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Memorial for Francis R. "Joe" Boyd

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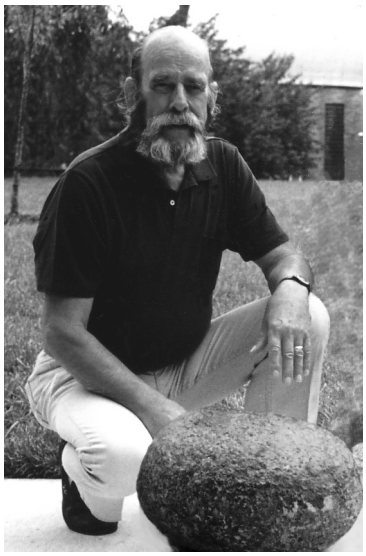
The careers of many scientists concerned with composition, structure, and history of the upper mantle are linked to the researches of Francis R. (Joe) Boyd. This was particularly the case from the mid-1960s when he became engrossed in kimberlites and their deep-seated xenoliths.

At the beginning of his career in 1956 he became a staff member at the Geophysical Laboratory, Carnegie Institution of Washington, and was widely regarded as a leading experimental petrologist. For example, in his work on phase equilibria studies, notably within the amphibole group, he developed a heating stage coupled with an X-ray spectrometer to record transitions. The Boyd and England high-pressure and high-temperature press, in which diamond was synthesised in 1960, was the most important development in allowing experiments to be conducted routinely, at mantle conditions. Like many of Joe's initiatives, it is still in use in most experimental petrology laboratories around the world. A hallmark of Joe's interest in the design of high-pressure apparati (latterly the cubic anvil) and their application to phase studies was his help and encouragement to colleagues, which extended to beyond his retirement! Joe's meticulous attention to detail and skill as an experimentalist, inherited in part from his mentor George Kennedy, laid the essential groundwork for experimentally calibrated thermobarometry at mantle conditions that is the mainstay of modern mantle petrology.

In the mid-1960s a kimberlite xenocryst, subcalcic diopside, focussed Joe's attention on rocks from the earth's mantle. Such pyroxenes plotted at very high temperatures, up to over 1400 °C on the En-Di solvus, which was one of the systems previously investigated by Joe with Frank Schairer. Although these "enstatite-diopside" analyses were known from old kimberlite literature they were largely ignored as inaccurate or pyroxene mixtures.

However, with the development of the automated electron microprobe at the "Lab" and with technical assistance by Larry Finger and Chris Hadidiacos, Joe was able to accurately analyse these mantle samples, as well as minerals from lunar samples being investigated by Steve Haggerty and coworkers. Thus the "probe" was the catalyst for the revolution in petrological investigations at that time.

Xenoliths were sent to Joe from the relatively fresh kimberlites in the mountain kingdom of Lesotho, which were free from the sampling restrictions elsewhere in southern Africa at that time. Joe's hours of attendance at the Lab were irregular and frustrating to some of his senior colleagues but in the late hours when most had gone home he produced first-class microprobe analyses—600 for the Lesotho Kimberlite volume[1] alone. Typically, at the end of a night's work he would dictate a letter to be dispatched the next day. One such letter arrived in Lesotho



Joe Boyd with a large peridotite nodule from the Premier Mine Kimberlite, South Africa.

with the puzzling phrase "*no jewels* were encountered in these kimberlites" until he pointed out this should read—"*nodules"!*

If mantle petrologists can be divided into "nodule" (xenolith) or kimberlite (lamproite, etc) groups then Joe was biased to the former. A benchmark paper in 1973 (see list of selected publications), delivered as President of the Geochemical Society extended thermometric measurements to include experimental barometric data of Ian Macgregor and coworkers (Al solubility in enstatite) in a chemical system comparable with that of the predominant mantle ultrabasic xenoliths.

For the first time xenoliths, which had been scrambled within single kimberlites (individual pipes from Lesotho), could be reassembled in order of depth stratigraphy, and their *PT* values of equilibration plotted on curves ("paleo-geothermal gradients" down to 200 km depth) frozen in Cretaceous time. The results confirmed the Clark and Ringwood continental geotherm and the Pollock heat flow value. There followed papers and conferences on these petrological "geotherms," with hotly debated arguments on their validity, the existence of the famous "kink" and its possible significance, and the origin of "sheared" peridotite xenolith textures—a real propaganda boost for mantle science.

[1] It was Joe's wish that his collection of rocks and his massive database of mineral analyses should be made available for research through the Smithsonian Institution.

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Following a suggestion by Joe and Henry Meyer in 1971, an International Kimberlite Conference (IKC) was held in southern Africa, where a little over 100 years before, the discovery of the Kimberley Pipes had provided the first examples of the host rocks of diamond. The Conference in Cape Town, 1973, was organized by John Gurney and colleagues, principally sponsored and facilitated by a "new" De Beers and staff, motivated by Barry Hawthorne. The Conference has been a template for the seven (so far) subsequent IKC values, key features being: organization by independent committees, sponsorship by institutions and companies, assistance for young scientists, sampling of kimberlite or allied volcanics (preferably with xenoliths and a hint of diamond) and conferences and poster sessions at entertaining venues. Boyd and Meyer masterminded the memorable (second) International Kimberlite Conference based in Santa Fe, in southwestern U.S.A.

After 10 years of voluminous correspondence, I (P.H.N.) at last met Joe. He came to Lesotho, prior to the Conference in 1973. I was intrigued to meet a striking-looking, long-haired (albeit thin on top) long-bearded, bronzed, courteous, warm-natured man, whom my four young daughters regarded as someone out of a fairy tale. He was an avid field worker, reflecting the demanding work in the Yellowstone Park for his Ph.D. (Harvard, 1958).

The 1970s marked an explosion of research in kimberlites and their xenoliths, with Joe at the helm of many novel multifaceted collaborative projects. Those co-investigated at the Lab, included the analysis of diamond inclusions (with Henry Meyer), the mineral composition and textures of ultrabasic xenoliths of Lesotho and Kimberley (Peter Nixon), and similar studies in Montana (Carter Hearn), and Premier and Angola (Bobby Danchin).

The discovery that diamonds were accompanied by lilac-colored low Ca knorringite-rich garnets at Finsch Mine by John Gurney was reflected by the garnets in diamonds analyzed by Joe and Henry Meyer. About the same time the publication of Ca-Cr plots of such garnets from Siberian kimberlites by Nick Sobolev and colleagues discriminated between a diamond-associated "harzburgite" field and a barren "lherzolite" field. These garnets were subsequently named G10 and G9 by Barry Dawson and Wes Stephens. Joe's acquisition of mineral concentrates from many kimberlite mine dumps yielded plots of Ca and Cr of over a thousand analyses of lilac/purple garnets that confirmed, with rare (but notable) exceptions, the relationship between the presence of G10 garnet and diamond in kimberlite.

Equally important was the confirmation of W.Q. Kennedy and Tom Clifford's rule of the early 1960s that diamondiferous kimberlites were restricted to continental cratons. The quantum leap in discovering the >3 Ga model age of diamond formation by Richardson and coworkers in 1984 revolutionized concepts of mantle evolution. Joe was in the thick of it. He and coworkers demonstrated (Body et al 1965; Boyd and Mertzman 1987) that the cratonic peridotite mantle (with overlying crust) was already in place within the Archean and that the ultra-depleted character of the "root" could be explained by early komatiite abstraction. This was a "first principles" and elegant approach using major element analyses of large fresh peridotite samples partly from the collections of his many friends. He plotted mg no. of constituent olivines with chemically calculated modal olivines to demonstrate that continental and oceanic peridotites were formed by different mechanisms.

The breadth and collaborative approach of his contributions is illustrated by publications on kimberlitic olivines (Boyd and Clement 1978), kimberlitic perovskite, and other oxides (Boctor and Boyd1980), Granny Smith diopsides (Boyd et al. 1984), ferric iron in garnets and their effect on thermobarometry (Luth et al. 1990), megacrystalline pyrope peridotites (Pokhilenko et al. 1993), and carbon isotopes of graphite in mantle xenoliths (Pearson et al. 1994).

Joe's enquiring mind focused on the need for geophysical collaboration at the first IKC in Cape Town where Tom Jordan was the sole representative whom the petrologists could bombard with impossible questions (why is your lithosphere not the same as ours?). Times have moved on but major questions remain. Joe was closely involved with the NSF funded multi-million dollar Kaapvaal Craton Project aimed at determining the 3D structure and chemistry of a segment of lithosphere stretching from Cape Town to Harare. Xenolith data from the world's best-known kimberlites are a key contribution. Joe generously provided access to his xenoliths and analytical database for this project and proved a marvellous catalyst for sub-projects ranging from Re-Os dating to density estimates of the craton root.

At the IKC 8, Joe gave his final, but characteristically lucid and informative lecture standing square to us, the audience—no notes, no Powerpoint—just a presence on stage telling us how it is…. Namibian lithosphere used to have diamondiferous roots but they were delaminated prior to kimberlite eruption.…Wow!

Joe first joined MSA in 1955–1956 and was elected a Fellow of the Society in 1962. He was awarded the prestigious 2004 Roebling Medal for his unmatched contributions to our science of mantle petrology, and for his global reputation.

Joe passed away on January 13, 2004. He leaves two children, Duncan and Hadley from his first marriage. His second wife, Margo Kingston, is a fellow professional geologist and the hostess of memorable times at their home in Chevy Chase in Washington. She provided tremendous support for Joe, tempered with good humour, and found time to accompany him in the field.

It is in the field, foraging on mine dumps for mantle samples, that we, his former colleagues and recipients of his unhesitatingly generous help, will cherish our memories of him.

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