of micrite, blotchy areas of a slightly more tan lithology are scattered throughout the sample - same as previous sample

**Thin Section Description:**
Dismicrite, rhombohedral dolomite grains comprise matrix of sample, cubic opaque grains are present throughout sample

**Twinning Measurements:**
No secondary twinning was observed within grains
JK78-3 Sample #4: Depth: 15.84 m - 15.93 m: Continued

X-Ray Diffraction Profile:

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<tr>
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<th>Intensity</th>
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<tbody>
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FWHM vs. 2θ:

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</table>
JK78-3 Sample # 4: Depth: 15.84 m - 15.93 m: Continued

Rietveld Comparison:
### JK78-3 Sample # 5: Depth: 18.29 m - 18.36 m

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
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</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Dolomitic mudstone, dry appearance: pale olive (10Y 6/2), wet appearance: light olive gray (5Y 5/2), HCL slightly reacts, sample has a thin semi horizontal layer across the sample, matrix of sample is micritic</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, rhombohedral dolomite comprises matrix of sample, opaque grains are present throughout sample – slightly cubic and rectangular habit, quartz grains are present – grains are sub-rounded, zones of spar dolomite (Do) present throughout sample</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>
JK78-3 Sample # 5: Depth: 18.29 m - 18.36 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2θ:

Smp 5
Amb
4.6GPa
17 GPa
26 GPa
29.8 GPa
JK78-3 Sample # 5: Depth: 18.29 m - 18.36 m: Continued

Rietveld Comparison:

![Graph of Rietveld Comparison](image-url)
JK78-3 Sample # 6: Depth: 22.61 m - 22.68 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
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<th>Thin Section Photomicrograph XPL (40x)</th>
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</table>

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<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Clasts are Camp Nelson Limestone</th>
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<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Brachiopodal dolomitic mudstone, HCL slightly reacts, dry appearance: dusky yellow (5Y6/4) – light olive gray (5Y 5/2), wet appearance: moderate olive brown (5Y 4/4), matrix of sample is micritic, possible normal fault across middle of sample, brachiopod shaped void at top left of sample, fractures present throughout sample</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, rhombohedral dolomite comprises matrix of sample, quartz grains (Qz) are present – grains are rounded – sub-rounded, opaque – rust colored mineral present throughout sample; in PPL mineral is rusty colored along the edges but turns opaque towards the center of the grain, opaque centers appear to be slightly cubic or angular</td>
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<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
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</table>
JK78-3 Sample # 6: Depth: 22.61 m - 22.68 m: Continued

X-Ray Diffraction Profile:

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<th>Intensity</th>
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<td>114.38</td>
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<tr>
<td>117.24</td>
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</table>

FWHM vs. 2Θ:

<table>
<thead>
<tr>
<th>2Θ</th>
<th>FWHM</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>100</td>
<td></td>
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<tr>
<td>120</td>
<td></td>
</tr>
</tbody>
</table>

- Smp 6
- Amb
- 4.6 GPa
- 17 GPa
- 26 GPa
- 29.8 GPa
JK78-3 Sample # 6: Depth: 22.61 m - 22.68 m: Continued

Rietveld Comparison:
JK78-3 Sample # 7: Depth: 25.81 m - 25.88 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image]</td>
<td>![PPL Photomicrograph]</td>
<td>![XPL Photomicrograph]</td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**
- Oregon Dolomite: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**
Dolomitic mudstone, dry appearance: moderate olive brown (5Y 4/4) – grayish olive (10Y 4/2), wet appearance: dark yellowish brown (10YR 4/2) – grayish olive (10Y 4/2), sample contains many fractures, semi horizontal stylolite layer present through middle of sample, matrix of sample is micritic, bedding of sample appears near vertical.

**Thin Section Description:**
Dismicrite, rhombohedral dolomite grains present within dolomitic fine grained matrix, stylolite (Sty) vein present diagonally across middle of sample – rusty in color, few rounded quartz grains are present at stylolite boundary, opaque grains common throughout sample – slightly cubic, cubic, and triangular crystal habit, few small quartz grains (Qz) within matrix – grains are rounded, vertical cracks are present within sample – cracks are not filled/can only see epoxy through sample.

**Twinning Measurements:**
No secondary twinning was observed within grains.
JK78-3 Sample # 7: Depth: 25.81 m - 25.88 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2θ:

Intensity

Intensity

2θ

2θ
JK78-3 Sample # 7: Depth: 25.81 m - 25.88 m: Continued

Rietveld Comparison:

![Rietveld Comparison Graph]

Intensity (cps) vs. 2-theta (deg)
JK78-3 Sample # 8: Depth: 28.04 m - 28.12 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
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<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
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</thead>
<tbody>
<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image]</td>
<td>![PPL Image]</td>
<td>![XPL Image]</td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**
Oregon Dolomite: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**
Dolomitic mudstone, dry appearance: dusky yellow (5Y 6/4), wet appearance: moderate olive brown (5Y 4/4), samples contain micro normal faulting, ~ 6 - 7 total, with displacement of ~1mm, matrix of sample is micritic, bedding of sample appears to be near vertical

**Thin Section Description:**
Dismicrite, rhombohedral dolomite minerals comprise matrix of sample, bedding is near vertical, multiple fractures/micro faults present, opaque grains common throughout sample – habit is cubic to slightly triangular, quartz grains scattered throughout sample – grains are angular to sub rounded

**Twinning Measurements:**
No secondary twinning was observed within grains
JK78-3 Sample #8: Depth: 28.04 m - 28.12 m: Continued

X-Ray Diffraction Profile:

<table>
<thead>
<tr>
<th>2θ</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
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<tr>
<td>22.86</td>
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</tbody>
</table>

FWHM vs. 2θ:

- Smp 8
- Amb
- 4.6 GPa
- 17 GPa
- 26 GPa
- 29.8
JK78-3 Sample # 8: Depth: 28.04 m - 28.12 m: Continued

Rietveld Comparison:
**JK78-3 Sample # 9: Depth 31.93 m - 31.98 m**

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Scanned Image of Hand Sample" /></td>
<td><img src="image2" alt="Scanned Image of Thin Section" /></td>
<td><img src="image3" alt="Thin Section Photomicrograph PPL (40x)" /></td>
<td><img src="image4" alt="Thin Section Photomicrograph XPL (40x)" /></td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**

| Oregon Dolomite: High Bridge Group (Middle Ordovician: 485-470 Ma) |

**Hand Sample Description:**

Dolomitic mudstone, dry appearance: pale olive (10Y 6/2) – grayish olive (10Y 4/2), wet appearance: moderate olive brown (5Y 4/4), matrix of sample appears to be micrite, sample has a bioturbated look - swirls of brown and light tan throughout sample.

**Thin Section Description:**

Dismicrite, rhombohedral dolomite grains comprise matrix of sample, voids are present within sample with dolomite grain growth within voids, opaque mineral present – grains are slightly cubic to cubic in habit, under 400x mag utter edges of minerals have a rusty colored outline, bedding of sample cannot be determined.

**Twinning Measurements:**

No secondary twinning was observed within grains.
JK78-3 Sample # 9: Depth 31.93 m - 31.98 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2θ:

Intensity vs. 2θ

FWHM vs. 2θ

Smp 9

Amb

4.6 GPa

17 GPa

26 GPa

29.8 GPa
JK78-3 Sample # 9: Depth 31.93 m - 31.98 m: Continued

Rietveld Comparison:

Intensity (cps)

2-theta (deg)

Intensity (cps)

Intensity (cps)
JK78-3 Sample # 10: Depth: 37.34 m - 37.41 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
</table>

**Member: Formation/Group (Age)**

Clasts are of the Camp Nelson Limestone

**Hand Sample Description:**

Matrix supported monimict breccia, dry appearance: pale olive (10Y 6/2), wet appearance: olive gray, upper piece appears to be monimict breccia matrix, section is highly vuggy, angular dolomite clasts, possible crinoid fossil in upper left corner, middle piece is dolomitic brachiopodal mudstone, brachiopod fossil ~ 1cm in length, matrix of this section appears to be micritic, possible mega block; bottom piece is the same as the top with possible shell fragments

**Thin Section Description:**

Dismicrite, ostracod shaped void, dolomite matrix, bedding of sample cannot be determined, opaque minerals present throughout entire sample – cubic to semi triangular habit, quartz grains are present throughout sample – grains are rounded to angular

**Twinning Measurements:**

No secondary twinning was observed within grains
JK78-3 Sample # 10: Depth: 37.34 m - 37.41 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2Ө:

<table>
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<tbody>
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Smp 10
Amb
4.6 GPa
17 GPa
26 GPa
29.8 GPa
JK78-3 Sample # 10: Depth: 37.34 m - 37.41 m: Continued

Rietveld Comparison:
JK78-3 Sample # 11: Depth: 41.58 m - 41.63 m

<table>
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<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
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<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image]</td>
<td>![PPL Image]</td>
<td>![XPL Image]</td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age):**
Clasts are Camp Nelson Limestone

**Hand Sample Description:**
Monomict breccia, clast supported, clasts appear to be sub-angular, dry appearance: pale olive (10Y 6/2), wet appearance: grayish olive (10Y 4/2), sample appears to have two megablocks or two large clasts of a similar formation with a light tan matrix separating them, both clasts appear to have a wavy textural contact with the tan matrix, brachiopod fossil in lower clast - 0.75cm long

**Thin Section Description:**
Dismicrite, rhombohedral dolomite grains scattered within a micritic matrix, matrix of top and bottom of sample is comprised of a majority of rhombohedral dolomite grains, rounded quartz grains throughout sample, unknown mineral at top of sample and within horizontal void along the middle left side of sample: color in PPL is pale yellow, color in XPL is 1st order orange and red, mineral show undulose extinction, shape of grains is highly erratic from sub rounded to strip like, mineral could be quartz; opaque mineral throughout sample – shape of grain is cubic to semi triangular

**Twinning Measurements:**
No secondary twinning was observed within grains
JK78-3 Sample # 11: Depth: 41.58 m - 41.63 m: Continued

X-Ray Diffraction Profile:

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<tr>
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<tbody>
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FWHM vs. 20:

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<td>1.5</td>
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- Smp 11
- Amb
- 4.6 GPa
- 17 GPa
- 26 GPa
- 29.8 GPa
JK78-3 Sample # 11: Depth: 41.58 m - 41.63 m: Continued

Rietveld Comparison:
JK78-3 Sample # 12: Depth: 48.84 m - 48.90 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
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</thead>
<tbody>
<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image]</td>
<td>![PPL Image]</td>
<td>![XPL Image]</td>
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**Member:**

<table>
<thead>
<tr>
<th>Formation/Group (Age)</th>
<th>Clasts are Camp Nelson limestone and Tyrone limestone</th>
</tr>
</thead>
</table>

**Hand Sample Description:**

Polymictic breccia, clast supported, clasts are angular in shape, average size ~0.25 cm, mean: ~0.75-1cm, clast color(s): light gray and an olive gray, matrix is a lighter tan color

**Thin Section Description:**

Clast supported polymict breccia, clast shape is angular to sub angular, clasts are from the Tyrone and Oregon formations; matrix is rusty in color in both PPL and XPL, matrix is composed of dirty rhombohedral dolomite crystals and quartz grains in a fine matrix, quartz grains are more common within the matrix of sample than within the clasts, quartz grains are rounded to sub angular, is difficult to distinguish matrix from sample in certain locations, two stylolite layers seen horizontally along sample

**Twinning Measurements:**

No secondary twinning was observed within grains
JK78-3 Sample # 12: Depth: 48.84 m - 48.90 m: Continued

X-Ray Diffraction Profile:

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<tr>
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<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>22.86</td>
<td>2</td>
</tr>
<tr>
<td>25.72</td>
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FWHM vs. 2Θ:

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</tbody>
</table>

Smp 12

Amb

4.6 GPa

17 GPa

26 GPa

29.8 GPa
JK78-3 Sample # 12: Depth: 48.84 m - 48.90 m: Continued

Rietveld Comparison:
JK78-3 Sample # 13: Depth: 59.06 m - 59.13 m

<table>
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<tr>
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<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image]</td>
<td>![PPL Image]</td>
<td>![XPL Image]</td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age):**

Tyrone Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**
Brachiopodal dolomitic mudstone, Dry: yellow gray (5Y 7/2), Wet: light olive (10Y5/4), reacts slightly with HCl, brachiopod voids present along the vertical mid-line, top of sample has a wavy texture to it, matrix of sample appears to be micritic

**Thin Section Description:**
Dismicrite, bedding of sample is close to 45 degrees, veins of calcite/dolomite are cutting diagonally through sample, vugs are present in sample with few rhombohedral dolomite grains, opaque minerals scattered about sample – shape of grains is slightly cubic to possibly slightly euhedral

**Twinning Measurements:**
No secondary twinning was observed within grains
JK78-3 Sample # 13: Depth: 59.06 m - 59.13 m: Continued

X-Ray Diffraction Profile:

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<tr>
<th>2Θ</th>
<th>Intensity</th>
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FWHM vs. 2Θ:

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- Smp 13
- Amb
- 4.6 GPa
- 17 GPa
- 26 GPa
- 29.8 GPa
JK78-3 Sample # 13: Depth: 59.06 m - 59.13 m: Continued

Rietveld Comparison:
**Member: Formation/Group (Age)**
Tyrone Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**
Dolomitic mudstone, dry appearance: pale olive (10Y 6/2), wet appearance: light olive (10Y 5/4), possible displacement within the sample, matrix of sample appears to be micritic, sample has a swirling layer of a slightly lighter colored matrix, possible replaced brachiopod valve in upper right corner

**Thin Section Description:**
Dismicrite, displacement has occurred: ~60-120 ticks (40x), direction of displacement cannot be determined, two different units are seen within sample – majority of sample is a rhombohedral dolomite matrix, next unit is a smaller and darker in color rhombohedral dolomite matrix, both units contain opaque grains – grain habit is slightly rectangular, slightly cubic, and slightly triangular

**Twinning Measurements:**
No secondary twinning was observed within grains
JK78-3 Sample # 14: Depth: 62.41 m - 62.48 m: Continued

X-Ray Diffraction Profile:

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Intensity vs. 2θ:

FWHM vs. 2θ:

Smp 14
Amb
4.6 GPa
17 GPa
26 GPa
29.8 GPa
JK78-3 Sample # 14: Depth: 62.41 m - 62.48 m: Continued

Rietveld Comparison:
JK78-3 Sample # 15: Depth 67.06 m - 67.13 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Clasts are of the Oregon Dolomite or Tyrone Limestone</th>
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<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Monomict breccia, angular clasts, appears to be clast supported, sample is very friable</td>
</tr>
<tr>
<td>Thin Section Description:</td>
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<tr>
<td>Twinning Measurements:</td>
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JK78-3 Sample # 15: Depth 67.06 m - 67.13 m: Continued

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<th>X-Ray Diffraction Profile:</th>
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<td>FWHM vs. 2θ:</td>
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JK78-3 Sample # 15: Depth 67.06 m - 67.13 m: Continued

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<th>Rietveld Comparison:</th>
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**JK78-3 Sample # 16: Depth: 72.95 m - 73.03 m**

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<th>Scanned Image of Hand Sample</th>
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<th>Thin Section Photomicrograph PPL (40x)</th>
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<tr>
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<td>![Thin Section Image]</td>
<td>![PPL Photomicrograph]</td>
<td>![XPL Photomicrograph]</td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age):** Oregon Dolomite: High Bridge Group (Middle Ordovician: 485–470 Ma)

**Hand Sample Description:** Dolomitic mudstone, dry appearance: dark yellowish orange (10YR 6/6) – dusky yellow green (5 YG 5/2), wet appearance: moderate yellowish brown (10YR 5/4), sample has fractures through, micro normal faults present with ~0.6 cm displacement, sample slightly reacts to HCl, matrix of sample appears to be comprised of micrite, yellow green color/unit comprises ~50% of total sample

**Thin Section Description:** Dismicrite, normal faulting observed, fractures are common, rhombohedral dolomite grains of varying size comprises matrix, haloing is seen along fault, opaque grains within sample – shape of grains is cubic, rectangular, and semi cubic, quartz grains are seen within sample, grains are rounded to sub angular

**Twinning Measurements:** No secondary twinning was observed within grains
JK78-3 Sample # 16: Depth: 72.95 m - 73.03 m: Continued

X-Ray Diffraction Profile:

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2θ |
---|
20 |
22.86 |
25.72 |
28.58 |
31.44 |
34.3  |
37.16 |
40.02 |
42.88 |
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85.78 |
88.64 |
91.5  |
94.36 |
97.22 |
100.08|
102.94|
105.8 |
108.66|
111.52|
114.38|
117.24|

FWHM vs. 2θ:

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</tbody>
</table>

2θ |
---|
20 |
50  |
100 |
120 |

---

Smp 16 |
Amb    |
4.6 GPa|
17 GPa |
26 GPa |
29.8 GPa|
JK78-3 Sample # 16: Depth: 72.95 m - 73.03 m: Continued

Rietveld Comparison:

![Graph showing Rietveld comparison with intensity on the y-axis and 2-theta degrees on the x-axis.]
**JK78-3 Sample # 17: Depth: 85.57 m - 85.62 m**

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Dolomitic mudstone, dry appearance: pale greenish yellow (10Y 8/2), wet appearance: pale green (5G 7/2), matrix of sample appears to be micritic, a vertical semi criss crossing layer is present along right side of sample with a vug at the top</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, rhombohedral dolomite grains comprise matrix of sample, opaque grains are common throughout sample – semi cubic, cubic, rectangular, and semi rectangular habit; sub-rounded to sub-angular quartz grains scattered in sample</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>
JK78-3 Sample # 17: Depth: 85.57 m - 85.62 m: Continued

**X-Ray Diffraction Profile:**

![Graph showing X-ray diffraction profile with intensity vs. 2θ.]

**FWHM vs. 2θ:**

![Graph showing FWHM vs. 2θ with different lines for ambient and various pressures.]

- Smp 17
- Amb
- 4.6 GPa
- 17 GPa
- 26 GPa
- 29.8 GPa
JK78-3 Sample # 17: Depth: 85.57 m - 85.62 m: Continued

Rietveld Comparison:

Intensity (cps) vs 2-theta (deg) graph is shown with peaks at specific 2-theta values.
JK78-3 Sample # 18: Depth: 90.68 m - 90.75 m

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Dolomitic mudstone, dry appearance: pale orange (10YR 8/2) - dusky yellow green (5GY 5/2), bedding of sample is ~70 degrees, from the top left corner to the bottom right the lithology alternates from a pale orange layer to a dusky yellow green - assumed original bedding plan, matrix of sample appears to be micritic</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, bedding of units is tilted ~ 60-70 degrees, rhombohedral dolomite grains of varying sizes comprise matrix of sample, opaque grains are common throughout sample but are will tend to accumulate in thin layers of slightly larger rhombohedral dolomite grains, opaque grains are slightly cubic to slightly triangular, zones of spar dolomite are present – opaque grains do not accumulate within the zones of spar</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>
JK78-3 Sample # 18: Depth: 90.68 m - 90.75 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2θ:

- Intensity vs. 2θ
- FWHM vs. 2θ

Smp 18
Amb
4.6 GPa
17 GPa
26 GPa
29.8 GPa
JK78-3 Sample # 18: Depth: 90.68 m - 90.75 m: Continued

Rietveld Comparison:
JK78-3 Sample # 19: Depth: 97.61 m - 97.69 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Hand Sample Image" /></td>
<td><img src="image2" alt="Thin Section Image" /></td>
<td><img src="image3" alt="PPL Photomicrograph" /></td>
<td><img src="image4" alt="XPL Photomicrograph" /></td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**

Oregon Dolomite: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**
Dolomitic mudstone, dry appearance: very pale orange (10YR 8/2) – pale olive (10Y 6/2), wet appearance: moderate olive brown (5Y 4/4) – grayish olive (10Y 4/2), normal faulting is present: ~ 0.3cm displacement, vertical slickensides along right side of sample, blotchy patches of olive unit throughout sample - assumed to be infilled burrows, matrix of sample appears to be micrite

**Thin Section Description:**
Dismicrite, matrix is composed of semi rhomboedral dolomite grains, bedding is near vertical, vertical slickenside cutting diagonally through left side of sample – opaque minerals are abundant throughout this layer with the highest accumulation in the center, shapes range from cubic to a semi sphere, one grain appears to be a set of cubes growing on top of each other; opaque grains are also seen throughout sample with similar characteristics but not in similar abundance, displacement has occurred within sample but the amount cannot be determined due to homogeneity of sample, quartz grains are present throughout sample – grains are rounded to sub-angular, some grains display undulose extinction

**Twinning Measurements:**
No secondary twinning was observed within grains
JK78-3 Sample # 19: Depth: 97.61 m - 97.69 m: Continued

<table>
<thead>
<tr>
<th>2Ө</th>
<th>Intensity</th>
</tr>
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<td>25.72</td>
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FWHM vs. 2Ө:

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<td>100</td>
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</tbody>
</table>

- Smp 19
- Amb
- 4.6 GPa
- 17 GPa
- 26 GPa
- 29.8 GPa
JK78-3 Sample # 19: Depth: 97.61 m - 97.69 m: Continued

Rietveld Comparison:

![Graph showing Rietveld comparison with 2-theta (deg) on the x-axis and Intensity (cps) on the y-axis. The graph displays a peak at 2-theta approximately 40 degrees with intensity ranging from 0 to 4e+004.](image-url)
### JK78-3 Sample # 20: Depth: 100.18 m - 100.23 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Oregon Dolomite: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Dolomitic mudstone, dry appearance: dark yellowish orange (10YR 6/2) – pale olive (10Y 6/2), wet appearance: moderate olive brown, fractures are common throughout sample, micro normal faulting is present: ~0.75 – 1mm, reacts slightly with HCl, diagonal stylolite layer in top left corner and in lower half of sample, matrix appears to be micritic, lithology has blotchy patches of pale olive colored unit throughout sample</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, rhombohedral dolomite grains comprise matrix of sample, bedding could be near vertical, stylolite layer placed diagonally along right corner and along the top of sample – color of layer is a rusty reddish brown in PPL, layer contains opaque cubic minerals, sub-rounded to rounded quartz grains present within sample – few grains experiencing undulose extinction</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>
JK78-3 Sample # 20: Depth: 100.18 m - 100.23 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2θ:

[Graph showing the relationship between FWHM and 2θ for different materials and conditions]
JK78-3 Sample # 20: Depth: 100.18 m - 100.23 m: Continued

Rietveld Comparison:

![Graph showing Rietveld Comparison](image)
JK78-3 Sample # 21: Depth: 111.40 m - 111.48 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Hand Sample Image" /></td>
<td><img src="image2" alt="Thin Section Image" /></td>
<td><img src="image3" alt="PPL Image" /></td>
<td><img src="image4" alt="XPL Image" /></td>
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<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Oregon Dolomite: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Dolomitic mudstone, dry appearance: light olive gray (5Y 5/2) – dusky yellow green (5GY 5/2), wet appearance: moderat olive brown (5y 4/9) – grayish olive green (5GY 3/2), ~2 -3 reverse microfaults present at top of sample: ~0.5mm displacement, matrix of sample appears to be micritic</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, bedding could be near vertical, opaque minerals are present within darker units of thin section – habit appear to be cubic; micro normal faulting is seen within the darker units of thin section – displacement is ~ 50 ticks (40x), matrix is comprised of semi rhombohedral dolomite grains, sub-rounded to sub-angular quartz grains are present but are far more common within the darker units of sample</td>
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<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
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</table>
JK78-3 Sample # 21: Depth: 111.40 m - 111.48 m: Continued

X-Ray Diffraction Profile:

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FWHM vs. 2θ:

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<th>FWHM</th>
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<tbody>
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<td>120</td>
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</table>
JK78-3 Sample # 21: Depth: 111.40 m - 111.48 m: Continued

Rietveld Comparison:
### JK78-3 Sample # 22: Depth: 134.65 m - 134.70 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Hand Sample Image" /></td>
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<td><img src="image3" alt="PPL Image" /></td>
<td><img src="image4" alt="XPL Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Dolomitic mudstone, dry appearance: dusky yellow (5Y5/2), wet appearance: moderate olive brown (5Y 4/4), matrix of sample appears to be micritic, semi horizontal layers across sample - believed to be the cause of bioturbation, microfault in left center of sample: ~ 2-3 mm displacement</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, sample is comprised of two units of rhombohedral dolomite grains – the first unit, which comprises the majority of the sample is of a larger grain size then the second unit, second unit is a smaller grain size then unit one and is also a muddy brown color, second unit is positioned horizontally and sub-horizontally along sample, unit is most likely the cause of bioturbation; opaque grains are present in both units – grains are cubic to rectangular in shape</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
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</tbody>
</table>
JK78-3 Sample # 22: Depth: 134.65 m - 134.70 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2θ:

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<th>Intensity</th>
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<td>114.38</td>
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<td>117.24</td>
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</tbody>
</table>

FWHM vs. 2θ:
JK78-3 Sample # 22: Depth: 134.65 m - 134.70 m: Continued

Rietveld Comparison:
**Member: Formation/Group (Age)**  
Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**  
Dolomitic mudstone, dry appearance: pale olive (10Y 6/2), wet appearance: moderate olive brown (5Y 4/4), semi horizontal stylolite layer across middle of sample, matrix of sample appears to be micritic, sample appears to be highly bioturbated

**Thin Section Description:**  
Dismicrite, matrix is composed of two units of rhombohedral dolomite grains each with their own grain size – one unit is a larger grain size while the other is smaller in size and is also a muddy color, patches of spar dolomite is present within both units, stylolite layer present along the top of sample – layer is a rusty brown color in PPL, opaque grains are present throughout sample – cubic to spherical in shape

**Twinning Measurements:**  
No secondary twinning was observed within grains
JK78-3 Sample # 23: Depth: 135 m - 135.05 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2θ:

Intensity

Intensity vs. 2θ

FWHM

2θ
JK78-3 Sample # 23: Depth: 135 m - 135.05 m: Continued

Rietveld Comparison:
**JK78-3 Sample # 24: Depth: 152.91 m - 152.98 m**

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
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<tbody>
<tr>
<td><img src="image1" alt="Hand Sample Image" /></td>
<td><img src="image2" alt="Thin Section Image" /></td>
<td><img src="image3" alt="Micrograph PPL" /></td>
<td><img src="image4" alt="Micrograph XPL" /></td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**  
Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**  
Dolomitic mudstone, dry appearance: dusky yellow (5Y 6/4), wet appearance: moderate olive brown (5Y 4/4), burrowed layers with olive gray color diagonally through sample, few vugs present, micro normal faulting present in sample, ~1mm displacement, bedding of sample appears to be near 85 degrees, matrix of sample appears to be micritic, shell shaped voids are present at top of sample

**Thin Section Description:**  
Dismicrite, displacement of 25-40 ticks (40x), halo present along fault plain, bedding alternates from thin layers of small grained rhombohedral muddy dolomite grains to a thicker layer of larger rhombohedral dolomite grains, bedding of formation is ~70 degrees, opaque grains are scattered throughout sample – grain shape is cubic to semi cubic, possibly source for upcoming breccia

**Twinning Measurements:**  
No secondary twinning was observed within grains
JK78-3 Sample # 24: Depth: 152.91 m - 152.98 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2Ө:

<table>
<thead>
<tr>
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<th>Intensity</th>
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<tbody>
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<td>88.64</td>
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</table>

FWHM (Full Width at Half Maximum) vs. 2Ө for different pressures:

- Smp 24
- Amb
- 4.6 GPa
- 17 GPa
- 26 GPa
- 29.8 GPa
JK78-3 Sample # 24: Depth: 152.91 m - 152.98 m: Continued
 JK78-3 Sample # 25: Depth: 163.65 m - 163.68 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Image" /></td>
<td><img src="image2.jpg" alt="Image" /></td>
<td><img src="image3.jpg" alt="Image" /></td>
<td><img src="image4.jpg" alt="Image" /></td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**  
Clasts are from the Tyrone Limestone and Oregon Dolomite

**Hand Sample Description:**  
Polymict breccia, clasts are angular to sub-rounded, average clast size: ~ 25mm with the biggest being 50mm and the smallest being ~ 0.5mm, clast colors are moderate olive brown and very pale orange, matrix supported, matrix is dark olive brown, clast appear to be from the Tyrone and Oregon formations

**Thin Section Description:**  
Dismicrite, clast supported monomict breccia, clasts are composed of rhombohedral dolomite grains, clast shape is sub-rounded to sub-angular, matrix is a rusty brown color in PPL and is comprised of small rhombohedral dolomite grains, opaque grains present throughout sample but are in much higher abundance in dolomite matrix

**Twinning Measurements:**  
No secondary twinning was observed within grains
JK78-3 Sample # 25: Depth: 163.65 m - 163.68 m: Continued

X-Ray Diffraction Profile:

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<th>Intensity</th>
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</thead>
<tbody>
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<td>22.86</td>
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<td>114.38</td>
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<tr>
<td>117.24</td>
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</tr>
</tbody>
</table>

FWHM vs. 2θ:

- Smp 25
- Amb
- 4.6 GPa
- 17 GPa
- 26 GPa
- 29.8 GPa
JK78-3 Sample # 25: Depth: 163.65 m - 163.68 m: Continued

Rietveld Comparison:
JK78-3 Sample # 26: Depth: 166.42 m - 166.50 m

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Tyrone Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Brachiopodal dolomitic mudstone, dry appearance: dusky yellow (5Y 6/4), wet appearance: moderate olive brown (5Y 4/4), brachiopod fossil along left edge of sample ~1cm, small vugs, shell shaped voids in middle of sample, matrix appears to be micritic, possible source of clasts in previous sample</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, sample is comprised entirely of rhombohedral dolomite grains, few vugs filled with dolomite grains, opaque grains (Op) throughout sample – cubic in shape, possible source for clasts of previous breccia unit</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>
JK78-3 Sample # 26: Depth: 166.42 m - 166.50 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2θ:

Smp 26
Amb
4.6 GPa
17 GPa
26 GPa
29.8 GPa
JK78-3 Sample # 26: Depth: 166.42 m - 166.50 m: Continued

Rietveld Comparison:

![Graph showing Rietveld Comparison with intensity (cps) on the y-axis and 2-theta (deg) on the x-axis. The graph displays a peak at 2-theta degrees 35 with intensity values ranging from 0e+000 to 5e+004.](image-url)
JK78-3 Sample # 27: Depth: 176.02 m - 176.07 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image 77x322 to 210x466" /></td>
<td><img src="image2.png" alt="Image 222x279 to 354x466" /></td>
<td><img src="image3.png" alt="Image 365x268 to 531x466" /></td>
<td><img src="image4.png" alt="Image 542x268 to 707x466" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Dolomitic mudstone, dry appearance: dusky yellow green (5GY 5/2), matrix of sample appears to be micrite, vugs are common throughout sample, olive gray semi layers and blotches are scattered throughout sample</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, sample contains two different units – first unit is a semi rhombohedral dolomite matrix but is quite vuggy in texture, second unit is a smaller grained muddy colored rhombohedral dolomite, opaque grains are scattered throughout sample – occurs in small cubic or rectangular in shape</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>
JK78-3 Sample # 27: Depth: 176.02 m - 176.07 m: Continued

X-Ray Diffraction Profile:

![X-Ray Diffraction Profile Graph]

FWHM vs. 2θ:

![FWHM vs. 2θ Graph]
JK78-3 Sample # 27: Depth: 176.02 m - 176.07 m: Continued

Rietveld Comparison:

![Rietveld Comparison Graph]

- Intensity (cps)
- 2-theta (deg)
**JK78-3 Sample # 28: Depth: 188.97 m - 189.05 m**

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Scanned Image of Hand Sample" /></td>
<td><img src="image2" alt="Scanned Image of Thin Section" /></td>
<td><img src="image3" alt="Thin Section Photomicrograph PPL (40x)" /></td>
<td><img src="image4" alt="Thin Section Photomicrograph XPL (40x)" /></td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Brachiopodal dolomitic mudstone, dry appearance: dusky yellow green (5GY 5/2), wet appearance: light olive (10Y 5/4) – grayish olive green (5GY 3/2), small brachiopod valves present in lower section of sample, matrix of sample appears to be micrite, bedding of sample is ~70-75 degrees, from top right corner to bottom left lithology alternates from a light olive to a grayish olive green - units have a wavy texture</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Fossiliferous dismicrite, bedding is ~ 70-75 degrees, matrix of sample alternates from a muddy color with rhombohedral dolomite grains to a slightly larger grained dolomite and with no muddy color, first unit most likely the result of bioturbation, spots of spar dolomite present, ostracod shell present</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>
JK78-3 Sample #28: Depth: 188.97 m - 189.05 m: Continued

X-Ray Diffraction Profile:

| 2θ  | 22.86 | 25.72 | 28.58 | 31.44 | 34.3 | 37.16 | 40.02 | 42.88 | 45.74 | 48.6 | 51.46 | 54.32 | 57.18 | 60.04 | 62.9 | 65.76 | 68.62 | 71.48 | 74.34 | 77.2 | 80.06 | 82.92 | 85.78 | 88.64 | 91.5 | 94.36 | 97.22 | 100.08 | 102.94 | 105.8 | 108.66 | 111.52 | 114.38 | 117.24 |
|-----|-------|-------|-------|-------|------|-------|-------|-------|-------|------|-------|-------|-------|-------|------|-------|-------|-------|-------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Intensity |       |       |       |       |      |       |       |       |       |      |       |       |       |       |      |       |       |       |      |       |       |       |       |       |       |       |       |       |       |       |       |

FWHM vs. 2θ:

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<tr>
<th>2θ</th>
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<th>60</th>
<th>80</th>
<th>100</th>
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<td>FWHM</td>
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</tbody>
</table>

- Smp 28
- Amb
- 4.6 GPa
- 17 GPa
- 26 GPa
- 29.8 GPa
JK78-3 Sample # 28: Depth: 188.97 m - 189.05 m: Continued

Rietveld Comparison:
JK78-3 Sample # 29: Depth: 194.16 m - 194.23 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image]</td>
<td>![PPL Photomicrograph]</td>
<td>![XPL Photomicrograph]</td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**
Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**
Dolomitic mudstone, dry appearance: dusky yellow (5Y 6/4), wet appearance: moderate olive brown (5Y 4/4), diagonal stylolite layer across lower right corner of sample, sample has two units that are darker than the surroundings running vertically through sample, matrix of sample appears to be micrite, microfault in center of sample: displacement ~ 1 - 2 mm

**Thin Section Description:**
Dismicrite, bedding of sample is near vertical, matrix of sample is similar, if not exact, to that of previous unit, opaque grains present – cubic in shape, common throughout sample: horizontal stylolite layer along bottom of sample

**Twinning Measurements:**
No secondary twinning was observed within grains
JK78-3 Sample # 29: Depth: 194.16 m - 194.23 m: Continued

X-Ray Diffraction Profile:

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<th>Intensity</th>
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FWHM vs. 2θ:

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<th>FWHM</th>
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<td>80</td>
<td>1.5</td>
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<td>100</td>
<td>2</td>
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</tbody>
</table>

- Smp29
- Amb
- 4.6 GPa
- 17 GPa
- 26 GPa
- 29.8 GPa
JK78-3 Sample # 29: Depth: 194.16 m - 194.23 m: Continued

Rietveld Comparison:
JK78-3 Sample # 30: Depth: 206.96 m - 207.04 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Scanned Image of Hand Sample" /></td>
<td><img src="image2.png" alt="Scanned Image of Thin Section" /></td>
<td><img src="image3.png" alt="Thin Section Photomicrograph PPL (40x)" /></td>
<td><img src="image4.png" alt="Thin Section Photomicrograph XPL (40x)" /></td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**
- Camp Neson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**
- Dolomitic mudstone, wet appearance: light olive (10Y 5/40, matrix of sample appears to be micritic, top left corner has a thin fracture diagonally across the upper left corner, darker olive brown matrix in top right of sample, clasts of ~0.5mm in size appear to be from light olive sample

**Thin Section Description:**
- Dismicrite, matrix of sample is rhombohedral shaped dolomite grains, vugs are present throughout sample, top left corner of sample is comprised of a smaller grained dolomite and is a rusty color, opaque grains are present throughout sample but are more common in top left unit, opaque grain shape is slightly cubic, opaque grains in top left corner are positioned in diagonal layers – bedding of sample could be along with these layers: ~70 degrees

**Twinning Measurements:**
- No secondary twinning was observed within grains
JK78-3 Sample # 30: Depth: 206.96 m - 207.04 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2Θ:

Smp 30
Amb
4.6 GPa
17 GPa
26 GPa
29.8 GPa
JK78-3 Sample # 30: Depth: 206.96 m - 207.04 m: Continued

Rietveld Comparison:
**Member: Formation/Group (Age)**
Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**
Dolomitic mudstone, wet appearance: light olive, sample has semi vertical layers of a darker lithology through entire length, small vugs are present throughout sample face, displacement has occurred within sample but no direction of movement could be determined

**Thin Section Description:**
Dismicrite, matrix is comprised of rhombohedral dolomite grains, displacement of 90 ticks (40x), opaque grains present throughout sample – shape of grains is semi cubic to semi spherical, vugs are present in sample

**Twinning Measurements:**
No secondary twinning was observed within grains
JK78-3 Sample # 31: Depth: 218.19 m - 218.24 m: Continued

X-Ray Diffraction Profile:

<table>
<thead>
<tr>
<th>2θ</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
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FWHM vs. 2θ:

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Mechanical properties:
- Smp 31: 4.6 GPa
- Amb: 17 GPa
- 4.6 GPa: 26 GPa
- 17 GPa: 29.8 GPa
JK78-3 Sample # 31: Depth: 218.19 m - 218.24 m: Continued

Rietveld Comparison:

![Graph of Rietveld Comparison](image-url)
<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
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</thead>
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**Member: Formation/Group (Age)**
Oregon Dolomite: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**
Dolomitic mudstone, dry appearance: dusky yellow (5Y 6/4) – dusky yellow green (5GY 5/2), wet appearance: light olive (10 y 5/4) – grayish olive green (5GY 3/2), 0.5 cm LxW dolomite growth in upper left corner - possible locations of deformation twinning, bedding of sample appears to be about 80-85 degrees, matrix of sample appears to be micrite, from top left corner to lower right lithology alternates from a grayish olive green to a light olive - possible cause is bioturbation, ~2 - 3 normal microfaults in sample: displacement ~0.25 mm

**Thin Section Description:**
Dismicrite, rhombohedral dolomite grains comprise matrix of sample, bedding seems to be near vertical, large dolomite grains (Do) present in top right of sample, opaque grains (Op) are present throughout sample and are seen in layers parallel to tilted bedding – shape of grains are cubic when small but become more oblong shaped as size increases

**Twinning Measurements:**
No secondary twinning was observed within grains
JK7-3 Sample # 32: Depth: 231.04 m - 231.12 m: Continued

X-Ray Diffraction Profile:

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FWHM vs. 2\(\theta\):

- Smp 32
- Amb
- 4.6 GPa
- 17 GPa
- 26 GPa
- 29.8 GPa
JK78-3 Sample # 32: Depth: 231.04 m - 231.12 m: Continued

Rietveld Comparison:
**Member: Formation/Group (Age)**
Oregon Dolomite: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**
Dolomitic mudstone, dry appearance: pale olive (10Y 6/2), wet appearance: moderate olive brown (5Y 4/4), matrix of sample appears to be micritic, vugs are present throughout sample, unknown bedding orientation, sample has a swirled look of a pale olive and tan color - bioturbation

**Thin Section Description:**
Dismicrite, matrix is comprised of rhombohedral dolomite grains, vugs are present with a few filled with dolomite, opaque grains are present – cubic to rectangular in shape

**Twinning Measurements:**
No secondary twinning was observed within grains
JK78-3 Sample # 33: Depth: 249.73 m - 249.78 m: Continued

X-Ray Diffraction Profile:

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FWHM vs. 2θ:

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</table>

Smp 33
Amb
4.6 GPa
17 GPa
26 GPa
29.8 GPa
JK78-3 Sample # 33: Depth: 249.73 m - 249.78 m: Continued

Rietveld Comparison:

![Graph showing Rietveld comparison](graphic.png)

- **Intensity (cps)**
- **2-theta (deg)**

The graph displays the comparison of intensity versus 2-theta for the specified depth range.
### JK78-3 Sample # 34: Depth: 253.21 m - 253.29 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
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<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Oregon Dolomite: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
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</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Dolomitic mudstone, wet appearance: light olive (10Y 5/4) – dusky yellow green (5GY 5/2), micro normal fault present in top of sample with displacement of ~1 mm, micro normal fault present in lower center with displacement of ~ 1.5 mm, micro reverse fault in top middle of sample with displacement of ~ 1.5 - 2 mm from left of sample to right of sample alternating layers of orange tan and olive gray units, bedding of sample could be vertical</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, micro normal faults present with displacement of 23 ticks (40x), bedding appears to be near vertical, spar dolomite filling voids in sample, matrix of sample is comprised of two units of rhombohedral dolomite grains – one unit has smaller grains than the other and has a muddy appearance, these units alternate back and forth, opaque grains are present within darker muddier unit – shape semi cubic to semi spherical</td>
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<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
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</table>
JK78-3 Sample # 34: Depth: 253.21 m - 253.29 m: Continued

**X-Ray Diffraction Profile:**

Intensity vs. 2θ:

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**FWHM vs. 2θ:**

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<td>80</td>
<td>2.0</td>
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</table>

Smp 34, Amb, 4.6 GPa, 17 GPa, 26 GPa, 29.8 GPa
JK78-3 Sample # 34: Depth: 253.21 m - 253.29 m: Continued

Rietveld Comparison:
JK78-3 Sample # 35: Depth: 258.45 m - 258.47 m

| Scanned Image of Hand Sample | Scanned Image of Thin Section | Thin Section Photomicrograph PPL (40x) | Thin Section Photomicrograph XPL (40x) |

**Member: Formation/Group (Age)**
Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**
Dolomitic mudstone, dry appearance: dusky yellow green (5GY 5/2), wet appearance: grayish olive (10Y 4/2), matrix of sample appears to be micrite, sample reacts slightly with HCl

**Thin Section Description:**
Dismicrite, rhombohedral dolomite grains comprise entire matrix, smaller muddy colored dolomite grains are present in lower left corner or sample

**Twinning Measurements:**
No secondary twinning was observed within grains
JK78-3 Sample # 35: Depth: 258.45 m - 258.47 m: Continued

X-Ray Diffraction Profile:

FWHM vs. $2\theta$:
JK78-3 Sample # 35: Depth: 258.45 m - 258.47 m: Continued

Rietveld Comparison:
JK78-3 Sample # 36: Depth: 282.75 m - 282.83 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
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<table>
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<tr>
<th>Member: Formation/Group (Age)</th>
<th>Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Dolomitic mudstone, wet appearance: light olive (10Y 5/4), matrix of sample appears to be micritic, sample reacts slightly with HCl, sample has diagonal layers of a darker olive unit across sample from top right corner to bottom left, units between layers appear to be bioturbated</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, sample has two different matrixes – unit one is composed of a rhombohedral dolomite grain while unit two is a smaller grained muddy dolomite; opaque grains are present throughout sample – cubic and triangular in shape, normal fault present above the center of the sample – displacement 25-30 ticks (40x)</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
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JK78-3 Sample # 36: Depth: 282.75 m - 282.83 m: Continued

X-Ray Diffraction Profile:

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FWHM vs. 2θ:

- **Smp 36**
- **Amb**
- **4.6 GPa**
- **17 GPa**
- **26 GPa**
- **29.8 GPa**
JK78-3 Sample # 36: Depth: 282.75 m - 282.83 m: Continued

Rietveld Comparison:
JK78-3 Sample # 37: Depth: 294.95 m - 295.02 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
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<tbody>
<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image 1]</td>
<td>![Thin Section Image 2]</td>
<td>![Thin Section Image 3]</td>
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<tr>
<td>![Thin Section Image 4]</td>
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</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**  
Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**  
Brachiopodal dolomitic mudstone, wet appearance: light olive (10Y 5/4) – olive gray (5Y 3/2), sample contains two different colored units: one is a bioturbated layer with a darker olive gray color than the surrounding light olive unit, units appear to be running diagonally through sample from top right to bottom left, brachiopod shell voids are present in middle of sample

**Thin Section Description:**  
Dismicrite, rhombohedral dolomite grains comprise matrix of sample, semi horizontal layers of smaller and muddy in color dolomite grains, opaque grains common throughout sample – cubic to triangular in shape

**Twinning Measurements:**  
No secondary twinning was observed within grains
JK78-3 Sample # 37: Depth: 294.95 m - 295.02 m: Continued

X-Ray Diffraction Profile:

![X-Ray Diffraction Profile]

FWHM vs. 2θ:

![FWHM vs. 2θ]
JK78-3 Sample # 37: Depth: 294.95 m - 295.02 m: Continued

Rietveld Comparison:
JK78-3 Sample # 38: Depth: 315.06 m - 315.11 m

| Member: Formation/Group (Age) | Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma) |
| Hand Sample Description:     | Brachiopodal dolomitic mudstone, wet appearance: light olive (10Y 5/4), brachiopod fossils: ~ 3mm long, possible stylolite layer diagonally across middle of sample, matrix of sample appears to be micrite, multiple dark olive gray layers from top right to bottom left of sample, possible brachiopod fossil with a friable matrix infill in bottom left of sample |
| Thin Section Description:    | Dismicrite, micro normal faulting present with 15 ticks (40x) displacement, bedding appears to be roughly 70 degrees, sample has two different matrixes – unit one is composed of a rhombohedral dolomite grain while unit two is a smaller grained muddy dolomite, very fine opaque grains throughout sample (100x) - cubic and triangular in shape, opaques seem to form layers along the contact of unit one and unit two |
| Twinning Measurements:       | No secondary twinning was observed within grains |
JK78-3 Sample # 38: Depth: 315.06 m - 315.11 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2θ:
JK78-3 Sample # 38: Depth: 315.06 m - 315.11 m: Continued

Rietveld Comparison:
JK78-3 Sample #39: Depth: 321.56 m - 321.64 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image]</td>
<td>![PPL Image]</td>
<td>![XPL Image]</td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**

| Tyrone Limestone: High Bridge Group (Middle Ordovician: 485–470 Ma) |

**Hand Sample Description:**

Dolomitic mudstone, dry appearance: pale greenish yellow (10Y 7/4), wet appearance: olive gray (5Y 3/2), possible normal fault with ~2.54 cm displacement, olive tan unit runs diagonally from top right to bottom left with a possible angular inclusion of quartz in top right of sample, dark olive layer runs vertically from top of sample until encounters tan olive layer: ~2 cm, HCl does not react with sample.

**Thin Section Description:**

Dismicrite, matrix of sample is comprised of semi rhombohedral dolomite grains of varying sizes, semi horizontal void on left side of sample – very angular and rounded large grains of quartz partially fill void.

**Twinning Measurements:**

No secondary twinning was observed within grains.
JK78-3 Sample #39: Depth: 321.56 m - 321.64 m: Continued

X-Ray Diffraction Profile:

<table>
<thead>
<tr>
<th>2θ</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
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<tr>
<td>25.72</td>
<td>2558</td>
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<td>31.44</td>
<td>343</td>
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<td>40.02</td>
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FWHM vs. 2θ:

<table>
<thead>
<tr>
<th>2θ</th>
<th>FWHM</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
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<tr>
<td>80</td>
<td>1.5</td>
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<tr>
<td>100</td>
<td>2</td>
</tr>
</tbody>
</table>
JK78-3 Sample #39: Depth: 321.56 m - 321.64 m: Continued

Rietveld Comparison:

![Rietveld Comparison Graph]

[Intensity (cps) vs 2-theta (deg) graph]

- Intensity (cps) scale ranges from 0.0e+000 to 1.5e+004.
- 2-theta (deg) scale ranges from 20 to 120.

The graph shows the comparison of experimental and calculated X-ray diffraction patterns.
**JK78-3 Sample # 40: Depth: 327.30 m - 327.36 m**

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Scanned Image of Hand Sample" /></td>
<td><img src="image2.png" alt="Scanned Image of Thin Section" /></td>
<td><img src="image3.png" alt="Thin Section Photomicrograph PPL (40x)" /></td>
<td><img src="image4.png" alt="Thin Section Photomicrograph XPL (40x)" /></td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**

<table>
<thead>
<tr>
<th>Hand Sample Description:</th>
<th>Thin Section Description:</th>
<th>Twinning Measurements:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brachiopodal dolomitic mudstone, Wet: light olive (10Y 5/4), matrix of sample is assumed to be micrite, dark olive greenish diagonal layers from top right to bottom left comprise a majority of sample - assumed to be bioturbation, small brachiopod fossil present in center of sample at contact between dark olive green and light olive units: ~2mm long and ~1mm thick</td>
<td>Dismicrite, sample has two different units – unit one is composed of a rhombohedral dolomite grain while unit two is a smaller grained muddy dolomite, small quartz grains uncommon throughout sample – sub-angular to angular in shape; opaque grains throughout sample – semi cubic to spherical in shape</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>

**Tyrone Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)**
JK78-3 Sample # 40: Depth: 327.30 m - 327.36 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2\(\Theta\):

<table>
<thead>
<tr>
<th>2(\Theta)</th>
<th>FWHM</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
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<tr>
<td>40</td>
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</tr>
<tr>
<td>60</td>
<td>1.5</td>
</tr>
<tr>
<td>80</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Sample 40

Amb

4.6 GPa

17 GPa

26 GPa

29.8 GPa
JK78-3 Sample # 40: Depth: 327.30 m - 327.36 m: Continued

Rietveld Comparison:
**JK78-3 Sample # 41: Depth: 335.59 m - 335.66 m**

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Hand Sample Image" /></td>
<td><img src="image2" alt="Thin Section Image" /></td>
<td><img src="image3" alt="PPL Image" /></td>
<td><img src="image4" alt="XPL Image" /></td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**

Oregon Dolomite: High Bridge Group (Middle Ordovician: 485–470 Ma)

**Hand Sample Description:**
Dolomitic mudstone, wet appearance: light olive (10Y 5/4) – moderate olive brown and olive gray – grayish olive green, matrix of sample appears to be micritic, sample appears to have two different bedding orientations - one bedding is ~85 degrees while the other is near horizontal, both units appear to be from the Oregon formation, a possible stylolite layer separates these two layers, micro normal fault cuts a crossed middle of sample ~ 1mm displacement

**Thin Section Description:**
Dismicrite, sample has two different bedding directions: horizontal and vertical, thin layer of stylolite layer separates the two units, opaque grains are common throughout sample – triangular and cubic in shape, matrix of both units within sample is comprised of muddy colored semi rhombohedral dolomite grains of varying sizes, micro normal fault present

**Twinning Measurements:**
No secondary twinning was observed within grains
JK78-3 Sample # 41: Depth: 335.59 m - 335.66 m: Continued

**X-Ray Diffraction Profile:**

![X-Ray Diffraction Profile](image)

**FWHM vs. 2Ө:**

![FWHM vs. 2Ө](image)
JK78-3 Sample # 41: Depth: 335.59 m - 335.66 m: Continued

Rietveld Comparison:

![Graph showing Rietveld Comparison with intensity (cps) on the y-axis and 2-theta (deg) on the x-axis. The graph displays peaks at various 2-theta values.](image-url)
JK78-3 Sample # 42: Depth: 341.35 m - 341.38 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image]</td>
<td>![PPL Image]</td>
<td>![XPL Image]</td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**  
Oregon Dolomite: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**  
Dolomitic mudstone, dry appearance: dusky yellow (5Y 6/4), wet appearance: light olive (10Y 5/4), matrix fo sample appears to be micrite, dark olive gray unit is scattered throughout sample - result of burrowing, microfault of some kind cuts sample from top left to middle right of sample: unknown displacement

**Thin Section Description:**  
Dismicrite, rhombohedral dolomite grains comprise matrix of sample, opaque grains are found throughout sample but tend to accumulate more in darker colored units – possible bioturbated unit, bottom right corner has a diagonal crack filled with rhombohedral dolomite grains

**Twinning Measurements:**  
No secondary twinning was observed within grains
JK78-3 Sample #42: Depth: 341.35 m - 341.38 m: Continued

X-Ray Diffraction Profile:

FWHM vs. $2\Theta$:
JK78-3 Sample #42: Depth: 341.35 m - 341.38 m: Continued

Rietveld Comparison:
**JK78-3 Sample # 43: Depth: 343.99 m - 344.09 m**

<table>
<thead>
<tr>
<th><strong>Scanned Image of Hand Sample</strong></th>
<th><strong>Scanned Image of Thin Section</strong></th>
<th><strong>Thin Section Photomicrograph PPL (40x)</strong></th>
<th><strong>Thin Section Photomicrograph XPL (40x)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Sample Image" /></td>
<td><img src="image2" alt="Thin Section Image" /></td>
<td><img src="image3" alt="PPL Micrograph" /></td>
<td><img src="image4" alt="XPL Micrograph" /></td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age):**
Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**
Dolomitic mudstone, dry appearance: dusky yellow green (5GY 5/2), wet appearance: light olive (10Y 5/4), matrix of sample could be micrite, thin diagonal layers of shale from the middle right to bottom left of sample and along bottom of sample - layers are alternating layers of brown, possible displacement along bottom left corner of sample, microfault at bottom of sample with displacement of ~ 0.25 - 0.5 mm

**Thin Section Description:**
Fossiliferous dismicrite, sample has two different units – unit one is composed of a rhombohedral dolomite grain while unit two is a smaller rained muddy dolomite, dolomite replaced ostracod shells (Os) in muddy unit, displacement along bottom left corner but hard to discern offset, opaque grains common throughout sample – cubic to triangular in shape, form thin layers parallel to muddy units bedding

**Twinning Measurements:**
No secondary twinning was observed within grains
JK78-3 Sample # 43: Depth: 343.99 m - 344.09 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2Θ:

Smp 43
Amb
4.6 GPa
17 GPa
26 GPa
29.8 GPa
JK78-3 Sample # 43: Depth: 343.99 m - 344.09 m: Continued

Rietveld Comparison:
 JK78-4 Sample # 44: Depth: 345.54 m - 345.62 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image 1]</td>
<td>![Thin Section Image 2]</td>
<td>![Thin Section Image 3]</td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**

Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**

Dolomitic mudstone, wet appearance: light olive (10Y 5/4), matrix of sample is comprised of micrite, dark olive green layer runs diagonally from middle left of sample and then branched to the top and middle right of sample - could be the result of displacement, calcite crystal 1.5 cm long and 2cm wide comprises majority of bottom sample - ~20% of total sample, shell shaped voids at top of sample

**Thin Section Description:**

Dismicrite, sample has two different units – unit one is composed of a rhombohedral dolomite grain while unit two is a smaller grained muddy dolomite, opaque grains are common throughout sample but form a thin layer parallel to muddy units bedding – cubic to triangular in shape, units or sparry dolomite are present within sample, large void filled with calcite grains present - no deformation twinning seen, possible stylolite layer running semi vertically through sample

**Twinning Measurements:**

No secondary twinning was observed within grains
JK78-4 Sample # 44: Depth: 345.54 m - 345.62 m: Continued

**X-Ray Diffraction Profile:**

![X-Ray Diffraction Profile]

**FWHM vs. 2θ:**

![FWHM vs. 2θ]

- Smp 44-C
- Smp 44-D
- Amb
- 4.6 GPa
- 17 GPa
- 26 GPa
- 29.8 GPa

Intensity vs. 2θ with Intensities ranging from 0 to 25000.
JK78-4 Sample # 44: Depth: 345.54 m - 345.62 m: Continued

Rietveld Comparison:

![Graph showing Rietveld Comparison](image)

- Intensity (cps) vs. 2-theta (deg)
- Axes labeled with appropriate units
- Graph scales clearly visible
**JK78-3 Sample # 45: Depth: 349.61 m - 349.68 m**

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Member: Formation/Group (Age)</th>
<th>Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Sample Description:</td>
<td>Dolomitic mudstone, wet appearance: moderate olive brown (5Y 4/4), matrix of sample seems to be comprised of micrite, sample appears to have two different units - one an olive brown while the other is an olive green, sample is heavily bioturbated</td>
</tr>
<tr>
<td>Thin Section Description:</td>
<td>Dismicrite, sample has two different units – unit one is composed of a rhombohedral dolomite grain while unit two is a smaller grained muddy dolomite, opaque grains are common throughout sample – cubic to rectangular in shape, stylolite layer through middle of sample</td>
</tr>
<tr>
<td>Twinning Measurements:</td>
<td>No secondary twinning was observed within grains</td>
</tr>
</tbody>
</table>
JK78-3 Sample # 45: Depth: 349.61 m - 349.68 m: Continued

### X-Ray Diffraction Profile:

<table>
<thead>
<tr>
<th>2θ</th>
<th>Intensity</th>
</tr>
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<tbody>
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<tr>
<td>117.24</td>
<td>170000</td>
</tr>
</tbody>
</table>

### FWHM vs. 2θ:

- Smp 45
- Amb
- 4.6 GPa
- 17 GPa
- 26 GPa
- 29.8 GPa
JK78-3 Sample # 45: Depth: 349.61 m - 349.68 m: Continued

Rietveld Comparison:
JK78-3 Sample # 46: Depth: 321.64 m - 321.72 m

<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
</table>

Member: Formation/Group (Age)  | Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma) |
Hand Sample Description:       | Dolomitic mudstone, wet appearance: light olive gray (5Y 5/2), matrix of sample possibly micrite, stylolite layer in bottom left corner, dark olive gray unit runs from top left to bottom right of sample, this comprises whole sample |
Thin Section Description:      | Dismicrite, sample has two different units – unit one is composed of a rhombohedral dolomite grain while unit two is a smaller grained muddy dolomite, opaque grains are common throughout sample – cubic to rectangular in shape, semi vertical stylolite (Sty) layers are found in both bottom corners of sample – rusty color in PPL |
Twinning Measurements:         | No secondary twinning was observed within grains |
JK78-3 Sample # 46: Depth: 321.64 m - 321.72 m: Continued

**X-Ray Diffraction Profile:**

**FWHM vs. 2θ:**

- **Smp 46**
- **Amb**
- **4.6 GPa**
- **17 GPa**
- **26 GPa**
- **29.8 GPa**
JK78-3 Sample # 46: Depth: 321.64 m - 321.72 m: Continued

Rietveld Comparison:
<table>
<thead>
<tr>
<th>Scanned Image of Hand Sample</th>
<th>Scanned Image of Thin Section</th>
<th>Thin Section Photomicrograph PPL (40x)</th>
<th>Thin Section Photomicrograph XPL (40x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Hand Sample Image]</td>
<td>![Thin Section Image]</td>
<td>![PPL Photomicrograph]</td>
<td>![XPL Photomicrograph]</td>
</tr>
</tbody>
</table>

**Member: Formation/Group (Age)**
Camp Nelson Limestone: High Bridge Group (Middle Ordovician: 485-470 Ma)

**Hand Sample Description:**
Dolomitic mudstone, wet appearance: grayish olive green (5GY 3/2), sample has thin layer of unknown material running across sample, matrix of sample appears to be micritic, sample appears to have a lighter tan unit intermixed with grayish olive green units.

**Thin Section Description:**
Dismicrite, sample has two different units – unit one is composed of a rhombohedral dolomite grain while unit two is a smaller grained muddy dolomite, opaque grains are common throughout sample – cubic, triangular, and rectangular in shape, sub-rounded to rounded quarts grains scattered throughout sample, diagonal stylolite layer in bottom right corner – rusty color in PPL.

**Twinning Measurements:**
No secondary twinning was observed within grains.
JK78-3 Sample # 47: Depth: 358.85 m - 358.93 m: Continued

X-Ray Diffraction Profile:

FWHM vs. 2θ:
JK78-3 Sample # 47: Depth: 358.85 m - 358.93 m: Continued

Rietveld Comparison: