

BOOK REVIEW

Claudio Tuniz, John R Bird, David Fink, and Gregory F Herzog. *Accelerator Mass Spectrometry: Ultrasensitive Analysis for Global Science*. Boca Raton, CRC Press, 1998: 371 p. ISBN 0-8493-4538-3. List price \$89.95 US (hardcover).

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Longtime readers of this journal know that Accelerator Mass Spectrometry (AMS) has transformed from an exciting curiosity 20 years ago to a current mainstay of applied isotope research, especially of radioisotope geochronology. AMS made possible the quantification of long-lived radioisotopes that could not previously be measured with routine practicality. AMS also radically affected the purview and practice of radiocarbon dating and tracing, the target of perhaps 80% of all AMS measurements. AMS particularly enriches research that is carried out by collaboration among AMS “physicists”, experienced practitioners of conventional counting, and isotope geo- or bioscientists.

I attended my first Radiocarbon Conference in Seattle (1982) shortly after abandoning my “planned” career in high-energy cosmic ray astrophysics. There were 20 AMS scientists at the meeting (13% of the 154 attendees), most of us representing some species of experimental nuclear physicist. We were surrounded by the greater number of earth and archaeological scientists who mesmerized us with discussions of lab multipliers, calibration statistics, and box-models. AMS methods then under development were inserted in the last section of the proceedings, and only one research paper in the proceedings presented AMS data from a natural matrix (measuring ^{10}Be , not ^{14}C !). At the 1997 Radiocarbon Conference in Groningen, AMS laboratories sent 20% of the 244 attendees, and AMS was fully integrated into all sessions, with approximately half the papers reporting results based on AMS measurements. Indeed, many of the participants used AMS data exclusively, or as often as expenses permitted. The increased overall attendance at Groningen was due in part to the successful efforts of the organizers to especially attract scientists from Eastern Europe. However, many of the participants, particularly new graduates and young scientists, were drawn to the field by the exciting opportunities that AMS brought to the study of ^{14}C in natural systems.

By the time of the Seattle conference, AMS scientists had also convened informally to discuss technological development (Rochester in 1978 and Argonne in 1981). These meetings evolved into a separate AMS conference series in counter-tempo with the Radiocarbon Conferences. The published proceedings of these Radiocarbon and AMS Conferences have served as the primary archived resource about AMS for the scientific and education communities during the past 2 decades. Unfortunately, such proceedings are not readily available to a large fraction of potentially interested readers, since they appear under the auspices of relatively specialized journals. AMS scientists still spend a significant fraction of our time educating new colleagues about the subjects discussed in these volumes. We often wish for an accessible text that could be cited as an introductory substitute for our personal instruction and our collated collections of *Radiocarbon* and “NIM” (*Nuclear Instruments and Methods in Physics Research*) articles. *Accelerator Mass Spectrometry: Ultrasensitive Analysis for Global Science* by Tuniz et al. has now summarized AMS technology and applications.

It is fitting that a phrase such as “global science” appears in the book title, since AMS studies now advance fields of research as varied as volcanic reemergence of subducted sediments, ocean water mass circulations, geomorphology on many scales, human history and archaeology, chemical and biological tracing, climatic effects of mass and energy reservoirs, nuclear interactions, and atmo-

spheric gas transport (to name just a “few” subjects). Indeed, “global” is insufficient to include the effects due to solar system debris (discoid science?) or galactic cosmic rays (spiral science?), but these effects are pursued using “globally” available reservoirs such as meteorites or ice cores. It is this global reach of AMS applications that presents a formidable barrier to summarizing AMS science in book form. The authors are to be congratulated for their courage.

All the authors have experience in the gritty world of natural sample collection and chemical purification. They also know the torment of bullying the first generation of AMS measurements from accelerator systems that had been designed as sledgehammers for nuclear physics collision research rather than as scalpels for exquisite isotope ratio mass spectrometry. They have remained in the field and experienced the later generation of versatile, high-throughput spectrometers. The authors are familiar with all areas of AMS technology and application but, perforce, maintain particular interests in the research that first led them to AMS. For all 4, this includes the very long-lived isotopes of light (<50 amu) elements in geological matrices and their production by high-energy nuclear interactions.

A glance at the table of contents reveals the inclusion of all topics and subtopics that one could hope for in a general book about AMS. A closer look reveals, however, that many topics and most subtopics are covered in less than a page. Anthropogenic isotope production, including the immensely useful ^{14}C bomb pulse, is covered in one page, while extraterrestrial production merits 18 pages. Oceanography is summarized in 5 pages, but rare nuclear physics interactions are accorded 15 pages. Thus, this is a book of personal science as well as global science. The reader must use this text as a jumping-off point into further literature to find the broader coverage. Readers will find mention of fields already subjected to AMS studies by browsing this book, but they may not find the depth of discussion needed to determine the value of AMS for their particular interests. The authors wisely provide guidance to the reader in the front of the book with a “User’s Guide” that diagrams their suggested paths through the material for maximal use of what they offer.

One must first understand what AMS is and how it has been used in order to determine the likelihood of applying it effectively to a research problem. The book’s introduction follows this obvious path. There are perhaps 3 starting points for an explanation of AMS techniques and applications: *isotope ratio mass spectrometry (IRMS)*, of which AMS is a type that is done with highly energetic ions; *quantification of radioactive isotopes*, for which AMS is primarily used by the largest number of researchers needing detection efficiency greater than decay counting; and *nuclear physics*, from which discipline the initial technologies and practitioners arose. These authors (prudently, I believe) choose a modified IRMS introduction which reinforces the concept that AMS does not depend on decay properties. The IRMS approach also emphasizes a chief distinction between AMS and decay counting—the incorporation of the elemental abundance directly in the measurement as the denominator of an isotope ratio. This is covered quickly in the Overview of Chapter 1, so quickly that neophytes might not notice the important message. A plot is used to convey the AMS sensitivity advantage over counting radioisotopes, but the simple equation relating activity to the number of isotopes present might have better brought out the inefficiency of decay counting and helped those familiar with counting to see the place of AMS in terms of isotope lifetimes. The Overview also provides a quick introduction to AMS analyses in the scientific fields covered in more detail later. The valuable properties of AMS are further explained in terms of precision, background, contamination, and isobaric interferences at the end of the second chapter. These are “hidden” behind a less interesting, but extensive, listing of the isotopes that have been investigated using AMS, a list that seems to intrude at this introductory position in the text.

The instrumentation of AMS is described in more detail in Chapter 3, but here the detail and broad survey of assorted approaches again buries the message of what exactly makes AMS inherently sensitive. Spectrometer components of AMS are presented as sequential elements, without stressing the aspects that make AMS more sensitive than conventional IRMS. Instead, negative ions are seen to limit the elements amenable to AMS, and electron stripping is described primarily from the physicist's view as a charge-changing approach to higher energies. This chapter could have used a few more diagrams explaining ion behavior for the non-expert whose curiosity desired more than the Overview in Chapter 1 but who is not up to the equations that are so familiar to the physicist. The final introductory chapter, Chapter 4, covers the topic that most needs to be understood by the field scientist as well as the analytical scientist: sample specification and preparation. Again, the coverage is broad but shallow. Section headings at least alert the reader to the types of samples that have been investigated for the various AMS isotopes, and details are available from the copious references, including a serendipitous table that covers most applications of ^{14}C . Comparatively detailed tables of procedures are provided for a number of isotopes extracted from rock matrices. This 4-chapter introduction is gentle enough to lead the dedicated reader into the rest of the book, but does not present a coherent path that is independent of external guidance. Although the authors plainly suggest in their user's guide that "readers interested chiefly in applications should proceed directly from Chapter 1 (Overview) to Chapters 9 to 14 (Applications)", I think that some judicious reading of the other introductory chapters will be needed to make this leap.

This leap over 4 chapters will definitely be the desirable path for most readers, because Chapters 5 through 8 present a dauntingly detailed discussion of the physics of *in situ* radioisotope production and distribution. Having started scientific life a cosmic ray enthusiast, I appreciate the collection of this material into 4 organized chapters, clearly the heart of the book in the authors' view. Exposure dating using *in situ* production of isotopes in rocks is a field that was nearly (totally?) impossible without AMS. This collection of the physics needed to interpret this revitalized research is now usefully in one place for the first time. The section is less essential to the "isotope tracers" in oceanography, atmospheric, climatology, carbon cycling, biology, and organic chronography. However, even the utilitarian tracers amongst us should know the sources of our isotopes, and a discussion of natural and anthropogenic environmental production and distribution (including some simplistic diagrams) could have been isolated from the copious rocky material for their benefit. Certainly sections 7.1 and 7.4 should be read by many readers on their way from the introductory chapters to Chapters 10 (Environmental Applications) and 12 (Archaeological Applications). A different arrangement of the book might have brought some application chapters forward, including some geoscience tracing, and delayed the production and distribution chapters for presentation with Chapter 9 (Extraterrestrial Applications) and some topics in Chapter 11 (Geoscience Applications). Had this been done, some of the repetition in Chapters 9 and 11 of material in Chapters 5–8 would have been more obvious (or eliminated), and most readers could proceed more easily from the introduction to non-*in situ* Applications.

Applications like archaeology, environmental tracing, biology, and material science have become some of the greatest pleasures to AMS physicists, if my understanding of my colleagues has been accurate. When many of us started down a road to experimental nuclear physics and related subjects, we were fulfilling a curiosity about fundamental properties of nature, probably with little thought to later employability. Little did we know that decades later we would be involved in studies with art curators, entomologists, soil chemists, climatologists, lunar prospectors, ocean biologists, and so on. Any description of the applications of AMS is always a pleasant read, and Chapters 9 through 14 of this text are no different. No matter what the research, the sensitivity of AMS provokes amazement

that “that” can actually be quantified and understood—choose your own “that”. I would have failed the Ph.D. qualifying exam if I had been asked how to determine the length of time that a meteorite had spent in space since it was blasted from a larger body and *then* to determine the length of time that the same object lay beneath the ice fields of Antarctica. Physicists can now even address biological conferences and actually command respect for data showing the cycling of 35 μg of folic acid in a human over hundreds of days. AMS is still a quiet revolution happening in many fields, and these chapters provide just a taste of the possibilities without exhausting the potentials. We all have our favorite subjects and could quibble with the authors over their choice of topics, but they capture, with varying success, the excitement of AMS in globally diverse research. The least satisfactory description is that of life science applications. I hesitate to criticize it, however, since the authors could complain in turn that those of us who are taking AMS into biology have not published as much as we might have. This subject is farthest from the authors’ interests and experiences. Life scientists will not gain enough from this text to begin their own use of AMS. A set of colored plates between Chapters 10 and 11 provides visual hints of the scientific fun to be had in applying AMS around the globe, despite the serious look of Dr. Tuniz in one photo that is also on the cover (shown holding a 2000-yr-old Madagascan elephant bird egg dated at ANSTO).

The 4 appendixes provide 2 lists and 2 text sections. Appendix 1 is a very handy form of the “Middleton Bible”, which simply is the starting point for all considerations of producing negative ions required for AMS. Appendix 3 attempts to list all the AMS facilities that had operated at the time of writing, including the sadly high fraction that produced only a demonstration of some AMS capability and those that have been discontinued at nuclear research centers. Appendixes 2 and 4 provide the equations and explanations of 2 concepts that are so central to the use of AMS that their appearance only as appendixes mystifies me. The interaction of energetic ions with matter (Appendix 2) forms the basis of both molecular destruction through electron removal and particle identification through energy loss that are fundamental to the advance of AMS over low-energy MS and decay counting. All students of AMS need *some* understanding of this material, while fewer users need understand the detailed production of isotopes that is accorded lengthy explication in the main text. The situation appears even more extreme in the case of Appendix 4, “Data Reduction and Interpretation”. One pedagogical approach to AMS would set forth the fundamental properties of decay counting (a subject not found in a single coherent form in this book) with a following contrast to the information derived from an isotope ratio or concentration. Some of this contrast is only suggested in this appendix and sparsely in other parts of the text. Many people come to AMS with prior experience in decay counting, and their success with AMS seems proportional to their ability to distinguish the reduction and interpretation of isotope ratios from counting data. This contrast affects the designs of all experimental use of AMS, whether the samples contain “natural” radioisotopes or tracer levels of applied isotopes. The sketchy view in this appendix mentions most of the relevant factors: fractionation, production, contamination, efficiency, comparison to standards, calibration, reservoir effects. Missing is a discussion of isotope dilution, equivalent to the carrier addition that is mentioned in passing in the various recipes for sample preparation. The authors hint at the importance of these appendixes by including them in a prominent place in “A User’s Guide” at the start of the book. At least 2 of them were worthy of a chapter among the introductory material.

Following the appendixes is a glossary of about a hundred words or phrases that the student will find useful, as may the curious specialist who uses the text to wander into a chapter far from his or her expertise. The definitions seem superficial, however, and define either words that are fundamental to isotopic studies or concepts that are so specialized as to appear only once in the whole text. In either case, they could have been well defined in the relevant introductory passages or at the time of

their single use, with lookup access through the index. The index itself is broad but lacking some discipline, with even cursory uses of a phrase sometimes indexed when they offer little additional information on the indexed topic.

The 1200 references are drawn heavily (about 50%) from the 2 journals that have been the mainstay of AMS publications, *Radiocarbon* and *Nuclear Instruments and Methods in Physics Research*. References are predominantly (about 2/3) to applications of AMS. The references thus form a strong base for more detailed reading about the use of AMS in diverse fields. They include meeting abstracts, which are less useful for archival recovery. The references, as well as the text itself, seem to be complete up to about 1994, or just after the Sixth International AMS Conference, whose proceedings were coedited by 2 of the book's authors. References beyond that date are decidedly more spotty, but journal databases available through the Internet can be used by the interested reader to fill in the recent work performed by authors referenced here. Confirming the proper link from a citation to a listed reference is not an enjoyable task in authoring papers, let alone in a book of this breadth. Unfortunately, it appears that there are at least a few misconnections, or that the authors were specifically loose with publications of this reviewer. The most egregious one noticed, under Figure 14.2, mistakenly credits the Zurich laboratory with biochemical kinetic studies at least 8 years before we obtained the data shown in the figure.



This volume will be comfortable territory for the physicist versed in nuclear or particle science. It will not be as readily absorbed by applied scientists or students from distant fields seeking to understand the capabilities, processes and limitations of AMS in their areas of research. While trying to capture the "global" impact of the AMS technique, the authors were tempted by too broad an approach. On the whole, the book fails to impart a truly global view of the moving body of AMS work. Some attention to a grander synthesis of isotope science and the underlying conceptual foundations of AMS would have more lasting value. This text is a good AMS reference that allows the reader to avoid many trips to a library in search of *Radiocarbon* or *NIM*, but it is an insufficient guide to the growing power of AMS in some fields. A knowledgeable instructor could construct a graduate geophysics course around this text. As the only purposely composed book (excluding proceedings volumes) about AMS, it is a useful reference for the AMS student, and partially serves the serious scientist approaching AMS for isotope quantification.

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