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Presentation of the Mineralogical Society of America Award for 2005 to Tiziana Boffa-Ballaran

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Mr. President, Ladies and Gentlemen:

It was a pleasant surprise when Tiziana asked me to introduce her as the recipient of the MSA award for 2005, as she has worked with many excellent mineralogists and crystallographers who have influenced and guided her career more than I. Indeed, I suspect I have learnt more from Tiziana than she has from me.

Like many senior crystallographers, Tiziana comes from a farming background, having grown up in the small village of Sella di Tavigliano on the flanks of the Piemontese Alps in northern Italy. Mineralogists know this area better as the Ivrea zone, and for the eclogites at Monte Mucronne that lie above her home. Despite these mineralogical influences early in her life, Tiziana choose to study chemistry for her undergraduate degree, first at the University of Milan, and then at Pavia. However, when one reads Tiziana's CV for her undergraduate years one sees the seeds of the two pervasive themes of her subsequent career. First, she won scholarships to spend semesters at other Universities in Europe (Aarhus in Denmark, Aveiro in Portugal, and Wroclaw in Silesia) and so develop scientific collaborations and friendships that cross many international borders. In this sense Tiziana is a representative of the new model of European integration, maintaining her strong regional roots and traditions while developing links that span the continent; her new young family is another product of such collaboration! The other theme that appears in Tiziana's undergraduate record is thermodynamics of solid solutions, the topic of both her senior thesis and her work in Wroclaw, and it is this theme that formed the basis of the work for which she is being honored today by the Mineralogical Society of America.

Having emphasized Tiziana's penchant for travel, it will surprise you to discover that in 1993 she moved, not across Europe, but across the campus of the University of Pavia to start a PhD project on cation ordering in omphacites under the direction of Vittorio Tazzoli and Chiara Domeneghetti. There she received her crystallographic training, but she did not give up traveling for science. She went to Cambridge to work with Michael Carpenter and performed infrared spectroscopic measurements on the omphacites to try and probe the local states of order for comparison with the long-range average structures she had determined by diffraction in Pavia. It was this work that opened up a completely new perspective on the importance of elasticity in determining the thermodynamic properties of minerals, the consequences of which both she and many others are pursuing as a major topic of research to this day.

Most minerals are solid solutions. Yet, before Tiziana started her research, our understanding of the properties of solid solutions lagged way behind our understanding of pure end-member phases. For end-members the variation in macroscopic thermodynamic parameters was clearly understood in terms of vibrational and elastic properties and, where appropriate, the interactions between structural phase transitions and ordering. By contrast, the behavior of solid solutions was described in various ad-hoc approaches such as regular solutions, mixing parameters etc., approaches that were essentially completely divorced from the microscopic properties of the minerals. Tiziana's fundamental contribution to mineralogy has been the bridging of this gap. She developed a novel spectroscopic method to determine the local variations of structure within solid solutions. This method of auto-correlation analysis of infrared absorption spectra provided for the first time a demonstrable and direct measure of the local structure of a solid solution on a length scale that is intermediate between the atomic scale and the macroscopic. She has thus provided the link between measurable *microscopic* properties of solid solutions and their *macroscopic* thermodynamic properties, a fact reflected in the titles of her two seminal publications in *American Mineralogist* in 1998, "Structural mechanisms of solid solution and cation ordering" (June 1998; vol. 83, p. 419–433 and p. 434–443.) Such is as close to a revolution in our thinking about minerals as one can envisage in the field of modern mineralogy. Tiziana has continued to extend and refine these techniques and has applied them to a wide range of minerals, publishing papers on garnets, defect perovskites, amphiboles, and other pyroxenes, while also publishing several papers on the methodology itself.

In parallel with this work, Tiziana started investigating the effect of local inhomogeneities on the displacive phase transitions that can occur in solid solutions. She had developed the idea that the different degrees of mesoscopic strain in solid solutions arising from different states of cation order should be reflected in the phase transition behavior. I was therefore fortunate that she choose to visit my lab in Bayreuth for short periods in 1997 and 1998 to determine the magnitude of these effects on the high-pressure displacive phase transition in the cummingtonite-grunerite system by single-crystal high-pressure diffraction. In a series of painstaking diffraction measurements she was able to successfully demonstrate renormalization of the phase transition as the composition and state of order varies. She was also able to demonstrate, for the first time for a high-pressure phase transition, the plateau-effect. That is, the transition pressure is independent of composition at low concentrations of the second

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component in a solid solution, and only changes at higher levels of substitution. This is an effect rooted in the interaction between the local inhomogeneities in the strain field that Tiziana had been measuring by auto-correlation analysis of infrared spectra.

Tiziana's successful development of the auto-correlation method also provides some valuable insights into her character as a scientist. Her identification of a possible experimental resolution of the long-standing problem of characterizing and predicting the excess properties of solid solutions shows her breadth of knowledge of, and her insight into, mineralogy and thermodynamics. To achieve these new insights, she not only had to characterize and prepare samples for spectroscopic measurements with painstaking care. But she also had to develop the skills and methods to make the *quantitiative* spectroscopic measurements themselves to a precision that some, including a former editor of *American Mineralogist*, found impossible to believe. But now the mineralogical community appreciates that Tiziana's experimental results can be relied upon absolutely, not only in spectroscopy, but also in whatever field she is working. Furthermore, she is now passing on her skills and attitudes to her own international group of students and post-doctoral colleagues.

For example, it was Tiziana's experimental care and critical analysis that resulted in the detection of the plateau effect in the amphiboles that I mentioned above. Similarly, her care in her study of lawsonite by single-crystal high-pressure diffraction resolved discrepancies between almost half-a-dozen published, yet contradictory, papers on the elasticity of this mineral. It also identified for the first time an extremely subtle transition in lawsonite at high pressure resulting from the ordering of protons with the structure, and this discovery also resolved the confusion and inconsistencies in the published literature regarding the phase transition sequence in lawsonite.

In summary, Tiziana Boffa-Ballaran has, at an early age, made a fundamental contribution to the mineralogical sciences that is revolutionizing our understanding of the behavior of solid solutions. We already see that the methods she has developed have become essential components of many studies published in *American Mineralogist* and other international journals. Her talent and expertise has already been recognized internationally through the award of Panichi prize of the Italian Mineralogical and Petrological Association (SIMP) and a Marie Curie Fellowship of the European Community that she took up at the Bayerisches Geoinstitut in Bayreuth. She has now been appointed as the staff crystallographer of the Geoinstitut where she continues to flourish in an environment that, since its foundation by Friedrich Seifert, has always strongly encouraged high-quality, high-precision science. The Humboldt Foundation has similarly recognized her contributions to science and her promise for the future by their award of the Sofja Kovalevskaja Prize worth some three-quarters of a million dollars. And now it is the turn of the Mineralogical Society of America to recognize her achievements. Mr. President, ladies and gentlemen, it is with great pleasure that I now introduce to you my trusted colleague, crystallographer and friend, Tiziana Boffa-Ballaran, as the recipient of the MSA Award for 2005.