

# An interview with Frank C. Hawthorne

Roy Kristiansen

This interview took part February 13, 2011 during the Tucson mineral show 2011.

**Introduction** (partly quoted from R.I. Gait in the IMA website).

*Dr. Frank C. Hawthorne (65) is a distinguished professor of geological sciences at the University of Manitoba, Canada, and one of the world's most distinguished Earth scientists. He is a mineralogist, crystallographer, spectroscopist and theorist. Thomson scientific lists Frank Hawthorne as both the most highly cited geoscientist as well as the most highly cited mineralogist/crystallographer for the decade 1996 – 2007. The Institute of Scientific information lists him as the world's most highly cited mineralogist 1990-2000 and the world's third-most cited geologist for the same period.*

*FCH recognized and refined systematic concepts of chemical bonding at the atomic level that have immensely improved our general understanding of mineral crystal chemistry and the factors that affect the crystallographic architecture and chemical compositions of minerals.*

*FCH have received many awards, including the principal medals for research from several geological societies. He is the recipient of the Carnegie medal of the Carnegie museum of Natural history, the Killam Prize in natural sciences of the Canada Council. He was awarded a Canada Research chair in crystallography and mineralogy, is an Officer of the order of Canada, and a Foreign member of the Russian Academy of Sciences. His latest awarding was the IMA medal 2009 for Excellence in mineralogy. The award ceremony took place during the IMA meeting in Budapest August 2010.*

## The interview

RK: My first question is: what can the collector/amateur contribute to mineralogical sciences today? Professional mineralogy have been so advanced that it is hard to understand and keep up with scientific papers in the way that you need at least basic foundation in chemistry and physics, although I think you can contribute in a way like you mentioned in the introduction of the Pinch medal.

FCH: Oh yes, the critical thing about doing mineralogy, doing experimental mineralogy, is samples. Particularly if you want to do crystal structure or spectroscopy you need samples that are suitable for each technique. So this is where the collector is critically important.

I always look at it as if I have tenth of thousands of collaborators who are looking for minerals. If I interact with collectors I will be able to find what I need, or they will be able to find for me, or they know somebody who has this size of crystal, or this particular mineral. I can't spend a lot of time in the field looking for minerals. I have a large laboratory that takes up much time because the equipment need to be maintained, the students need to be supervised, plus normally people have to teach and to do administrative work as well. So there is not a lot of time available for collecting, specimen collecting, and recording details about paragenesis. My feeling is that this is where the collector plays a crucial role. Few, if any, professional mineralogists now record information on paragenesis. This is one of the most interesting areas in mineralogy that should be thought about, trying to correlate why minerals crystallize in the sequences that they do. And the crystal structure and chemistry is related to details of their paragenesis, what is the temperature, the pressure, and where in the crystallization sequences minerals of a particular deposit or area occur. Our understanding of this even now is rudimentary at best. And the reason why is that it is not enough detailed paragenetic information available. Here is where the collector can play a very very important role.

Similarly, as you very well know, when we are trying to do crystal structures of minerals it is a matter of finding crystals big enough to give diffraction to collect the data. It is the collector that finds these crystals. Much of the work I have done has been in collaboration with collectors who have been looking for crystals of specific minerals for me, looking in the field, talking to their friends or other collectors; "Frank wants this and that...", "do you have this...". This is crucially important to what I do, and a lot of the work I have been doing couldn't have been done without collaboration with mineral collectors.

RK: But you have to be selective or otherwise you would be overrun by collectors?

FCH: Yes, that's right. I can't have people sending me minerals: - what is this? - what is that? What you find is that there are expert mineralogists whose eyes are really really good. So I know when Bill Pinch, Charles Key or Roy Kristiansen sends me a mineral, then it is going to be something interesting and peculiar. If it's a normal mineral they recognize that, and won't send it. So either it's going to be a strange chemistry of a known species or a new species. And this is basically why I promoted setting up a Pinch award.

RK: Can we still foresee an annual number of new species as of today, 90 – 100 species, or will the number increase?

FCH: Oh yes, I think that could easily increase as our capabilities for characterization increase. If we think about it, we can't characterize crystals usually smaller than about 50 micron. Sometimes you can do a little bit smaller than that, but still huge in terms of the size of the unit cell of a mineral. The whole range of crystals between the Ångstrom scale and the micron scale we can't really look at yet. As our capabilities increase we'll find a large number of minerals there. So I think we can look forward to see a tremendous expansion in the number of minerals in to the foreseeable future.

If we look at the minerals we characterize now most of them as small crystals. You don't find anything 4 – 5 inches long now as new species any more. Occasionally you can find it, but normally then people have mistaken them for another mineral.

RK: I have the impression that the instrumentation and the facilities are improved so that you can more and more go down in size to make structures analysis. You have seen improvement over the years that things left aside for example 10 years ago have their structures solved today.

FCH: That's quite right. I have crystals in my laboratory that people gave me 20 years ago. Back then we couldn't do anything with, but as new equipment is coming we gradually are able to do something with them. I had a new diffractometer about a year ago and we have analyzed several minerals since then that were totally impossible with our previous instrumentation. We put it on, and there were absolutely no signal at all. This time we got enough diffractive intensity to solve the structure and characterize it as a new mineral.

RK: This means that in the future you will probably have no less new species as the equipments improve. You will be able to solve the structure of ever smaller crystals than you could do before.

FCH: That's right. The thing is that the size of a crystal is relative to our size. We are approximately 5 – 6 feet tall. That's totally alometry from the physics and chemistry of natural processes. And if you think that Avogadro's number, approximately  $10^{24}$ , scales things from the atom scale to essentially the human scale. Most of that range of size is still inaccessible to us at the moment. This will increase into the future. So there are still a lot of minerals in there that we don't know. This means that it's a lot of natural processes going on that we are still unaware of.

RK: But you are down to nanomineralogy?

FCH: Oh yes, that's right, but we are still in the micron. But we can get a lot smaller than that.

RK: Well, there is a key word that I picked up during your presentation in the IMA meeting in Budapest last August: bond-topology. Can you explain that in short words, please?

FCH: Topology is the mathematics of the shapes of things, the way things connect together. It's not connected to their geometry. It's connected to the way they connect. So, for example; a circle and a square have identical topology. Topology is identical if you can deform them, without breaking anything, one shape into another. If you can think of a crystal structure as an assemblage of chemical bonds, then the topology of that assemblage of chemical bond actually characterizes the structure. And, in fact, if we talk about minerals, for example tourmalines, we have dravite, schorl, elbaite etc., these all have the same bond topology.

Something with discrete bond topology has a specific crystal structure, and there can be a large number of minerals with that bond topology, or there can be only one mineral with that bond topology. A very small number, like for example quartz, have a similar bond topology like berlinite.

Yes, and what bond topology does, it allows you to connect the crystal structure of a mineral to the energetics of a mineral. So then you can start to say what aspect of the bond topology of the connectivity of a bond is important to the energy of the crystal, or what aspect are of lesser importance.

RK: I understand that amphiboles besides tourmalines are still on top of your engagement, and why are they? I believe it is a big challenge in the structures of these minerals because there are so many substitutional possibilities?

FCH: Yes, the complexity is a challenge, and I have a philosophy toward minerals and crystal structures in general; the more complicated a mineral or structure is, the more information it contains about the way they were formed. For example quartz doesn't have very much information, whereas an amphibole carries a lot of chemical and structural information. Working on amphiboles over a long period one of the interesting things for me that came out of this work is the importance of short-range order in minerals. This has emerged in the past 10 to 15 years, and didn't come out of crystallography, but came out of spectroscopy when looking at amphiboles. This spectroscopy provided a proof of short-range order. That's the way atoms cluster together in a structure. The combination of this, with the ideas of bond topology, made me realize that this is a major factor controlling continuous chemical reactions that we have been totally unaware of until now, and in fact does not fit the normal thermodynamic models of minerals at the moment. This is forcing us to develop better thermodynamic models for calculating temperature/pressure and other active components in rocks, and models that take in short-range order as well. So, the amphiboles are intrinsically interesting because of their complexity and the difficulty in figuring out the arrangements of atoms.

I also like to do crosswords puzzles and extreme suduko! But also this made me realize and provided the first strong evidence for short-range order in minerals, and it's important.

RK: I mentioned before that Igor Pekov wrote a paper entitled "Amazing new minerals: freak of nature or key to a solution of nature enigmas?" Because these small "insignificantly" tiny minerals may be neglected by many geologists, in that small minerals are just *curiosa*, so to say, and have no importance. I disagree with that because as even the most tiny ones reflects conditions of its formation of a mineral of unusual chemistry, and structure is a fine indication of unusual physical or chemical parameters of mineral-forming medium. And I think that these tiny minerals are also part of, let's use the word, mineral evolution.

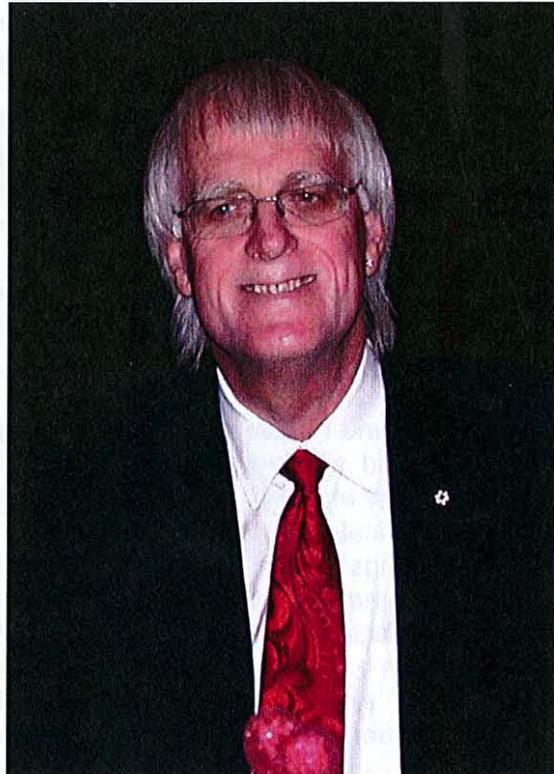
FCH: Yes, Pete Williams (chairman of CNMMN/IMA) put it very well when he said: "Every mineral has its own story". In addition to this, what I found in my work over the years is that "insignificant" minerals and new minerals often have structure characteristics we haven't been aware of before,

and sometimes they allow us to tie a whole bunch of minerals together, from a structural perspective into a structural hierarchy because they make you realize: - Ah, this is important!

Without that link you didn't realized the connections. The smallest or tiniest mineral can give you the information that gives you that link, and starts to join all the other structures together in to an understanding of the paragenesis.

RK: Well, I think that's more than I expected, Frank. Thank you very much!

FCH: You're welcome!



Frank C. Hawthorne in Tucson February 13, 2011.  
Photo Roy Kristiansen.