



METALLOGRAPHIC INTERPRETATION OF THE MORPHOLOGY OF THE VERY OLD PEARLITE

DR.M.SAMPATH, Associate Professor, Dept of EEE,
SREE CHAITANYA INSTITUTE OF TECHNOLOGICAL SCIENCES, KARIMNAGAR.

ABSTRACT: Metallography has been utilized to discover hot-forged hypoeutectoid steels in almost 2,000-year-old items. They demonstrate how the texture of pearlite has evolved throughout time. The structures observed in this old pearlite differ from those observed in newly manufactured and standardized hypo-eutectoid steels. To put it another way, the pearlitic form maintains thermodynamic equilibrium for an extremely long time.

Keywords: Old pearlite, Metallographic, Morphology, Steel, Archaeometallurgy.

1. INTRODUCTION

The point of archaeometallurgy is to look into and figure out how metalworking worked in the past. In it, they study extractive metallurgy, metallurgical manufacturing methods, and metal artifacts from the Stone Age. Not only does knowing these facts help us understand the past, but it also helps science move forward in many ways today. This is shown by the planning and study of how long big public works projects or underground factories will last, as well as the use of archaeological and industry models to deal with high-level nuclear waste.

Archaeometallurgy has always been used to learn about how people have changed over time. It also improves science by looking at a sample from thousands of years ago, which shows how metals have changed over such a long period of time. There is information on corrosion in burial grounds as well as very slow diffusion processes that last hundreds of thousands of years. It is very important for this study that diffusion data be spread out at room temperature for very long periods of time. When we looked at Roman high-imperial

carbon steels from the first and second centuries AD using metallography, we found very strange pearlite structures.

Hot-forged mild hypo-eutectoid steels were used to make nails, tool parts, and other metal goods. The way it was made was by hot forming steel parts with different amounts of carbon. When you fuse several metals together, you might get a bigger item made up of many smaller pieces. All of the parts were cooled down to room temperature. The steel finally has grains that have been distorted by the forge and a structure like hypo-eutectoid steels with different amounts of carbon. Perlitic crystals can be seen in a ferrite framework. We can look at structures in these medieval and ancient steels that are very different from structures in modern steels by using metallographic research.

The difference between old and new steel buildings is the amount of time they have been through very slow spread processes. Even though the spread has been slow, it has been enough to move the microstructure toward more balanced shapes. A Roman High Imperial period steel nail was found between the first and second centuries B.C. and A.D. inside a

concrete wall that belonged to a cistern at the archaeological site of Cerro de La Coja in Cerro Muriano (Córdoba, Spain). This study shows how the metal was structured.



Figure 1: The concrete wall of the Roman cistern at Cerro de La Coja is shaped like a cyclopean and is uneven.



Figure 2: A cyclopean piece of concrete that is held together with a steel nail.



Figure 3: It was found that a steel nail had metalcore pieces inside it. Scanning Electron Microscopy (SEM) was used for the metallographic study.

2. EXPERIMENTAL TECHNIQUE

The steel nail was found in a piece of concrete wall from a Roman tank. This nail was used to build the wall and is part of the wooden forms that were used (Figures 1 and 2). The steel nail was prepared for metallography and then put into epoxy glue. It was used for the strike at 4%. According to the micrographic inspection (Figure 3), a significant percent of the metal core had been saved from corrosion.

The samples made with gold blasting were looked at with a scanning electron microscope (SEM). A Jeol 6400 JSM microscope was used, which had a thermionic cathode electron gun with tungsten filament, a secondary electron detector, a retrodispersed electron detector, image sharpness at 25 KV, and EDS analysis built in.

As seen under an optical microscope (Figure 4), some areas were mostly ferritic, while other areas had a lot of perlite colonies (Figure 5). This means the steel is very different from one another. It was probably made by hot shaping steels with different amounts of carbon. A metallographic study, focusing on the perlite zone, helps us track how these traits change over time.

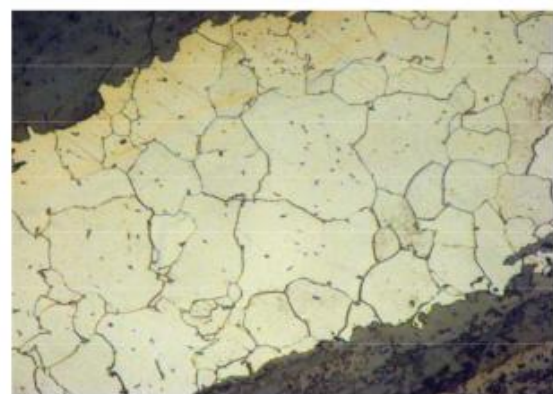


Figure 4: It is decided to look at the

Roman nail's ferritic zone.

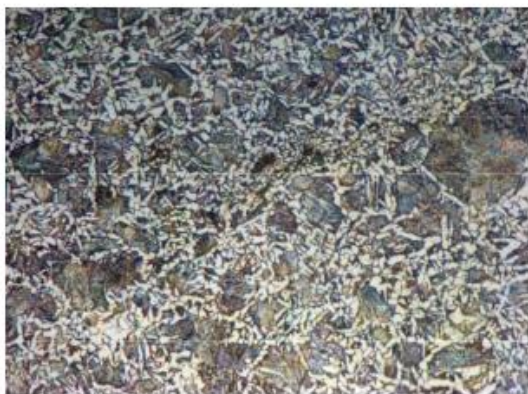


Figure 5: A ferritic-perlitic pattern can be seen in the nail zone

3. RESULTS

The development of pearlite clusters in carbon steels has been the subject of extensive scholarly research. However, the fact that these structures have been altered for thousands, if not hundreds, of years implies that they are unbalanced. This is due to the fact that they were engineered to endure temperature variations.

Steel buildings that have been buried for almost 2,000 years show that pearlite creation persists at archaeological sites. At room temperature, carbon undergoes minor changes and displaces at a glacial rate. This demonstrates that, despite the fact that equilibrium has not yet been reached, traditional metalworking processes yield perlite structures.

Because of this true equilibrium, long-term change occurs in each of these systems. The parallel and linear motions of the cementite sheets (Figures 6-8) quickly catch our attention. These lines suggest the presence of ancient pearlite deposits adjacent to them.

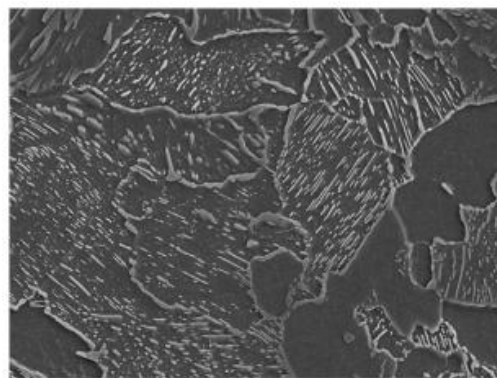


Figure 6: Cementite is used to join the iron granules at their extremities, resulting in old pearlite. The construction is shaped like a straight line. A significant gap between the layers is good for ferrite.

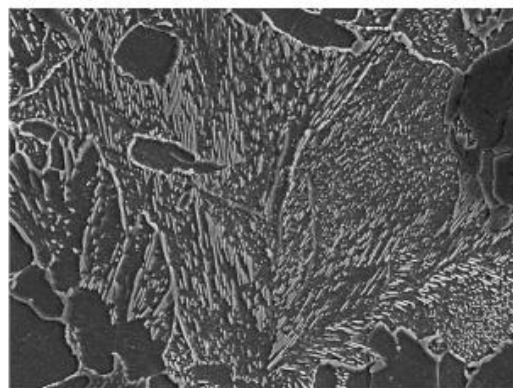


Figure 7: Cementite sheets that have been removed and reconstructed in various areas are common in very old pearlite houses.

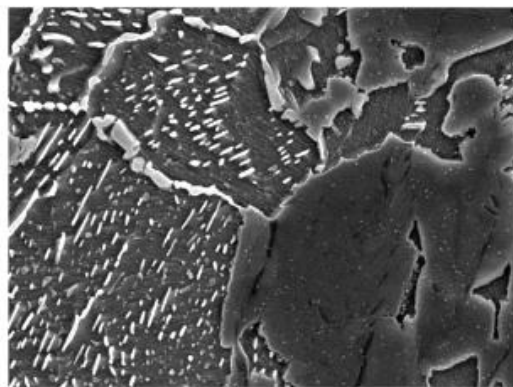


Figure 8: Very old pearlite has prominent cracks in the cementite and cementite sheets along the grain boundary. A magnetite (iron oxide) layer is visible in the lower right quadrant of the nail

corrosion. The images in Figures 9 and 10 show geometric progression with considerable interlayer voids. This pattern differs from what is found during the creation of pearlite under conventional thermal formation gradients.

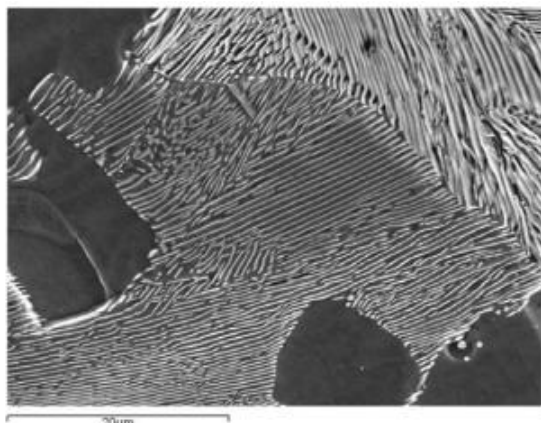


Figure 9: Steel is currently being created that has been normalized, hot-rolled, and injected with normal pearlite. The vast majority of cementite segments are made up of a single lengthy segment..

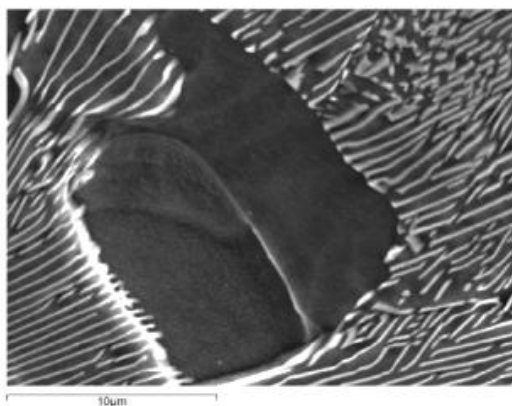


Figure 10: This is hot-rolled pearlite steel that has been modified and standardized. There is an abundance of interlayer space discovered.

In comparison to cementite, old pearlite rocks contain a high amount of ferrite. The occurrence of cementite sheets within vast ferrite zones demonstrates this. The observed behavior could be explained by the production of celite near the pearlitic groups (Figures 6 and 8). Cementite

appears to be re-evaporating, developing, and growing around the peripheries of these colonies in the ferrite matrix. Figures 7 and 8 depict the occurrence of laminar cementite thinning and fracturing once more.

The progressive disintegration of the cementite sheets created by the pearlite wave causes a considerable amount of carbon atoms to traverse the ferrite. Furthermore, carbon particles re-dwell in regions of greater equilibrium, such as the colonies' peripheries or pearlitic grains (Figure 6). As a result, the cementite sheets undergo a visual metamorphosis and eventually vanish.

The high carbon content of the ferrite matrix facilitates the creation of new carbides, as these carbides can be deposited in the most stable ferrite planes (Figure 7), which keep their linear, transparent structure.

The flat, linear shape of the old pearlite makes it easy to identify. At the tip of this shape, a translucent Widmanstatten structure may be seen (Figures 11 and 12). So far, every ancient pearlite fragment studied in the context of artifacts has unambiguously proven the Widmanstatten structure of cementite. It is a prominent and obvious feature of them

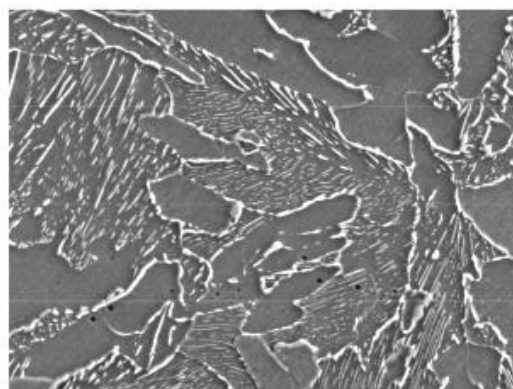


Figure 11: Cementite sheets made from discarded pearlite typically resemble

Widmanstatten. A significant amount of cementite has collected along the grain boundaries..

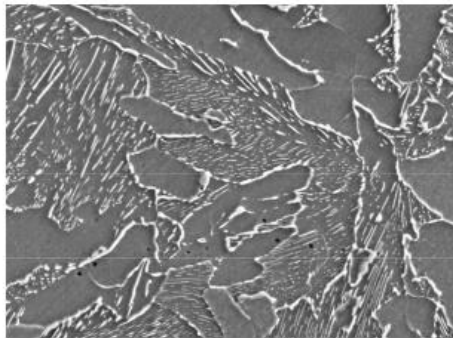


Figure 12: Cementite in motion can be seen within the Widmanstatten structure's decaying pearlite. Cementite coatings can also be found near the grains' extremities. The significantly fractured appearance of the cementite sheets (Figures 7, 13, and 14) is another notable feature of certain areas of the aged pearlite rocks. Because they have not yet degraded completely, the cementite sheets resemble icebergs in the refining plane of the ferrite sheet sections (Figures 13 and 15). Figures 16 and 17 show that when the depth of the 4% Nital attack rises, this behavior becomes much more visible and understandable. Old pearlite sheets appear to be unusually thin and pliable due to their immense height, as if they could be bent without fracture. Apertures formed in the ferrite during the following disintegration of the cementite sheets may also be seen.



Figure 13: The image of the cementite

sheets in a state of substantial fragmentation can be found in old Pearlite.

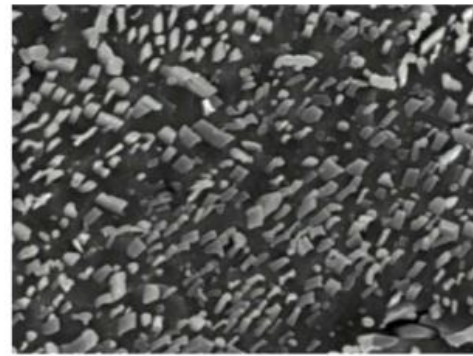


Figure 14: An image of the component of the preceding figure.

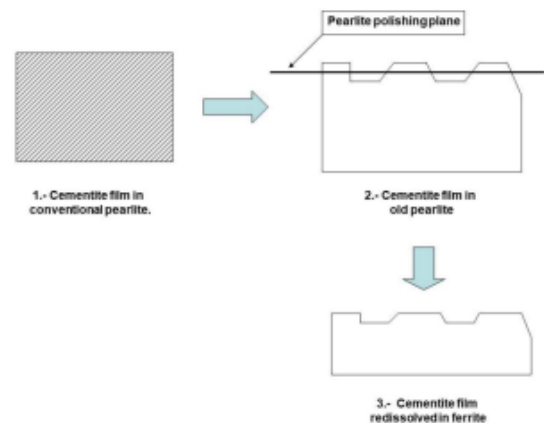


Figure 15: The figure below depicts cementite degradation within the ferritic phase of aged pearlite.

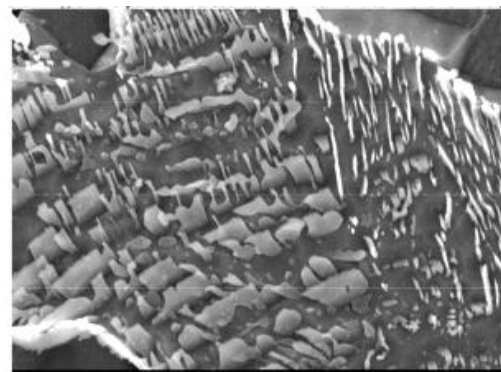


Figure 16: An improved shot of degrading pearlite that shows the re-decomposition of cementite sheets. The sample will appear to have been crudely sliced into segments when viewed from the processing plane.

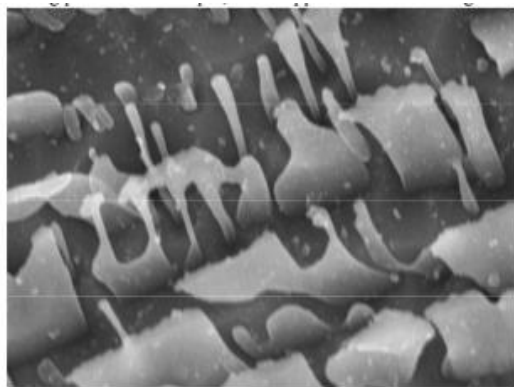


Figure 17: An ancient pearlite specimen is made up of broken slabs of cementite induced by re-dissolution of ferrite.

4. CONCLUSIONS

To demonstrate, typical pearlite formation includes the subcooling of austenite in conditions with low temperature changes. The look of ancient pearlite colonies is noticeably different from that of healthy pearlite. In terms of thermodynamic stability, ancient pearlite is thought to be the most stable. Almost definitely, all pearlite kinds would want to switch to safer variations. The slow mobility of carbon within the ferritic phase causes the change. A significant length of time has passed before measuring this diffusion, and the temperature is approaching that of room temperature. Based on archaeological metalworking, these epochs could have lasted thousands of years. This means that the precise time period used is unimportant.

The oxidized pearlite often evolves into more uniform and stable structures over time. Everything that happens is caused by carbon converting into ferrite. Carbon will be present for as long as cementite sheets remain. It is well acknowledged that larger carbon fragment sizes indicate increased carbon flow at the source. The time

necessary for the cementite sheets to degrade completely or partially varies. They commonly build constructions that resemble Widmanstätten, in addition to having exceedingly regular geometric features. The conversion of cementite to ferrite supplies carbon sources while also limiting the size of ferritic granules.

Although a general indication of this structural evolution's junction is possible, definitive evidence in the form of artifacts or excavation samples remains elusive.

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