Student questions: SESE coloquium
Dr. Peter Buseck: "From Earth to Deep Space A Half Century (Almost) of Nanomineralogy"
9/5/22

Is it possible to see zoning within a magnetic crystal that produces non-magnetic and magnetic regions?
PB: Yes.

What kinds of asbestos can form at the same time, and what types of regions do they form in?
PB: Amphibole and serpentine asbestos both form under metamorphic conditions but not together because the formation conditions differ.

The speaker, Peter Buseck, mentioned of the time when Bill Clinton stated that there was life on Mars due to the finding of small magnetite crystals that are similarly found it bacteria. I understand that the magnetite crystals where similar in size but not in shape of those found in bacteria, My question is then where exactly where those magnetite crystals found on Mars?
PB: In a meteorite that came from Mars. It is not known in what environment on Mars they formed.

In the early days of Dr. Buseck's work with microscopy he stated that the real important finding was the existence of defects in minerals. The understanding of how these defects formed then lead to many other findings, what was the next major stepping stone after the defects?
PB: Determining the range of defect types, the minerals in which they occur, and their geological significance.

There was a slide showing a mineral with tons of deformation going on under the microscope. You said it was showing "metamorphism in action". Does that mean that the mineral shows spectacular evidence of metamorphism or does it mean that the metamorphism itself (or its effect) was ongoing?
PB: It meant that the metamorphism was not complete but "frozen" during the process, on the way to forming a new metamorphic rock type.

Was it challenging to argue against the scientists who believed that the magnetites present in the Martian meteorite were a sign of life on Mars?
PB: Absolutely. The controversy lasted for several years before our data, as well as that of others, was accepted.

Has microscopy ever been used to identify and/or characterize microfossils?
PB: Scanning electron microscopy rather than transmission microscopy is the method of choice.

Is there any evidence that suggests pseudocarbynes occur in protoplanetary disks?
PB: No (perhaps not yet?).

Could nanoparticles, such as Fe nanoparticles, be used to make inferences about certain portions of a planet's geological history?
PB: Probably, but that is work for the future – perhaps by someone in this class?

What other kinds of mineral nanoparticles that could potentially be used as evidence for life on other planets?
PB: Evidence for past life on other planets is an area of active research. At this time it is not known what sort of evidence would be both likely and convincing.

During the talk there were multiple different structures of carbon atoms presented aside from the usual graphite and diamond, in what ways do these different structures effect the properties of the material.
PB: Different structures based on carbon have different types of chemical bonding and therefore different properties such as hardnes, electrical conductivity, optical properties, and so forth.

How are these different carbon structures synthesized.
PB: Most at elevated temperatures and pressures, some in vacuum, some with laser beams, and some with other methods.

How did the mineral "Jimthompsonite" get its name and what is it used for?
PB: It was named after a distinguished metamorphic petrologist at Harvard named Jim Thompson.

What are the key differences in shapes of the magnetic crystals in magnetotactic bacteria and those on martian meteorites that led scientists to conclude that they are not the same?
PB: Interesting question. Those in bacteria differ from those on Mars, with (technical) details depending on specifi combinations of crystallographic forms that include prisms, scalenohedra, rhombohedra, and pinacoids.

Even though the bacteria magnet shapes don't match known sizes couldn't they possibly match some bacteria that we haven't found?
PB: It is always possible in science that things we haven't yet found might be discovered and then change the way we think. That's one of the things that makes science stimulating and fun.

You said that sp (single chains) appear all of the time, but also say that we can't make them. What do you mean that they appear?
PB: I did not intend to say that they appear all the time in solids although they do occur as single molecules in the gas phase in or near stars.

Regarding your work with the magnetite crystals and proving they were not of a bacterial origin, how was this research received compared to other projects you have worked on? Did you find there was more scrutiny because the topic of life on Mars was in the public eye or more 'controversial'?
PB: It certainly did receive more scrutiny, and its reception was mixed. Those people whose papers we challenged were less pleased than others.

Can you please elaborate more on the true origin of the unique shapes of the magnetite crystals in the meteorite?
PB: In general the factors that control crystal shapes are not known.

Having been in a particular field for so long, would you have expected the field to evolve that much / in these directions when you started?
PB: Not at all. As Yogi Berra reportedly said, "It's hard to make predictions, especially of the future."

What could be the industrial applications of pseudocarbynes, if any?
PB: We won't know until they are made and tested. All we know now is that new materials typically have new properties, some of which can be useful.

The microstructural elements and defects within a mineral are not visible in the hand specimen, not even under the optical microscope. Then, how it is possible for one to understand which part of a particular mineral may have that kind of defects. Is it all about trial and error methods and random discoveries while studying many mineral grains under the electron microscopes?
PB: Basically yes, although we can make intelligent guesses. For example, minerals from stressed environments such as within faults or metamorphic zones will be likely to contain defects.

Why do cross-links among 1D carbon chains cause explosions?
PB: The instability of the bonds is so great that energy is released rapidly in forming the cross linking.

In light of the non-biological origin of the martian meteorite studied already, what key mineral evidence would indicate a biological origin for future martian samples to be returned to the Earth (which minerals, and what physical structures, etc.)?
PB: This is a matter of great interest and controversy, but the answer is unknown.

If one were trying to prepare an analog material for martian dust, would simply mixing its various expected constituent minerals (altered basalt, some sulfates, possible carbonates, etc.) in nano-scale agglutinates be sufficient/appropriate in replicating its spectral (visible/near-infrared/thermal infrared) characteristics?
PB: This is an area that Dr. Phil Christensen and his students are actively studying, with the assumption that the answer is positive.

If carbyne is detected in the interstellar medium, what is the significance of that finding?
PB: As a non-astronomer, my undertsanding is that the range of molecules found in the ISM are of interest because they potentially provide information of stellar formation and destruction.

Is it possible for the magnetites found in Martian meteorites to still belong to magnetotactic bacteria even if the magnetites are not the same shape as in magnetotactic bacterias as we know them?
PB: Many things are possible, but in science we try to work from things that are known, always recognizing that surprises can and do occur.

How do defects in crystals form?
PB: By growth that is too rapid for atoms to fully organize, by stresses that distort the crystals, or by other disruptions during or following crystallization.

If Psuedocarbynes are actually detected in the ISM, what kind of environments would these molecules form in?
PB: Not known.

What are carbonaceous chondrites and why are they so important?
PB: They are a type of meteorite that has experienced little metamorphism and so is thought to retain the minerals that it had when formed.

How is a carbonaceous chondrite created/formed?
PB: Not known, but of great interest.

Are there theories about how the magnetite crystals could have formed on Mars?
PB: None that I know.

What makes diamonds so hard? In other storms capable of forming 4 bonds like silicon, can they create the same bonding structure as diamonds and if so, how does that hardness compare?
PB: Materials containing atoms with four bonds are hard, with the details depending on the bond strengths.

Why are the spiral forms of asbestos dangerous whereas other shapes are not?
PB: It is not the sprial froms but the unsatisfied bonds on the fiber surfaces that I think make some types of asbestos (amphibole) dangerous.

What causes a crystalline structure to become magnetic?
PB: The orientations of the electron spins of the atoms in the crystal, e.g., https://www.britannica.com/science/crystal/Magnetism.

How did you decide to pursue both the fields of climate change through the study of aerosols and meteorology as they seem to be very different fields with different techniques?
PB: I study aerosols and mineralogy using transmission electron for both.

Based on your experiences in climate studies, what methods of conveying to the public the importance of science for our communal future do you find to be most successful?
PB: I'm not expert on that, but any media that has large numbers of readers (books, newspapers, magazines), watchers (TV) or listeners (radio, podcasts) helps.

A battleship sinks by one nanometer if a gull lands on its deck. How is the value calculated?
PB: Calclating it uses basic physics, but I obtained the value from the web.

Except magnetite crystals, is there anything else that might prove life on Mars?
PB: That is a matter of active research and speculation.

You mentioned that graphite and diamond require significantly different pressures to form, what would cause the graphite-diamond intergrowth or conversion?
PB: Interesting question with an unknown answer.

Has carbyne only been stabilized as pseudocarbyne using gold clusters, or are there other metals that have been shown to also work, and if so is the stability of the carbyne chains dependent on the type of metal in the clusters?
PB: Interesting question with an unknown answer; is the subject of active, ongoing research.

Dr. Buseck showed a picture of a graphite-diamond intergrowth - does the convergence area of the two / where the two meet have any intermediate phase or is the change immediate between the two lattice shapes?
PB: No intermediate phase is known, which is why the change from one to other looks abrupt.

When talking about the gold setting of the carbyne, Dr. Buseck mentioned using laser energy to break gold bonds, but wouldn't that destroy the carbon bonds as well? How can you make sure they bond to each other rather than other atoms of the same element?
PB: The laser breaks the bonds in the solvent above the gold. The pseudocarbyne froms from the products of the of the disruption cause by the laser.

How can a metamorphic mineral like chrysotile coexist in the Murchison meteorite with whewellite, which was also found in Murchison but should degrade in chrysotile's formation conditions?
PB: Whewellite is an oxalate whereas chrysotile is a silicate. Being so different chemically, we would predict that they formed under different conditions. If they occur side-by-side in Murchison, and I don't know that they do, then that would probably be because they were mixed after formation.

I've heard a lot about carbon fiber materials being hard but brittle -- what is the sp bond configuration of carbon fiber compared to the other carbon configurations you showed?
PB: My guess is sp2.

How did the magnets (the chemical composition / structure) in the magnetotatic bacterium compare to magnets found on Earth and/or Mars?
PB: The magnetite in the magnetotatic bacteria was formed by the bacteria and so are terrestrial. It is not known how the magnetite on Mars formed.

While viewing the Precambrian graphite/carbon for early evidence of life what sorts of indicators were you looking for? (A similar question was asked my Professor Semken during which this was answered)
PB: Shapes reflecting those of known organisms.

What is it about the tubular structure of one type of asbestos that makes it benign, whereas the other structures are malevolent (change in chemical make-up?)?
PB: I think it is the unsatisfied bonds on the surface of the amphibole structure whereas there are no such dangling bonds on the surface of chrysotile.

What, specifically, was the experiment done to test the hypothesis of adding atom clusters to form pseudocarbynes? (Instruments used and process)
PB: Details are in Pseudocarbynes: Linear carbon chains stabilized by metal clusters, J. Phys.

Chem. C 124, 19355–19361, 2020.

If pseudocarbynes are created with metals other than Au (such as Fe), will clusters of the metal still form when irradiated by an electron microscope?
PB: Good question. This is being actively studied.

Is the shape of asbestos (wavy vs. tubular) determined primarily by the crystal structure or defects?
PB: It's the underlying structure rather than defects. The defects occur within the structure.