

Addressing the False Narrative that TCP is Identical to Talc

Prepared by Natural Enrichment Industries' R&D Division

In response to statements falsely claiming that Tricalcium Phosphate (TCP) is talc, it is the intention of this paper to show that the claim is demonstrably false. The cited data herein shows that talc is a hydrated magnesium silicate whereas TCP is a calcium phosphate, containing neither magnesium nor silica in any relevant amount. It is the conclusion of this document that the claim "TCP is talc" is not accurate by any empirical definition and stands without any intellectual merit.

Since talc is $Mg_3Si_4O_{10}(OH)_2$ ^{1,2} and TCP is $Ca_3(PO_4)_2$ ^{3,4} there are significant differences in both the elements that compose these molecules as well as the overall crystal structure. This in turn leads to chemical and physical properties that are quite different between the two molecules. Because of talc's role as a possible carcinogen⁵ it is imperative to state that **TCP is not talc**, and the rest of this document will explore methods that support that assertion. There are multiple methods for the determination of a structure and elemental composition of a compound however, for the sake of brevity this document will focus on only two of them: X-Ray Diffraction (XRD) and elemental analysis.

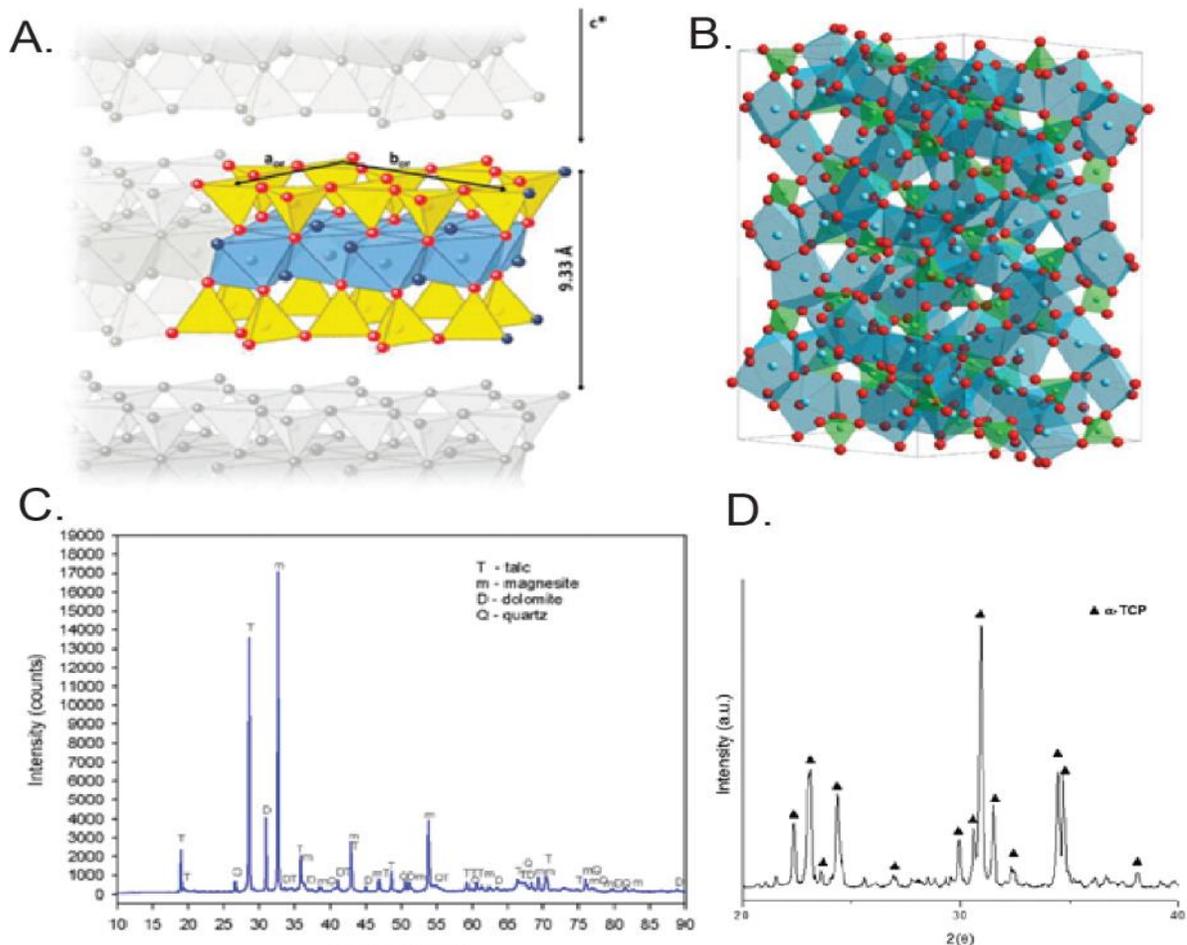


Figure 1 A. Crystal structure of Talc (red: oxygen, dark blue: hydroxide, light blue: magnesium, yellow: silicon) B. Crystal structure of β -TCP (red: oxygen green: phosphorus, blue: calcium) C. XRD of Talc Showing other constituent minerals D. XRD of TCP note significant peaks at 25 2(theta) position absent in 1C.

XRD is a highly useful method for the study of crystal structures.^{6,7,8} This technique works by irradiating a crystal with X-rays. The X-rays are diffracted by the electrons of atoms in the crystal. The angle and energy of this diffraction is used to not only examine the composition

of the crystal but also the real spatial arrangement of atoms inside a crystal.^{8,9} Since atoms of different types say calcium or magnesium have different amounts of electrons (20 vs.12 respectively)^{3,1} the result is that different atoms in specific configurations will have highly unique diffraction patterns that can be used to determine crystal shape and composition when compared to a library of diffraction patterns for known compounds.^{9,10} When used on talc, XRD reveals alternating layers of tetrahedral silica and magnesium in octahedral sites(Figure 1 A.)^{10, 11,12,6} compared to XRD of TCP, (Figure 1 B.)¹³ which shows a uniformly amorphous crystal composed of groups of phosphate tetrahedra surrounding calcium atoms.^{3, 14, 15} The difference between the two substances is apparent in even the XRD spectra Figure 1 C. for talc¹⁶ and 1 D. for TCP.¹⁷ Showing major differences in peak heights and positions.

Elemental Analysis can be done several ways; however, the most common methods are via Flame Atomic Absorption Spectroscopy (AAS)^{18, 19} for quantitative measurements and Inductively Coupled Mass spectrometry (ICPMS) for detection of specific elements in a sample.²⁰ Most methods in this field work one of two ways: either by measuring the emission spectra from the ionization of the compound, or by determining the mass of the compound and its fragments.^{20,19} In the case of AAS, the compound is burned in a flame, thereby releasing ions. The presence of these ions causes the flame to change color.¹⁹ Changes in the absorption of light in this flame are detected by a photodetector, which then yields an absorption number corresponding to the amount of the detected ion in the sample.¹⁸ When used on a sample of TCP, AAS reveals that the sample is about 38% Ca and ~23.9% Phosphorus.^{4,21} Further analysis will show that ~38% oxygen makes up most of the remainder of the molecule with any remaining mass belonging to hydrogen and trace elements.^{4, 22} These results can be compared to talc, which is composed of 18%Mg and 29%Si with the remaining mass percent belonging to oxygen and hydrogen.^{1, 23-25}

To conclude, by a variety of methods shown above, that there is no validity to the claim that TCP is chemically or physically equivalent to talc. The only elements that these compounds share in abundance is oxygen. Coupled with the complete difference in crystal structure, the only logical conclusion is that **TCP is not talc and never will be talc**. To say otherwise is not only patently false but is to ignore scientific fact.

References:

1. Martin, F.; Micoud, P.; Delmotte, L.; Marichal, C.; Le Dred, R.; de Parseval, P.; Mari, A.; Fortuné, J.; Salvi, S.; Béziat, D., The structural formula of talc from the Trimouns deposit, Pyrénées, France. *The Canadian Mineralogist* **1999**, *37* (4), 997-1006.
2. Ferrage, E.; Martin, F.; Petit, S.; Pejo-Soucaille, S.; Micoud, P.; Fourty, G.; Ferret, J.; Salvi, S.; De Parseval, P.; Fortune, J., Evaluation of talc morphology using FTIR and H/D substitution. *Clay Minerals* **2003**, *38* (2), 141-150.
3. Brunner, T. J.; Bohner, M.; Dora, C.; Gerber, C.; Stark, W. J., Comparison of amorphous TCP nanoparticles to micron-sized α -TCP as starting materials for calcium phosphate cements. *Journal of Biomedical Materials Research Part B: Applied Biomaterials: An Official Journal of The Society for Biomaterials, The Japanese Society for Biomaterials, and The Australian Society for Biomaterials and the Korean Society for Biomaterials* **2007**, *83* (2), 400-407.
4. Tung, M. S., Calcium phosphates: structure, composition, solubility, and stability. In *Calcium phosphates in biological and industrial systems*, Springer: 1998; pp 1-19.
5. Vallyathan, N. V.; Craighead, J. E., Pulmonary pathology in workers exposed to nonasbestiform talc. *Human pathology* **1981**, *12* (1), 28-35.
6. Aglietti, E. F., The effect of dry grinding on the structure of talc. *Applied Clay Science* **1994**, *9* (2), 139-147.
7. Raynaud, S.; Champion, E.; Bernache-Assollant, D.; Laval, J. P., Determination of calcium/phosphorus atomic ratio of calcium phosphate apatites using X-ray diffractometry. *Journal of the American Ceramic Society* **2001**, *84* (2), 359-66.
8. Suryanarayana, C.; Norton, M. G., *X-ray diffraction: a practical approach*. Springer Science & Business Media: 2013.
9. Guinier, A., *X-ray diffraction in crystals, imperfect crystals, and amorphous bodies*. Courier Corporation: 1994.
10. Moore, D. M.; Reynolds, R. C., *X-ray Diffraction and the Identification and Analysis of Clay Minerals*. Oxford university press Oxford: 1989; Vol. 322.
11. Dumas, A.; Mizrahi, M.; Martin, F.; Requejo, F. G., Local and Extended-Order Evolution of Synthetic Talc during Hydrothermal Synthesis: Extended X-ray Absorption Fine Structure, X-ray Diffraction, and Fourier Transform Infrared Spectroscopy Studies. *Crystal Growth & Design* **2015**, *15* (11), 5451-5463.
12. Singh, V.; Agrawal, H., Qualitative soil mineral analysis by EDXRF, XRD and AAS probes. *Radiation Physics and Chemistry* **2012**, *81* (12), 1796-1803.
13. Goto, T.; Katsui, H., Chemical Vapor Deposition of Ca-P-O Film Coating. 2015; pp 103-115.
14. Pan, Y.; Huang, J.-L.; Shao, C., Preparation of β -TCP with high thermal stability by solid reaction route. *Journal of materials science* **2003**, *38* (5), 1049-1056.
15. Tampieri, A.; Celotti, G.; Szontagh, F.; Landi, E., Sintering and characterization of HA and TCP bioceramics with control of their strength and phase purity. *Journal of Materials Science: Materials in Medicine* **1997**, *8* (1), 29-37.
16. Banjuraizah, J.; Mohamad, H.; Ahmad, Z. A., Crystal structure of single phase and low sintering temperature of α -cordierite synthesized from talc and kaolin. *Journal of Alloys and Compounds* **2009**, *482* (1), 429-436.
17. Vásquez Niño, A. F.; Santos, L. A. L. d., Preparation of an injectable macroporous α -TCP cement. *Materials Research* **2016**, *19* (4), 908-913.
18. Kirkbright, G. F.; Sargent, M., *Atomic absorption and fluorescence spectroscopy*. Academic Press London: 1974; Vol. 798.
19. Welz, B.; Sperling, M., *Atomic absorption spectrometry*. John Wiley & Sons: 2008.
20. Jenner, G.; Longerich, H.; Jackson, S.; Fryer, B., ICP-MS—A powerful tool for high-precision trace-element analysis in Earth sciences: Evidence from analysis of selected USGS reference samples. *Chemical Geology* **1990**, *83* (1-2), 133-148.
21. Joschek, S.; Nies, B.; Krotz, R.; Göpferich, A., Chemical and physicochemical characterization of porous hydroxyapatite ceramics made of natural bone. *Biomaterials* **2000**, *21* (16), 1645-1658.
22. Oguchi, H.; Ishikawa, K.; Ojima, S.; Hirayama, Y.; Seto, K.; Eguchi, G., Evaluation of a high-velocity flame-spraying technique for hydroxyapatite. *Biomaterials* **1992**, *13* (7), 471-477.
23. Bernas, B., New method for decomposition and comprehensive analysis of silicates by atomic absorption spectrometry. *Analytical Chemistry* **1968**, *40* (11), 1682-1686.
24. Guest, R.; MacPherson, D., The use of flame procedures in metallurgical analysis: Part I. Determination of silicon in sulphide and silicate minerals. *Analytica Chimica Acta* **1974**, *71* (2), 233-253.
25. Rohl, A.; Langer, A.; Selikoff, I.; Tordini, A.; Klimentidis, R.; Bowes, D.; Skinner, D., Consumer talcums and powders: mineral and chemical characterization. *Journal of Toxicology and Environmental Health, Part A Current Issues* **1976**, *2* (2), 255-284.