The Vinland Map:

Transmission Electron Micrograph of the Ink

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Abstract:

The evidence that the Vinland Map is a modern forgery is not supported by the bi-pyramidal shape of the anatase crystals shown in the transmission electron micrograph of the ink of the Map. The proposed presence of a modern pigment was related to the identification of the anatase shown in the micrograph as having a rounded regular crystalline shape as contrasted to the bi-pyramidal shape that this paper has identified .

Keywords: *Vinland Map, transmission electron micrograph of ink, anatase, goethite*

1. INTRODUCTION

The Vinland Map is a map of the world that shows lands in the North Atlantic and is purported to date from the early part of the 15^{th} century. The controversy regarding the authenticity of the Vinland Map has been based largely on the interpretation of the discovery of the presence of anatase in the ink of the Map. In his 1988 paper, Walter McCrone explained that the anatase present in the ink had to be interpreted as that of a 20^{th} century pigment. He stated "The titanium white was shown to be the modern anatase pigment by particle size and shape using the transmission electron microscope. " His interpretation of the anatase in the Map ink is that it is anatase that has been calcined at temperatures in the range of 600-900 ^{0}C and that this method of preparation of anatase would not have been available in the 15^{th} century.

2. Transmission Electron Micrograph

Figure 1 in this paper is a reproduction of a transmission electron micrograph (TEM) of the Vinland Map ink that has been annotated for this paper to show the anatase crystals. It was labeled as Figure 2 in the 1990 paper by Towe titled, "The Vinland Map: Still a Forgery" and identified as Figure 1 of McCrone's Report to Yale University, 1975 and Figure 5 of McCrone's 1988 *Analytical Chemistry* paper, "The Vinland Map." The legend of the image Towe published in *Accounts of Chemical Research* states "Note rounded crystallites in the ~1000-A^{0} size range."
The crystals that are labeled in Figure 1 of this paper are crystals of anatase shown in the TEM of the Vinland Map ink that are not rounded, except for the one crystal labeled as being 80 nanometers. The large majority of the crystals of anatase are bipyramidal with 8 {101} faces and two {001} faces.[4] It is true that anatase that is produced by calcination at high temperatures is nearly spherical in shape [5] but the anatase shown in the TEM of the Vinland Map ink is not spherical. The shape is described as a "bi-pyramid" that is actually truncated (thus showing two {001} faces). Each pyramid has 4 {101} faces (or {011} face), since {101}={011}), determined by the tetragonal structure of anatase.[6]

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3. Source of the Anatase Remains in Question

The interpretation of the anatase in the ink of the Vinland Map is therefore based on an error in identifying the crystalline structure of the anatase as rounded when it is in fact bipyramidal. This fact not only requires reconsideration of the interpretation that the anatase had to have been heated to very high temperatures and thereby produced in the 20th century but also raises the question of how it was produced. Could it have been produced over time at room temperature from amorphous anatase that resulted from the interaction of ilmenite in the ink with the acidic environment of the ink? Although there are no published results stating that amorphous anatase can convert to crystalline anatase over time, there is unpublished information provided by staff from the Nanogeoscience Center at LBNL.[6] The report is that amorphous anatase produced in that laboratory in ~2001 was reexamined in ~2005-2007 and was found to have crystallized into nanoanatase.

4. Significance of Goethite Identification

The evidence to date from the analysis of the ink of the Vinland Map and from the radiocarbon dating of the parchment of the Mapall need to be included in consideration of the authenticity of the Map .[7] As explained, the bipyramidal shape of the anatase in the ink of the Map does not support the need for calcinations at high temperatures. This prompts the need for a review of the interpretation that the anatase proves that the Map is a forgery. The 15th century date of the parchment of the Map supports the origin of the Map in the 15th century.

An explanation of the origin of the anatase as a material that was introduced in conjunction with the presence of an iron gall ink involves the need to prove the use of an iron gall ink by the person who drew the Map in the 15th century. I have provided an explanation for why iron is missing from many areas of the ink[8.]This is based primarily on the fact that goethite was identified in particles found in the crevice of the Map and that these particles were listed in the table of x-ray diffraction results included in Walter McCrone's Report to Yale University in 1974 although no discussion of their origin was included in the report. I have proposed that iron from the ink is present in those goethite particles. I also propose that the examination of the Map using ultraviolet light be reviewed so that more of the information that examination provides can be evaluated with regard to the question of whether or not the ink of the Map is an iron gall ink.[8]

5. PIXE and Identification of Anatase Presence in Ink

Evidence that the titanium is present in the ink of the Map rather than in the parchment is supported by the PIXE analysis of the ink.[9] The proposal that the anatase is the result of production from ilmenite either during preparation of the materials of an iron gall ink or while present in an ink used for the Map is entirely consistent with the titanium in the form of anatase being present only in the ink and not on or in the parchment.

6. Conclusion

The historical references for the history of the Vinland Map and the associated manuscripts are the 1965 and 1995 editions of the Yale University Press publication, **The Vinland Map and the Tartar Relation.** [10] Historical evidence for the origin of the Map as the Council of Basle that was held AD 1431-1449 is presented in the 1971 University of Chicago Press volume, **Proceedings of the Vinland Map** Conference, Smithsonian Institution.[11] The evidence that is presented is in the form of the identification of a notary, BartholomaeusPoignare , who was appointed as a notary to the Council in 1435 and whose name appears on a pastedown from the *Speculum Historiale*. As explained in the Yale University Press publications, the *Speculum Historiale*has been proposed as having been the manuscript with which the Map was bound in the 15th century. The physical evidence from the watermarks of the paper of the *Speculum Historiale* and from the *Tartar Relation* support the conclusion that the origin of the *Speculum Historiale* and the *Tartar Relation* was the region of the Council of Basle. The watermark evidence associates these two manuscripts to each other and to the Council meeting. A 15th century date is supported by the radiocarbon date of the parchment of the Map and coincides with the time of the Council of Basle. Evidence that the Map is a modern forgery based on the shape of the antase particles in the ink of the Map is shown in this paper as less clear cut than has been formerly proposed. It has been proposed that a modern forger of the Vinland Map obtained parchment of the correct date for the Council of Basle, but no evidence has been presented to confirm that.

Although questions continue regarding the uniqueness of the Vinland Map and the lack of known cartographic information that would have been used for its preparation in the 15th century, the material evidence shows a consistency that is important to consider.

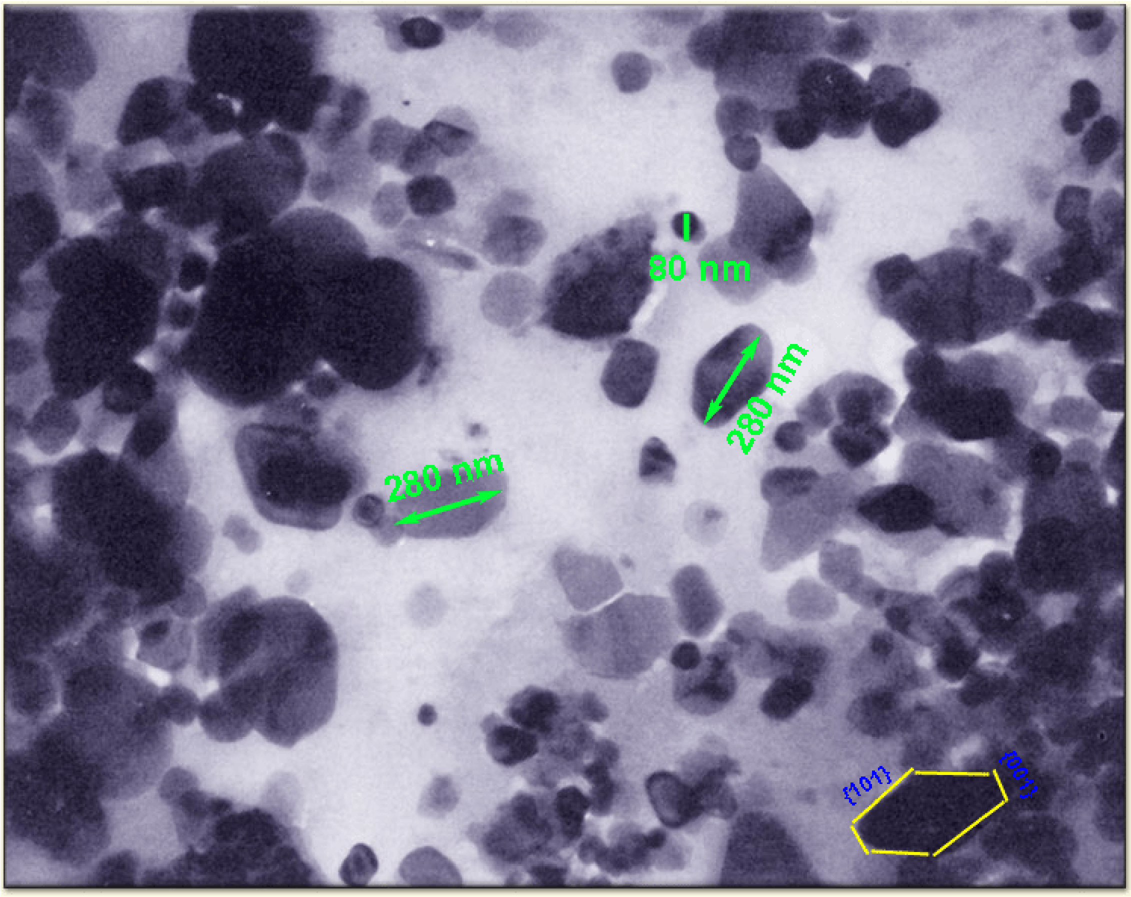

Figure 1. Transmission electron micrograph of anatase particles from the ink of the Vinland Map (reproduced from **Figure 2** of Towe 1990). Labeled particle sizes are estimated using the reported image magnification and the image dimension for the figure from Towe, 1990. Anatase particles present the equilibrium morphology of truncated tetragonal bipryamids as indicated by green arrows. Seemingly spherical smaller particles are likely of the same shape, but this is hard to confirm due to limited image resolution. Particles with lower image contrast (grayer) may be other minerals whose cations have lower atomic numbers than titanium (e.g. calcite, or quartz). Reprinted with permission from Towe, K.M., *Acc. Chem. Res.,* **1990**, *23*, 84-87. Copyright 1990 American Chemical Society.

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