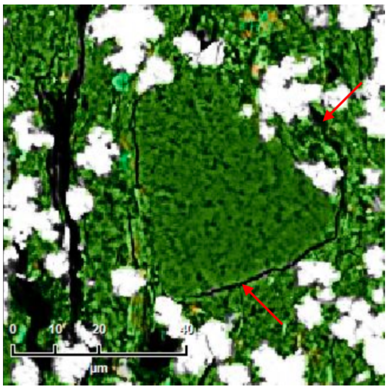

Figure 14: PLE 1 ROI Small Sample NanoMin Clay Feldspar Replacement

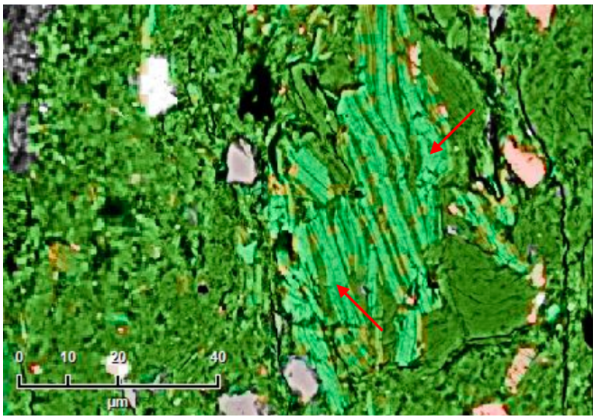

Figure 15: PLE 8 ROI Large Sample NanoMin Muscovite

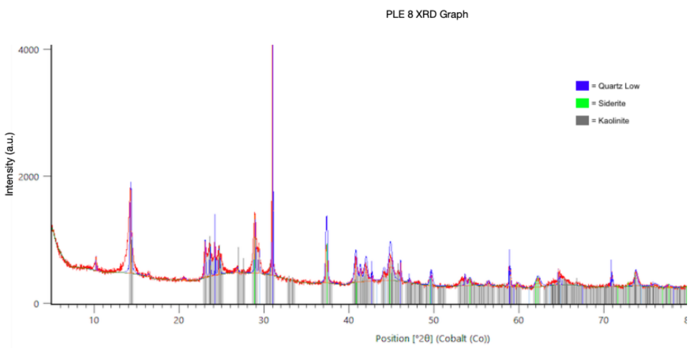

Figure 10: PLE 8 Sample XRD Graph

Figure 16: PLE 7 Raw Sample with Ripple

"Petrology and diagenesis of Narrabeen group sandstones, Sydney Basin, New South Wales" Results:

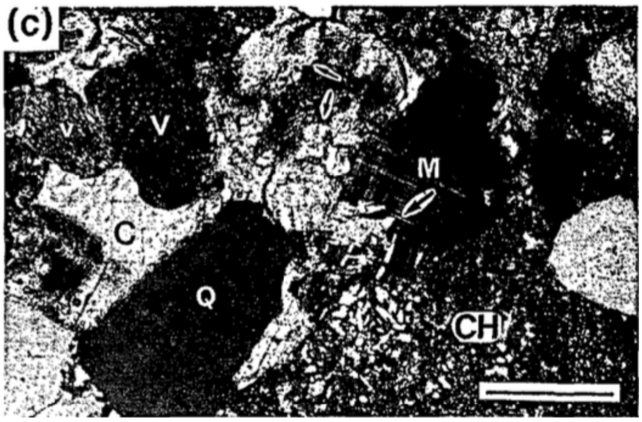

Figure 17: SEM Photomicrograph Overgrowth corroded by Calcite (small arrows) Microcline (M) replaced by calcite (large arrow)

Figure 18: SEM Photomicrograph Grain-Coating Rhombohedral Siderite Crystals (S) Enclosed by a Pore-Filling Ankerite Cement (A)

Figure 17: SEM Photomicrograph Grain-Coating Mixed-Layer Illite/Smectite (I/S) Partly Enclosing Stacked Kaolin Crystals (K)

Discussion:

Overall, the visual observations of samples (before analysis) all displayed a shale structure, PLE 1 being a dark brown colour and coarse grained, PLE 7 was fine grained and displayed a possible ripple possibly caused by alluvial/fluvial systems (figure 16) and PLE 8 was a fine grained and grey in colour. In the SEM, PLE 1/7/8 (figure 5, figure 6, figure 7) displayed variant levels of grain size from finer grains (~50μm) in PLE 1/7 to coarser grains (~300μm) in PLE 8 measured in the SEM analysis, PLE 1/7 more so suggesting a river or lake environment. Clear evidence of white mineral material was spread throughout each sample which was further identified as siderite (figure 8), more prominent in larger grain size in PLE 8. The copper standard used in the SEM allowed the white shade determined to reflect an iron base (due to its white colouration). This was the second highest found material by conformation of the XRD analysis, first being quartz and third being kaolinite (figure 12). This evidence of siderite ruled out any signs of organic compound residue within the samples as it demonstrated that possible pore-water was prevalent within Turimetta Headland. Furthermore minimal pyrite formations (figure 11) were displayed within the edges of PLE 7 as any primary evidence had been flushed out.

Strong evidence of chemical weathering was also apparent within each sample (figure 9) as well as small igneous compounds (~40μm) (figure 13), which were prevalent due to the pore-water influences, similarly occuring within the Narrabeen Group (G. P. Bai., J. B. Keene. 1996). Feldspar replacement (figure 14) was seen with an illite (clay mineral) infill in the position of the original feldspar grain that was once prevalent. This evidence was strong across PLE 1/7/8 and reflected the secondary replacement. Muscovite/clay strips (figure 15) were also abundant within each sample and similarly reflected the secondary replacement. These mudstone deposits suggested a possible lake or river prehistoric environment within the Late Permian depository due to each sample's fine grained formation as well as its rich clay composition (sciencedirect.com).

Within the "Petrology and diagenesis of Narrabeen group sandstones, Sydney Basin, New South Wales" results, an indication of secondary replacement was clear, specifically siderite formations. These were found to be the most common carbonates distributed across the basin and throughout the Narrabeen Group experiment (G. P. Bai., J. B. Keene. 1996). In this case, siderite formations acted as a pore-filling cement as well as a replacement for detrital feldspar and volcanic grains, which was seen within the majority of white materials across all SEM and NanoMin images in this experiment's results (figure 8). This evidence showed a significant influence from pore-water damage caused from the pore-water present within the Turimetta Headland. The iron-rich chlorite within the cliff face reduced the Fe^{2+} concentration within the pore-water. Over time, this caused cementation of the carbonate which was done so in a reducing environment, usually with freshwater present. This occured as the sediments were buried and oxygen in the atmosphere was no longer available to pore-waters, causing a depletion of oxygen and organic decay that created the reducing environment (G. P. Bai., J. B. Keene. 1996). Figure 17 and 18 in the Narrabeen experiment pointed out the siderite formations intruding into other grains in the micrographic images as a result of this process, similarly displayed within figure 8. This allowed for a connection to be made between the similar pore-water processes that occurred within the Narrabeen Group as well as Turimetta Headland. Therefore proving this experiment completed was quite reliable based on the line up of the surrounding evidence in the Narrabeen Group Literature.

The pore-water process further flowed onto reducing any organic matter from remaining within the cliff face as the fossils were replaced through the siderite formations and clay infills. PLE 7 was the only sample that demonstrated small pyrite formations (figure 11), in which were possibly formed from organisms or bacteria that were able to remove oxygen from the sulfate within the pore-water reacting with the iron in the cliff face. (Rickard. D, 2021). Other replacements of primary feldspar grains with clay deposits in figure 14, further displayed the influence of pore-water. As the original material dissolved away and was replaced with mudstone minerals such as illite and kaolinite, secondary material made up the majority of each sample matter, flushing out any primary organic compound residue. This process was similarity displayed within figure 19 in the Narrabeen Group experiment and the replacements of igneous compounds within figure 13. The chemical weathering in figure 9 similarly demonstrated the significant influence of pore-water infiltration as the primary material was disintegrated out of the area and flushed in with secondary chemicals or material . These processes helped to conclude that no primary organic evidence was left within the samples to determine the environment at time of deposition which was similarly within the Narrabeen Group experiment. However the experiment completed does demonstrate climatic and environmental conditions, such as a reducing environment, over time that have affected and dissolved the primary deposits leading to secondary depositional grains within Turimetta Headland.

The use of the SEM analysis allowed for an equal comparison between the experiment itself and the Narrabeen Group paper as the same machinery was used to take the micrographic images. Copper was used as the SEM's standard and could conduct electrical currents better than any other metal except for silver. This gave the SEM images a highly accurate classification (specifically siderite) within the black and white shades prevalent in the micrographic images. However, some of the images taken were quite blurry or doubled over which could have been due to the polish residue that made its way into the sample itself, affecting the accuracy of analysis completed on each sample.

The further use of the NanoMin analysis allowed for averagely correct mineral identifications within large and small ROI, however some NanoMin images were glitchy in the colour identification. This could have been due to a number of issues such as: only having one scanner working in the machine at the time of its use, minerals identified not being programmed into the machine or there may have been an unknown problem with the machine itself. All these reasons contributed to a level of uncertainty and inaccuracy into the classification of the minerals as well as the "unclassified" label that the siderite was given in the first analysis through the NanoMin machine. These issues could be fixed when conducting a future investigation by making sure the NanoMin machine scanners are serviced and working/classifying rock material correctly.

However, the use of the XRD analysis allowed for the siderite classification to be measured reliably (figure 12) as a similar process was run again giving similar results of the types of minerals found within each sample. The XRD graph peaks and troughs, however, can be slightly off as the concentration of the data being collected is so large. This could have possibly affected the amount of mineral found within the sample being measured, even though it was accurate in its classification. Although only three samples were tested (due to time and high expenditure) all samples gave a fairly reliable outcome, relating similarly to the surrounding literature in pore-water chemistry and the mudstone findings within the microscopic images and content measured by the XRD graphs.

The experiment conducted was valid as variables such as contamination, type of analysis run for each sample and area of extraction were kept controlled in the beginning and throughout the investigation task. This allowed for the Scientific Research Question to be answered and the hypothesis to be proven with analysis to be partially correct.

Conclusion:

Through the use of SEM, NanoMin and XRD analysis, the three samples taken from Turimetta Headland were discovered to have no organic compound residue and limited amounts of mineral evidence to investigate the early environmental and climatic conditions at the time of deposition. The analysis process proved the hypothesis to be partially correct. Mineral evidence found within the Turimetta samples somewhat suggested that the Late Permian environment was a lake or river system specified by the illite, muscovite and other clay minerals depositories as well as the samples physical formation of shale. It is also suggested that the finer grain material within the PLE 1/7 samples are evidence for the clay-like physical properties,

and therefore creates evidence for the prehistoric lake environment.
However the majority of this material is formed by secondary replacement from the pore-water infiltration into the cliff face, adding a level of uncertainty to the results. This evidence was also linked with the "Petrology and diagenesis of Narrabeen group sandstones, Sydney Basin, New South Wales" paper, in which similar evidence of siderite formations and pore-water chemistry was found in the surrounding areas of Turimetta Headland.

Within the literature reviewed on the Sydney Basin, many geological processes that have occurred in different climatic conditions can influence the formation of certain rock types such as the Wandrawandian Siltstone, created in possible glacial conditions. This knowledge can now be linked to the shale samples extracted from the Turimetta Headland to understand how this formation reflects the lake or river environment of the depository. Other Sydney Basin connections can be made in the variant levels of organic matter found within each sample, and how some, such as this experiment, can be affected or terminated by small levels of water contamination, further paralleled in the Narrabeen Group paper.

Overall, this experiment allowed for an in depth understanding of the types of geological processes that can occur within a rocks lifetime as well as how the types of environments or climates affect the primary deposits.

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