cron-sized minerals in polished thin sections are possible. Although quantitative analysis with this technique is still difficult and many problems in its application have yet to be overcome, the potential of the instrument has already been demonstrated in a number of excellent recent studies in mineralogy and petrology. There is no doubt that in the next few years, this new tool will open new frontiers of research in mineralogy and petrology that heretofore have essentially been beyond experimental approach. I am thinking, for example, of the measurement of the distribution coefficients of trace elements in synthetic and natural systems. Undoubtedly, Castaing's work will once again have a profound impact on our science.

Raimond Castaing is a Professor in the "Laboratoire de Physique des Solides" at the University of Paris at Orsay, one of the most outstanding laboratories in the world in this field. I should also mention that he is an accomplished mountain climber and excellent rugby player. He has published over 100 papers and has lectured extensively not only in Europe, but also in the United States. In fact, Castaing's frequent visits since 1951 to the U.S.A., particularly in the early years of electron microprobe development, have much contributed to the considerable progress that was made in this country in this field. Professor Castaing has been honored over the years by many scientific institutions and organizations, both in Europe as well as in the United States. However, it is especially gratifying that recognition now comes from the mineralogical scientific community which has benefitted more from his work than any other group of scientists.

Mr. President, it is a special honor for me to present the founding father of electron microprobe analysis, Professor Raimond Castaing, as the 1977 recipient of the Roebling Medal of the Mineralogical Society of America.

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Acceptance of the Roebling Medal of the Mineralogical Society of America for 1977

RAIMOND CASTAING

Université de Paris-Sud, Orsay, France

Mr. President, Dr. Keil, Members of the Mineralogical Society of America, and Guests:

I was extremely proud indeed when I knew that the Mineralogical Society of America had awarded me the Roebling Medal; but my essential feeling was a deep gratitude for the community of mineralogists, who have taken so large a part in the success of that technique of microprobe analysis that I had developed initially for metallurgical applications.

It was nearly thirty years ago, in the late forties, when I tried to apply X-ray emission spectroscopy to point analysis of metallic samples. I was just fresh from the Ecole Normale Supérieure and I had joined the Materials Department of the ONERA, the French office for aeronautical research. I had been given there in 1947 a magnificent Christmas gift: two electron microscopes, together with the suggestion of using them for studying the fine structure of the light alloys used in aircraft industry. I still remember my enthusiasm when I observed for the first time on the

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fluorescent screen the beautiful arrangements of tiny platelets or needles, parallel to the cubic axes, that the heat treatments developed in the aluminum alloys, and their selective nucleation on the individual dislocations along a polygonization boundary. Those observations were made on well-defined binary or ternary alloys, free of impurities; the composition and the structure of the precipitating phases were known from the X-ray diffraction studies that Professor Guinier was carrying out on the same samples. It was in the course of a discussion with him that I realized how unprepared the metallurgists were at this time for identifying the various phases they observed in the light microscope when looking at industrial alloys, where the number of components and impurity elements introduces a terrific amount of possible combinations. X-ray diffraction, or indirect methods based on the coloration by specific reagents, were applicable to known phases only and no technique was available for analyzing an unknown inclusion if its diameter was substantially less than one tenth of a millimeter. Guinier suggested that I explore the possibility of concentrating an electron beam onto such tiny inclusions and identifying their constituent elements from the emitted X-ray spectrum. That was the beginning of two years of alternating disappointment and excitement: disappointment when I realized that, however small the diameter of the electron probe, the spatial resolution would be limited anyway to the micron level by the diffuse penetration of the fast electrons in the specimen; great excitement when I found that the comparison of the same characteristic line, when emitted by the sample or by a known standard under the same electron bombardment, made possible cancelling out all instrumental parameters and getting the concentration of the emitting element in an absolute way. Finally, the experimental model of the microprobe that I had built by converting an electron microscope worked quite satisfactorily and a lot of workers came to my laboratory to put their specimens through the instrument. I still suspect that some of them tried to lay a snare for me when it happened that none of the elements they asked me to dose was present in their sample!

Apart those applications to specific problems, I shared my time between establishing the physical foundations of microprobe analysis and building a more sophisticated model of the microprobe itself, including magnetic lenses, vacuum spectrometers and an improved viewing system which used a reflecting objective; that instrument was put on the market by the CAMECA company and the first commercial unit was sold in this country, twenty years ago, to International Nickel. Meanwhile, a strong impulse had been given to the technique when Cosslett and Duncumb initiated the scanning mode of operation which allowed an automatic visualization of the distribution of the various component elements over an extended area. As for me, I had been appointed lecturer at the University of Toulouse; returning to my early loves, I developed an ion thinning procedure for preparing metallic samples thin enough for transmission electron microscopy. In the course of related experiments that I carried out with my young student Slodzian, we observed that the ion bombardment resulted in the ejection of secondary ions from the target. This had been reported by other workers several years before, but I realized on that occasion that I could combine both my fields of interest: microscopy and point analysis. I was not entirely satisfied with the scanning technique of producing distribution images, which looked to me a little tricky; I had tried without success to find a practical way for obtaining directly such images with the characteristic X-rays: the secondary ions were a possible solution.

I confess that, when Slodzian and I started the development of secondary ion microanalysis, we were attracted primarily by the nice exercise in particle optics which consisted in producing high resolution images with a mass spectrometer; I confess too that we spent two uncomfortable years before being convinced, by observing the first characteristic images on a copper–beryllium sample, that the secondary ions were produced at the sample surface—which was essential for microanalysis—and not by charge exchange in vacuum between the primary ions and the sputtered neutrals.

That procedure of producing sharp images through the non-gaussian optics of a magnetic prism worked surprisingly well and we spent exciting times in applying it with Hennequin and Henry to energy filtering in electron microscopy. Isolating the images produced by the electrons which had undergone a characteristic energy loss in the specimen provided the equivalent of color microscopy, and we found there a very convenient way for studying the so-called "coherency" of the various interaction processes between the fast electrons and the sample lattice. It is clear today that the development of field-emission electron guns and high resolution scanning microscopy has made this type of image filtering somewhat obsolete in electron microscopy, but the situation is not the same in secondary ion microscopy, due to the present

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lack of ion guns delivering high intensities in micron-size probes. The work of Slodzian and his coworkers has brought secondary ion microscopy to the point where it becomes possible to get in a few seconds distribution images of any element or isotope with a spatial resolution much better than one micron. The instrument is especially convenient for the examination of minerals, where the ionic bonds enhance the emission of secondary ions very strongly. In the hands of mineralogists, it has made it possible to visualize exsolutions and zoned structures with component elements whose average concentration is less than 100 ppm, in images of a striking beauty. That is indeed another reason why I feel indebted to your fascinating science, much more than it is indebted to me.

Mr. President, I am much honored to have been adopted so kindly by the community of mineralogists, and I accept this Medal with deep thanks to the Mineralogical Society of America.

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Presentation of the Mineralogical Society of America Award for 1977 to J. G. Liou

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Mr. President, Members of the Society, and Guests:

It is an honor and a privilege for me to introduce the MSA Award Recipient for 1977, J. G. Liou, of Stanford University.

Louie entered UCLA as a beginning graduate student in 1965 and, after a brief period of adjustment, embarked on a remarkable course of geochemical studies and experimental research which set the pace in our laboratories for the next decade. The current crop of grad students surely has grown weary of my regaling them with how much Louie accomplished in just *four years*. Not only was he phenomenally adroit at p-chem and thermo, but he coaxed equilibrium phase assemblages from some of the most recalcitrant chemical systems known to man: *P–T* diagrams were cranked out for wairakite, laumontite, lawsonite + quartz, prehnite and analcime. Unlike some of my own work, his phase diagrams seem to have withstood the test of time. During 1970–72 at NASA-Houston, Louie focused his attention on such well-recognized extraterrestrial problems as the stability relations of epidote and of andradite + quartz, and he experimentally modeled the greenschist → epidote amphibolite facies *P–T* transition zone in a natural basaltic system. Louie evidently was too busy finding out about the Earth to look up. He has continued broadening his laboratory studies since joining the Stanford faculty in 1972, but at the same time has turned to the field + petrochemical investigation of the lower grades of metamorphism as developed in Vancouver Island, western California and the Coastal Range of Taiwan; in addition, Louie has undertaken a comprehensive and definitive petrochemical study of the East Taiwan ophiolite.

This latter work represents part of a U.S.–Republic of China project in which John Suppe of Princeton and I are coinvestigators. We have been continually astonished at the scientific drive, creativity and incredible productivity of Louie. John and I live in constant fear of receiving phone calls from him; these invariably begin with a modest recitation of his latest burst of data collection, followed by a communication that we are soon to be sent a first draft manuscript of eighty pages (single spaced), and conclude with an ever-so-mild reminder to please try to finish up our small parts. I now appreciate the meaning of being "killed with kindness."

The MSA Award is meant to call attention to the significant accomplishments of a young mineralogically-oriented researcher, and to encourage his further activities. I am not sure whether the U.S.–Republic of China project—never mind the mineralogical world—is ready for increased productivity from Louie. Nevertheless, Mr. President, it is with the greatest pride and admiration that I give you our current MSA Award Recipient, J. G. Liou. Try not to encourage him too much!

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