locally derived. Geoff Percell (SUNY, Albany) detailed his XRF study of Yugoslavian pottery from the Roman occupation. He can distinguish localized clay beds. Matrix variations in the pottery, particularly in iron content, can cause problems. Henry Chaya (SUNY, Albany) used XRF to determine that Bear Gulch, near Yellowstone, was the source area for several Hopewell artefacts that had not been previously identified. Ba and Sr were the best discriminants for the sample suite.

The evening's discussion took place amid totem poles, reconstructed pots and the original survey map of Teotihuacan in the Archeology Museum, and was fuelled by lots of Buffalo-style wings, munchies, wine, beer and decadent desserts. This informal gathering allowed everyone a chance to talk to everyone else in stimulating surroundings.

On Sunday morning, Henry Schwarcz (McMaster) summarized his group's recent studies into stable isotopes in bones and pot residues. Bone isotopes show that maize was introduced to southern Ontario gradually, beginning at about 500 AD, but the isotopes from cooking residues in pots suggest that the maize was not used as a major component in stews. In Alaska, some local native groups did not exploit marine species, but used local terrestrial plants and freshwater animals. Isotopes of bones from North Africa indicate a dramatic shift in diet away from seafood to significantly more terrestrial plants at the Mesolithic-Neolithic boundary. Analyses of bones from Nubia show that children were weaned when about 3-6 years old, while analyses of hair indicate that more people died in the summer when food supplies were restricted. Hilary Stuart-Williams (McMaster) described his experiments to improve the analytical technique for measuring oxygen isotopes in bone. Diagenetic alteration destroys the $^{18}O$ signal.

The conference concluded with a discussion of the future for archeometry. Ezra Zubrow (SUNY, Buffalo) noted that, in 5 major US university libraries, some 3500 archeological books existed, compared to less than 20 archeometry texts. He felt that archeometry was not a "field", since it lacked a coherent theory and had no problems unique to archeometry. Discussion pointed out that most archeometry results are published as adjuncts to archeology reports. Where published alone, archeometry results occur in diverse and often obscure journals. The Library of Congress cataloguing system does not lend itself to easily finding archeometry references, nor does the split in journals between disciplines. Due to the lack of data bases for the social sciences (*i.e.*, data bases like GEOREF), getting access to information is exceedingly difficult. Meredith Aronson (Smithsonian Institute) commented on the poor "join between archeometry and archeology" in their common understanding of each other's problems and methods. For example, few archeologists attend archeometry conferences. Discussion suggested that the problem partially arose from the current American system for training archeologists within anthropology departments, thereby emphasizing social theory rather than scientific method. The newness of the field and the general low funding level available were cited as reasons for the lack of theory and adherents. Ron Hancock (Toronto) pointed out that archeology seeks to answer the "big questions", whereas archeometry often focuses on the "small problems". Rip Rapp (Minnesota) cautioned that archeology and archeometry must not grow apart. He added that we need to create archeology departments to train archeologists. Much of geology's recent success has been from applying the latest technical developments in the physical sciences to geological problems. Archeology and archeometry could emulate that also. Dean Snow (SUNY, Albany) commented that as an archeologist in a department dominated by social anthropologists, he feels as if he is having an academic mid-life identity crisis. Discussion also explored the differences between field-oriented archeologists and lab-oriented archeometrists. Certainly, some consensus was reached in the need for "transparent data bases" with easily understood key words. A major gap in the participants occurred between those who felt archeometry needed a theory to hold it together (predictably, mostly those trained in the social sciences) and those who wondered why the "problem" was even raised (generally, those trained as scientists). The discussion continued long and loud during lunch. An interesting personal view (Alvarez, 1991) regarding interdisciplinary research can be found in *GSA Today*.

The graduate students who organized the workshop should be congratulated. I think it proved valuable for all who attended. Certainly, the easy informal format fostered discussions, particularly spontaneous ones, which held people's interest. Future workshops may occur at other venues. People interested in attending next year's workshop or with ideas for future discussion topics are asked to contact Ezra Zubrow at the Department of Anthropology, SUNY, Buffalo, or at apyezra@UBvms.

## REFERENCE

Alvarez, W., 1991, The gentle scientific art of trespassing: GSA Today, v. 1, p. 29-34.

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# Accelerator Mass Spectrometry Workshop

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On April 15-16, 1991, more than 75 scientists from Canada and around the world attended the Accelerator Mass Spectrometry (AMS) Workshop hosted by the Canada Centre for Inland Waters, Burlington, Ontario. Its purpose was to review the state of AMS research in Canada, with a view to developing a plan for improving existing facilities and possibly developing new ones. Among the many reasons for such a workshop was the increasing difficulty in obtaining research funding in Canada for more expensive projects, such as new AMS facilities. Interestingly, the National Sciences and Engineering Research Council (NSERC) contributed significant support to bring in several international AMS experts to offer their advice.

The conference began by overviewing AMS facilities and capabilities worldwide. In reviewing the status of AMS research in the USA, David Elmore (Purdue University) quickly summarized the method and potential applications. The nine operating or planned machines in the USA have capacities ranging from 100 to 1000 samples per year, depending on the isotopes being analysed and the precision needed. Only three, however, do regular service work, although most will do samples in collaboration. Each of the various accelerators, which range from 3 to 9 MV, can analyse some or all of $^{14}C$, $^{26}Al$, $^{10}Be$, $^{129}I$, $^{3}H$, $^{36}Cl$, $^{41}Ca$ and several stable isotopes. W. Mook (Groningen University) noted that in Europe, ten laboratories were fully or almost operational, with capacities ranging from 300 to 2500 samples per year, mainly concentrating on $^{14}C$ and $^{10}Be$, with some $^{26}Al$ and $^{36}Cl$. Ken Purser (High Voltage Engineering Europa) described the new Woods Hole facility, which will concentrate on $^{14}C$ from ocean water samples, with a planned capacity of 5000 samples per year at ±2% and a six-week turnaround when fully operational.

Henry Polach (Australian National University) described the four facilities in Australia and New Zealand, which do or will do mainly $^{14}C$ and $^{36}Cl$ in geological (*sensu lato*) samples. In his experience, archeologists delivered 10% of the samples and 90% of the problems! He suggested that sample capacities could be increased if the current β laboratories were to produce some targets for AMS, but interlaboratory calibration is critical. To ensure quality dates, a laboratory cannot expect to date more than 300 to 500 samples per professional geochronologist per year. He noted that, in the most recent interlaboratory calibration, 45% of the $^{14}C$ analyses were outliers to the distribution! Mark Anthony (Texas Instruments) explained the advantages of AMS over SIMS for analysing very low trace concentrations of stable isotopes in materials. Although the capability to scan over a significant range of mass units is still being developed, the AMS applications in testing integrated circuits, semi-conductors, and other materials will soon be enormous. Jim Barker (Manchester University) described some uses for $^{26}Al$ analysis by AMS in biomedical applications. At the Lawrence Livermore Laboratory, John Vogel has been using $^{14}C$, $^{3}H$ and many other isotopes to test carcinogenic susceptibilities, define geotoxic substances, and trace biochemical pathways. He noted that the major worries, namely machine and laboratory contamination from the high concentrations of radioactive tracers in biomedical samples, could be reduced by isolating each stage of the target preparation from the accelerator and retraining the medical technicians in "clean" chemical practices.

Four reports from Canadian institutions were presented to review the current Canadian situation. R.K. Andrews reported that Atomic Energy of Canada Ltd. (AECL) is now running $^{36}Cl$ and $^{14}C$ on their AMS system at Chalk River. AECL has found that the gassy magnet significantly reduces the $^{36}S$ contamination, but that what $^{36}S$ does get through is then harder to separate from $^{36}Cl$. Using AgBr metal in the source may solve the problem. They plan to begin analysing for $^{32}Si$ and possibly for $^{99}Tc$. Ted Litherland (Isotrace, University of Toronto) noted that they average 600 samples per year, with typically a 3 to 4 month turnaround, mostly for $^{14}C$, with 70% of samples from Canadians. Their research and development program has concentrated on testing for negative ion production from many elements and oxides, developing new sources, improving isobaric separation, and defining ion optics. He reported that $Yb^{-}$ exists. In describing efforts to date to develop an AMS facility in Alberta, T.S. Lam (University of Alberta) listed several research departments in Alberta that support the effort. Dick Johnson (University of British Columbia (UBC)) uses $^{26}Al$ to study Al poisoning in dialysis patients and Alzheimer's disease. Work to understand osteoporosis will require $^{41}Ca$, while $^{129}I$ has several uses, including ensuring that used chromatographic resins from radioactive ion production are safe for disposal. The UBC group uses machine time at the University of Pennsylvania and the Hebrew University in Jerusalem.

Given these overviews, plus two written submission on the status of AMS in China (Li and Chen) and Japan, the participants broke into working groups according to their expertise or interests to answer the questions:

(1) Should AMS facilities and capacities in Canada be expanded?

This required estimating the potential analytical needs, including numbers of analyses, turnaround time, precision, isotopes needed, research and development, and availability of (or competition for) time at non-Canadian facilities.

(2) If expansion is needed, how to we go about it?

This required considering how to deal with user fees, accessibility, personnel, research and development needs, sample preparation needs, possible locations, and regional aspirations, in addition to the types and levels of support from governments, industry and the universities.

The eight working groups reported their findings after many hours of deliberation.

The oceanographers, as reported by G. Vilks, expressed a need for high precision dates and analysis of small samples, especially from estuary profiles and the global change program, where numbers of samples are expected to increase dramatically as funding is approved. They advocated a dedicated $^{14}C$ machine, fed by regional sample preparation laboratories. Research and development should concentrate on technical improvements, especially for $^{14}C$. Collaborative research involving dedicated teams for specially focussed research was preferred over user fees.

Henry Schwarcz (McMaster University) reported for the terrestrial earth science users group. They noted that sample costs often dictate demand, and felt that regional sample preparation laboratories would shorten turnaround times. A significantly increased demand for analyses using several isotopes will result from the global change program, which will also require research and development into several new isotopes, better precision, and smaller sample sizes. They suggested that down time could be reduced by having a continent-wide pool of spare parts and a second machine, dedicated to research and development, while the current Isotrace machine did service contracts. They indicated that each AMS laboratory needs to be a national/international facility, and that an "oversight" committee should be established to award free analyses to needy users, such as graduate students, and to priorize queues. Experience has shown that at least four years are required from AMS purchase to full operation, so we need to get started on expansion.

On behalf of the archeologists, Patrick Julig (Laurentian University) reported that they will continue to need high precision dates on small samples that represent 15-20% of total analyses, with potential increases coming from the authentification and cultural resource management applications. Sample turnaround time must be no greater than 3-4 months, but submissions tend to be very seasonal. Therefore, they thought that expansion is necessary, but that it should maximize existing resources, such as manpower, idle machines and existing buildings. Regional sample preparation would utilize existing expertise, maintain regional employment, speed turnaround, and probably decrease costs for commonly analysed materials, but interlaboratory calibration and quality control must be assured. Since Canada cannot afford to lose more AMS experts to the USA, we must find money to support new faculty positions, particularly in applications research. Wherever expanded facilities are located, the university must provide a guarantee of 10-15 years of staff and infrastructural support for the facility and the associated education programs, while governments must also provide a guarantee of 10-15 years of financial support for the collaborative research and educational initiatives, particularly increased funding for archeological research and better scientific training for archeologists. Education is critical to improve sampling and teach users about the limitations, applications, and potential for the various methods. In particular, specialists in applications are needed to liaise between the physicists and the clients. In the ensuing discussion, people noted that although archeologists are notoriously the most underfunded of AMS clients, they potentially have the largest numbers of samples and their results tend to be the most interesting to the public. Interdisciplinary research also is chronically underfunded. While any new/expanded facility must be located at an institution that can train graduate students, perhaps starting a second facility would increase the potential for that training.

The medical scientists, as reported by Doug Milton (AECL), noted that AMS potentially has applications in xenobiotics (cancer and toxicology research), metabolic studies, diagnoses and screening. AMS is particularly good for human testing, since doses can be much smaller than recommended dose limits. Analyses using $^{26}Al$, $^{14}C$ and $^{3}H$ could generate up to 10,000 samples per year (*i.e.*, approximately 16 times the current total

Canadian capacity!) at ±5% precision with a turnaround time averaging 2-3 weeks, while the other isotopes could generate another 500 samples per year, after the applications have been demonstrated. Research and development will be required to demonstrate the applications. The sample preparators must be re-educated to reduce contamination. Due to the high government and public support for medical research, a medical AMS champion is needed to push this application.

The hydrologists, represented by B. Andrews, expected to double their needs for $^{14}C$, $^{36}Cl$ and $^{129}I$ within 5 years, provided the reliability of the data is assured. They will need more research and development into smaller samples, a longer age range, and applications using new isotopes. A dedicated machine with assured base level funding and a linked graduate training program would ensure future Canadian expertise. With their increased environmental concern, industry should also support the facility. Perhaps a new funding category within the granting agencies is needed to ensure that infrastructure grants continue so that no user fees need be established. In the discussion, someone commented that, with current housing costs in Toronto, graduate students and even some researchers find it difficult to visit Isotrace for long-term collaborations. The University of Toronto also finds it hard to attract and keep qualified academic staff and students.

Reporting for the materials scientists, Jim Brown noted that their samples need little or no preparation. Research and development, however, are needed to accommodate the depth and spatial profiling, and rapid mass switching to enable spectral analysis across 50 to 250 mass units. Industry support will only be forthcoming *after* results have been demonstrated, therefore requiring extensive research and development into both applications and technology, but "if Canada does not get going at it soon, we'll miss the boat!" They favoured redirecting Isotrace to research and development, and dedicating a second machine to service. In the discussion, it was emphasized that research and development must occur even at a dedicated service machine, to ensure that personnel have a challenge.

Graham Wilson (Isotrace) summarized the needs of the economic geologists. They favoured expansion and automation of Isotrace, but not another machine. AMS offers several attractive features that other current technology (SIMS, ICPMS, RIMS, PIXE, NAA, AAS, TIMS) can not match, especially for low level trace analysis. Demand may increase to 1500 Au-Ag-PGE analyses per year, with ppb sensitivity and ±10% precision. After other applications have been demonstrated, further demand is likely. Research and development are needed to develop automation techniques, new elements for analysis, new analytical reference standards, depth profiling, and variable beam current and size (30-300 μm). They suggested that another faculty member be added to Isotrace to conduct research into these needs.

Henry Polach represented the international experts, who were specifically requested as a group to offer their opinions. After praising Canada for its long initiative in AMS, Henry reported that the group thought a second machine at Isotrace, dedicated to $^{14}C$, along with another faculty position would fulfill current and the short-term needs. Target preparation laboratories could be developed elsewhere. They stressed the need for more support from the University of Toronto, broader interaction and collaborative research both within Canada and abroad, new educational programs, more visiting fellowships and sabbatical leaves for AMS workers, increased graduate research, client education programs, continued high quality control, increased participation at international workshops and conferences, and increased research grants to allow clients to go outside Canada for analyses if Isotrace is unable to provide them. They did not seriously consider the medical or material science needs, which they thought might not be compatible with Isotrace, but might best be started at McMaster. In the discussion, the constant brain drain to the USA was bemoaned, as was the NSERC funding decision which allowed the McMaster facility to be downsized, with concomitant staff losses.

In the general discussion, which endeavored to synthesize the reports of the different working groups, participants reached a consensus on several points:

(1) Our Canadian AMS reputation cannot be allowed to erode further. We cannot afford to lose more manpower abroad. Current facilities must be maintained or improved to ensure continued status as a leading nation in AMS research.

(2) Canada needs a second machine now, and may soon need a third or even a fourth machine for medical and material sciences applications.

(3) A unified front by the AMS community is needed to ensure that support from NSERC, SSHRC and MRC is guaranteed, otherwise worthy applications may be rejected.

(4) The second machine should be dedicated, *but not technologically limited*, to $^{14}C$.

(5) The location for the second machine should be decided only after an open competition, but proposals that emphasize the utilization of currently existing facilities, either machines, staff, buildings or administrative infrastructure, should be preferred to help reduce costs. Proposals must also demonstrate long-term commitments from the host institution for staff, infrastructure and educational support.

(6) Whether or not expansion occurs at Isotrace at the University of Toronto, the machine there must be maintained and improved.

(7) A major function of the second machine will be to train graduate students, particularly in applications. It will have to be a national/international facility, with assured access to anyone needing it.

(8) Governments will be expected to provide continued long-term infrastructure funding for the current initiatives and for any expansions.

(9) Significant research and development will be needed to develop and demonstrate the utility of AMS in medical and material sciences. Development of analytical methods for new isotopes and new applications must continue. Continued technological improvements must also be studied.

Although consensus was not reached on several other points, the following ideas were advanced:

(1) Canada is a leader in earth science research.

(2) Canada cannot hope to compete with the USA in mega-projects, such as building a supercollider, but must cooperate with other multinational groups in those projects.

(3) Canada can excel in medium-sized (medium-priced) technological developments, such as AMS.

(4) Some money from the global change program and medical research funds should be funnelled into AMS development.

(5) The FN machine is the best general machine for current AMS needs and research and development.

(6) Isotrace may have to be established as an individual institute, distinct from the Physics Department at the University of Toronto.

(7) Archeological training and funding in Canada must be moved from social sciences to sciences.

(8) More emphasis in Canada must be placed on interdisciplinary research, of which AMS is an excellent example. Particularly, more funding and more academic staff positions are needed.

All participants were invited to assist in writing the final summary report of the workshop, which David Carlisle plans to release as soon as possible. Copies will be sent to NSERC, SSHRC, and MRC. Anyone wishing copies may contact Dr. Carlisle at Environment Canada, Ottawa, Ontario, K1A 0H3.

I think most participants felt that the time invested in the workshop was well spent. We all hope that Canada will continue to lead the world in AMS research. Certainly, this workshop endeavored to plan for AMS research for the next few years, and to help ensure continued funding. I congratulate the organizers — David Carlisle, Ted Litherland and Liam Keiser — for their foresight and organization. We need more conferences of this type in other interdisciplinary fields to foster co-operation rather than competition.

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