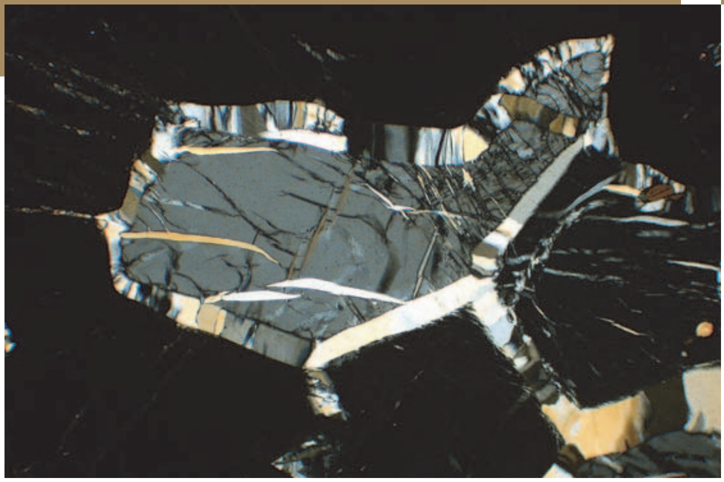
THE LITTLE MINERAL THAT CHANGED EVERYTHING

From the managing editor: In his iconic 1984 paper, "Coesite and pure pyrope in high-grade blueschists of the Western Alps: a first record and some consequences"—cited 711 times since publication and mentioned in 4 papers in this issue—Christian Chopin concluded his abstract with the following statement, "Eventually the role of continental crust in geodynamics may have to be reconsidered." Rarely does a single paper have an impact that leads to the development of a whole new area of research. Chopin's paper, and David Smith's paper the same year, heralded a new field of research. I thought it would be interesting to get the story of how this discovery came about, and Christian graciously accepted to be interviewed.



Photomicrograph (crossed polarizers) of a coesite rimmed by palisade quartz in pyrope garnet. Picture width about 1.3 mm. Courtesy of H.-P. Schertl

What led you to study the Dora-Maira rocks?

Mineralogist doing humble work: Christian Chopin at the pyrope–coesite locality near Martiniana Po, Italy, ca. 1984. Interesting minerals even pave the dirt road. Photo courtesy of C. Boberski

In 1979, after my *thèse de 3ᵉcycle* (French equivalent of the PhD) on the petrology of the Gran Paradiso massif (one of the three internal crystalline massifs of the Western Alps, along with the Monte Rosa and Dora-Maira massifs), I went for a postdoc at Bochum with Werner Schreyer to do experimental work at high pressure. Some of the rocks I had mapped for my *thèse de 3ᵉ cycle* were highly magnesian and offered promise as fine recorders of metamorphic evolution at high pressure through reactions among talc, chloritoid, garnet, carpholite, and chlorite, but these reactions had to be quantified. For more than 2 years, I did high-pressure experiments in the MASH system, working out the stability fields of the Mg end-members of chloritoid and carpholite. In the lab a whole group of people were working on various high-pressure and high-temperature phases. For example, Peter Mirwald and Hans-Joachim Massonne were working on the coesite–quartz transition, a classical pressure-calibration reaction, so I became familiar with these high-pressure phases.

Valle Varaita, Piemonte, Italy, in the heart of the Dora-Maira massif

After being hired as a CNRS researcher at the École Normale Supérieure (ENS) in Paris in 1981, I systematically searched for these magnesian rocks. I had already done reconnaissance work on the Monte Rosa massif, where I had found magnesian assemblages that pointed to higher pressures than in Gran Paradiso. So the next step was Dora-Maira, and a literature search led me to the 1966 *thèse d'état* of Pierre Vialon on this massif. He described the assemblage pyrope–talc–chlorite, which, to me, with my fresh experimental background, seemed impossible in Alpine rocks of crustal origin, as pyrope-rich garnet had so far only been found in mantle rocks. I was very intrigued. In the fall of 1982, with colleagues Bruno Goffé and Bill Murphy and armed with the crude location map provided in the thesis, we set out to search for these rocks. We parked the car and spent over an hour walking around trying with no success. After returning to our starting point, we took a closer look at the outcrop next to the car and noticed unusual whitish nodules. They turned out to be garnet, but the garnet was so magnesian that it was almost white. Vialon was right! We sampled the outcrop and I had thin sections made.

How did the coesite discovery come about?

When I studied the thin sections, I noticed weird, high-relief, low-birefringence inclusions in pyrope with radial fractures around them and their breakdown into quartz. If pure pyrope was there, however unbelievable it seemed, why not coesite? There was one simple way to confirm this—probe them. We had an easily accessible, entirely manual electron microprobe at ENS. I sure remember the day I probed these inclusions and confirmed that they were pure SiO_2. So simple and so exciting. Intense jubilation!

At that time, coesite was known in impact rocks and in xenoliths in diamond-bearing kimberlites. So what would coesite be doing in crustal rocks? For the Alpine petrologist, the straightforward hypothesis was that it was metamorphic coesite, but this was also the idea with the farthest-reaching implications. So I took several weeks to consider alternative hypotheses. For example, could it be an impact product, a placer mineral, or a high-shear product? But in the end, the simplest hypothesis by far was the metamorphic one—with all the implications it carried.

Did you have trouble selling your idea to reviewers or other scientists?

No, probably because the petrographic evidence was so compelling. I gave a talk on the discovery at the European Union of Geosciences meeting in the spring of 1983. Afterwards, I was approached by David Smith (Muséum d'Histoire Naturelle de Paris) who thought he had a similar quartz texture in Norwegian eclogites he was studying. As he had access to a Raman spectrometer, we were able to get a confirmation of the coesite structure of a tiny, relict grain within a quartz inclusion in the Norwegian sample.

Meanwhile, I had submitted a manuscript documenting my work to *Contributions to Mineralogy and Petrology*. The only negative comment the reviewers made was that the paper was long, but I wanted to provide a thorough petrological description. The paper was published in 1984, and David Smith's paper was published in *Nature* a few months later. After publication, I discovered that these pyrope megacrystals were actually already known within the Alpine community and that there were some samples in museums and collections. This shows how an extraordinary object can remain inconspicuous and unnoticed if there is no context to view it in. My good fortune was to be the one looking at these rocks with both a field and an experimental background. Serendipity or just "helping luck"?

Did this publication influence your career?

Yes, indeed. I spent the following 10 years mapping the extent of these magnesian rocks and clarifying the geological setting (with PhD students Caroline Henry and Gilla Simon, and colleagues in Bochum, Jerusalem, Kiel, Montpellier, and Torino). What was the relationship between this oddity and the country rocks that apparently had no special attributes (granitic gneiss with rafts of marble, metapelite, and eclogitic mafic rocks)? Was it just an exotic lens or, as it turned out, a part of a coherent, regional-scale metamorphic unit sharing these uncommon conditions of origin?

I then tackled the mineralogy, and this kept me occupied for another 10 years or so—these highly magnesian rocks were like Ali Baba's cave. We described several near Mg end-members of known minerals like staurolite, chloritoid, and dumortierite, accessory minerals, and new structures like the beautiful series between ellenbergerite (purple silicate) and its blue-green phosphate counterpart. This was the beginning of a long-standing collaboration with crystallographers. Investigating the same object using two completely different and independent approaches—crystallographic and chemical, and sometimes the spectroscopic approach—each of us pushing the others to the limits of their method, is a very gratifying intellectual challenge, which I am still enjoying. Not always on high-pressure phases, admittedly, even if I am currently involved in a study of blueschists in Turkey.

Christian Chopin was born in 1955 and grew up in Lyon, France. During family holiday trips through the Massif Central, across a horst and graben structure, to recent volcanoes and old leucogranites, he may have got an early feeling for Earth matters. After passing the national selection exam to enter the École Normale Supérieure (ENS) in 1974, he studied Earth sciences at the two nearby universities, Paris 6 and 7. He had teachers like F. Albarède, C. J. Allègre, V. Courtillot, and K. Lambeck, but he was attracted to metamorphic petrology through J. Touret, G. Guitard, and J.-R. Kiénast. During these formative years, he profited from the early laboratory access offered by ENS to its students. In Martine Lagache's group, he familiarized himself with experimental petrology and field mineralogy. He completed an Alpine thesis under the guidance of Pierre Saliot, studying the phase relations of Mg–Al-rich rocks at high pressure. He held a two-year postdoc position in Bochum, attracted by the enthusiastic personality of Werner Schreyer and a very active high-pressure experimental group. This stay marked the beginning of collaborations and friendships that shaped his career. He was hired by CNRS as a researcher at ENS Paris in 1981.

Exciting years followed, in his long scientific collaboration with Bruno Goffé. Goffé worked on lower-grade high-pressure rocks—and hunted carpholite worldwide—while Chopin studied the higher-grade ones, focusing on the Dora-Maira Alpine massif. Chopin became editor of the nascent *European Journal of Mineralogy* in 2001, and he has been head of the Laboratoire de Géologie at ENS since 2006. He is a firm believer in the publishing role of learned societies as an inexpensive alternative to monopolistic publishing houses.

What's next in UHP metamorphism?

Ever deeper! Since 1989, there has been a steady stream of discoveries of UHP rocks, and continental subduction is now seen as a standard feature of collisional belts. But as we study rocks that have reached higher and higher pressure, and so higher temperature, it becomes increasingly likely that we will only observe retrograde products—and so evidence is more and more elusive.

The recent discoveries of diamond in Alpine oceanic rocks and of what is interpreted as coesite pseudomorphs after stishovite in the Luobusa chromitite of Tibet are fabulous. I feel the same excitement as when I discovered coesite. This is the primacy of observation: a simple observation suddenly reveals huge gaps in the understanding we have of our planet. Like vertigo. Just compare our understanding of continental behavior 25 years ago with the present one, and imagine the progress 25 years after the Luobusa findings: our understanding of how the mantle works might then be radically different.

Some references paving the way to the coesite finding, and later related references:

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