





National Ocean Sciences Accelerator Mass Spectrometry Facility

Providing high-precision, high through-put AMS radiocarbon dating services since 1989

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|--|--|---|

The Woods Hole Oceanographic Institution's **National Ocean Sciences Accelerator Mass Spectrometry Facility (NOSAMS)** was established in 1989 to serve the ocean sciences community with high-precision C-14 AMS measurements. About 60% of our analyses are made on carbon extracted from 500 ml seawater samples collected in the framework of WOCE (World Ocean Circulation Experiment): Check out some of the results.

The remaining analyses are on a wide range of carbon samples prepared from organic and inorganic materials of marine origin. Presently, we report analyses with a routine precision of below 4 per thousand on samples with a C-14 content of more than 70 % of that of a *modern* sample.

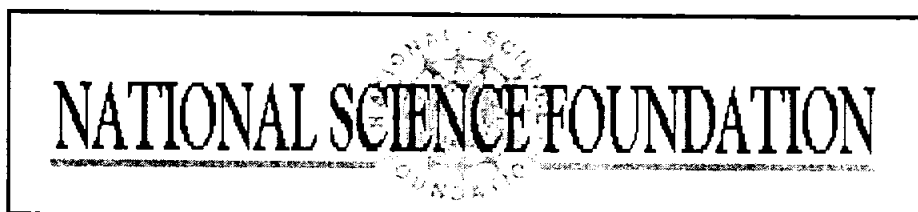
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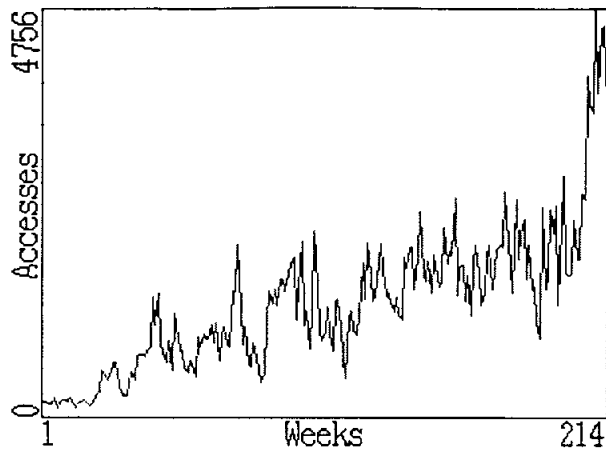
[Send E-mail to the NOSAMS Staff!](#)

Our work has been funded by the *National Science Foundation* and we are all grateful to the agency and program managers for their support.



NOSAMS Facility server usage statistics (via wusage 3.2).

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The NOSAMS Facility has been recognized as a Magellan 3 Star Web Site!



● *This home page will be updated continually. Last updated July 20, 1999. Please be patient as we change things.* If you have any comments, criticisms, corrections or complaints, please email: kvonreden@who.edu or rhealy@who.edu



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NOSAMS Frequently Asked Questions

- Where is NOSAMS located?
- What services can NOSAMS provide?
- How much does an AMS analysis cost?
- How long does it take to get a result?
- Why should I send my samples to NOSAMS?

Where:

The National Ocean Sciences AMS Facility is located on Cape Cod, Massachusetts between Falmouth and Woods Hole on the campuses of the Woods Hole Oceanographic Institution. Please see our local [map](#) for more details. Our mailing address is

National Ocean Sciences AMS Facility
Mail Stop #8
McLean Lab, Quissett Campus
Woods Hole Oceanographic Inst.
Woods Hole, MA 02543
tel. 508-289-2469
fax 508-457-2183

Services:

NOSAMS supports research not just for the ocean sciences, but for all studies of global change. Any carbon-bearing material has the potential to be AMS analyzed and our facility has an on site Sample Preparatory Laboratory (SPL) capable of treating a large variety of materials containing carbon (see [submission information](#)).

- *organic carbon - sediment, plant, wood, charcoal, textiles*
- *inorganic carbon - minerals, carbonate shell, sediment, dissolved inorganic carbon (DIC)*

We will gladly accept CO₂ samples and routinely run graphite samples produced by several outside Sample Prep Labs

Sample sizes:

- Standard (typical) sample analyzed in the AMS: 300-500 ug C (precision <= 4 per mille)
- Smallest sample yielding full precision: 300 ug C
- Ideal total submission: = (yields) 1 mg C
- Smallest samples analyzed: 20 ug C (*see Eglinton et. Al., Science 277, 796-799, 1997*)

Turnaround time:

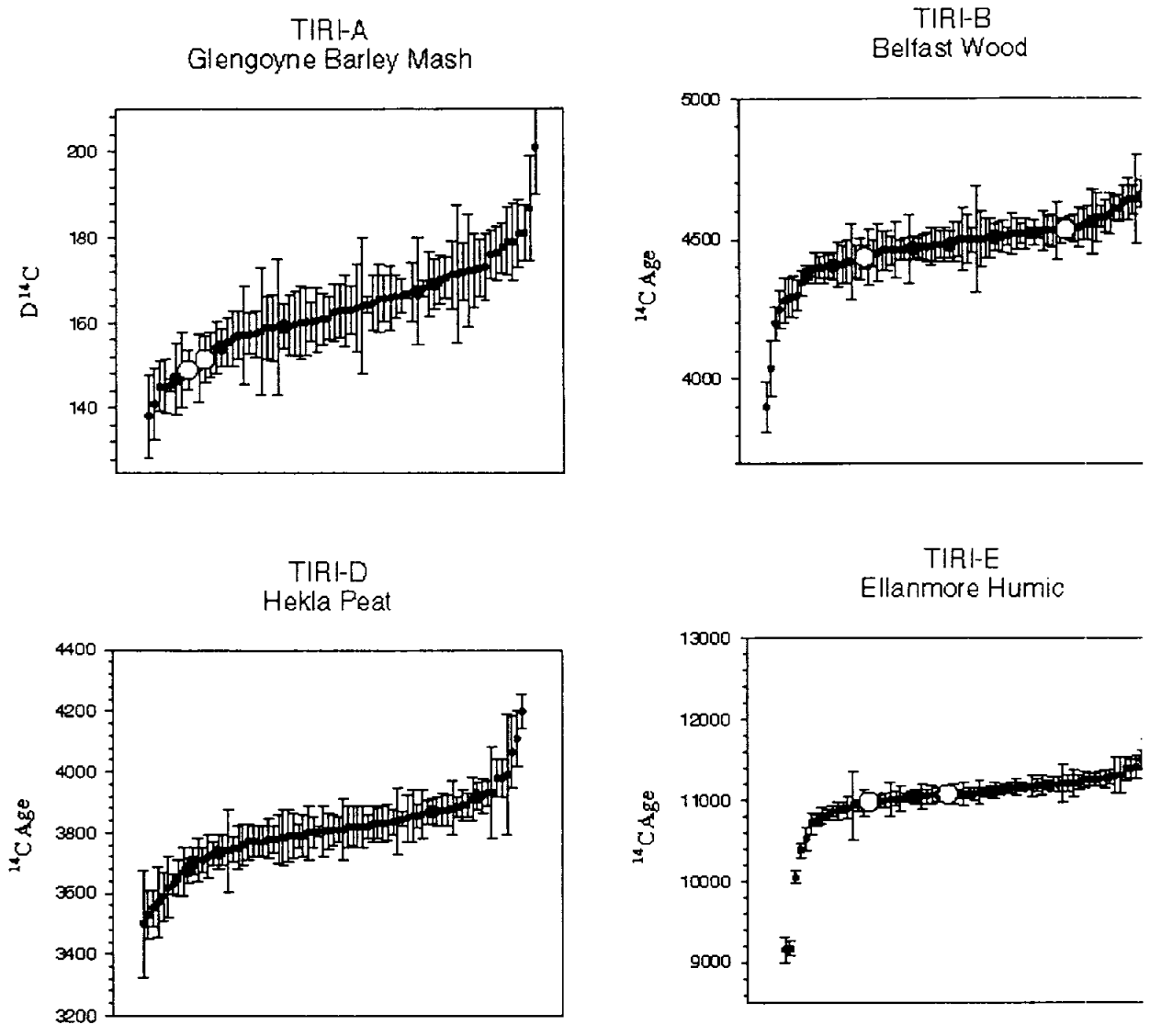
The turnaround time can depend largely on the type of sample(s) submitted (amount of pretreatment required prior to AMS analysis). Current *average* turnaround times for different sample types are available [graphically](#).

We also provide a faster, Quick-Turnaround Queue for investigators with pressing need. A letter or e-mail requesting quick turnaround may be addressed to Director John Hayes (jhayes@who.edu). Evaluation will be based on the scientific significance of the proposed work together with any limits imposed by deadlines. NOSAMS is committed to lowering the turnaround time between submission and reporting of results to meet the needs of investigators.

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Why should I send my samples to NOSAMS?

- We are committed to providing the highest quality of sample preparation techniques as well as the highest levels of AMS precision. (See Section 5 Papers and Other Documents')
- Participation in the Third International Radiocarbon Comparison (TIRI) show that NOSAMS blanks are among the lowest in the world and that our calibrations are in precise accord with international norms.
- We're willing to work with clients. We welcome and encourage communication in order to attain the best and most appropriate radiocarbon results addressing your particular research problem.
- Our ongoing developments in new areas of research interest using AMS radiocarbon techniques expand the possibilities of your research. These recently include:
 1. acquisition of a two-dimensional preparative capillary gas chromatograph system to expand present work in the study of compound-specific ^{14}C measurements.
 2. addition of 10 new microscale graphitization reactors to process smaller samples (as small as 25 ug C).
 3. acquisition of a new, larger NEC sputter ion source (handles 134 samples/wheel as opposed to current 60/wheel) with improved reliability.
 4. development of a gas phase ion source with potential to improve direct analysis of small volume CO_2 samples (current ion sputter source analyzes solid carbon targets).



Results from analysis of samples included in the Third Radiocarbon Intercomparison (TIRI) Study. Preliminary results from other participating laboratories (filled black circles) and 60 AMS analyses made at NOSAMS (filled yellow and red circles).

| <i>Sample Submission Information for:</i> | <i>Sample Processing Information for:</i> |
|--|--|
| <u>Bulk Sample Submission</u> | |
| <u>Inorganic Carbon</u> | <u>Acid hydrolysis (HY)</u> |
| <u>Organic Carbon</u> | <u>Closed tube combustion (Organic Carbon)</u> |
| <u>Gas (CO₂)</u> | <u>Graphitization (OSG)</u> |
| <u>Graphite</u> | <u>Target Press</u> |
| <u>Targets</u> | <u>AMS Analysis</u> |

The NOSAMS database consists of over 120 tables, which contain more than 1200 fields. The process numbers above, (rec, HY, OC, OSG, TP, and OS) are linked in this relational scheme such that any procedure performed on a sample is tracked in the database (see [database overview in PDF format](#)).

The daily status of sample processing is made available to submitters via our web-based [Sample Status](#) application. If you input your sample receipt number (or a range of rec #'s), the status of your sample is displayed on-line with a process number and date.

Organic Carbon

Plant or wood material

- Twigs, leaves, bark, seeds, peat
- charcoal, gyttja, seaweed, pollen

Total Organic Carbon (TOC)

- Sediment or soil TOC

Miscellaneous

- Parchment, insect parts, fish scales, cellulose

Submission of Organic Carbon Material:

Purify your samples as much as possible. We do not clean or separate raw components in the Sample Prep Lab. All submitted material undergoes the appropriate pretreatment scheme and is then converted to CO₂ using a closed-tube combustion procedure. Plant or wood samples undergo an *acid-base-acid* pretreatment procedure to remove any inorganic carbon and certain mobile humic materials before conversion to CO₂. Sediment (C_{org}) samples undergo the acid pretreatment only, to remove inorganic carbon before combustion.

If you are submitting plant, wood or charcoal types of material, make sure that you have properly cleaned and separated any non-plant, wood or charcoal type material from the sample. It is obviously best to date clean, pure materials such as charcoal rather than a mixture of components. It can be very difficult to determine the origin of bulk organic matter in sediment and that is the very reason charcoal (or another more specific material) can be the preferred dating material. If extraneous material is included with your submitted sample that contains organic carbon, the radiocarbon results can potentially be contaminated by younger or older carbon. For example, modern roots or rootlets can penetrate to levels where sediments are collected. Separation or purification of the component you wish to analyze should be performed by gently cleansing samples, sieving and using a wet "picking" brush under microscopic or magnified examination. Then, if further cleaning is necessary, gently sonicate samples with distilled water and draw off the supernate. Repeat until clear. Dry, weigh and store samples in clean glass vials.

When preparing organic samples for submission, avoid directly touching them since oils from your skin can contribute carbon to the sample. Aluminum foil is used in our Sample Prep Lab only after it has been baked in a muffle furnace and rinsed with solvent to remove the petrochemicals that coat the surface and could come in contact with a sample. We prefer that samples arrive in clean glass vials rather than foil because glass is easily cleaned and the sample material remains visible. Foil is awkward and material can be lost when opening and closing. Before sending samples, visually inspect them in the vial. If you see fibers, terrigenous or any extraneous material, REMOVE it please! The most common contaminant is fibers from clothing or strands of hair that make their way into the sample container.

The organic carbon content of materials such as sediment, wood or charcoal can vary considerably. So please, either indicate on the submittal form what the measured % organic carbon content is and the method used to determine this or indicate that this procedure must be performed in the Sample Prep Lab with a CHN analyzer (for an additional small fee). This information is required for us to correctly gauge an appropriate amount of sample for the closed-tube combustion. Too much material will cause the tube to explode and the sample to be lost and too little material will result in an insufficient amount for AMS analysis. Organic carbon samples will not be processed without this information unless there is not enough material to spare for a %OC analysis. In these cases we simply combust the sample and see what we get. In any case where less than 500 micrograms of pure carbon are produced, a dilution technique must be considered. The dilution process adds to the cost per analysis (see [NOSAMS fee calculator](#)) and reduces the precision depending on the amount of carbon submitted and its ¹⁴C content, e.g. age. (Click here to learn more about the dilution technique and *small sample analysis at NOSAMS*.) If you are not sure whether, or expect that less than 500 micrograms of pure carbon will be extracted in the Sample Prep Lab, please indicate on the submittal form whether you wish for us to perform a dilution. This can streamline and speed up the processing if this issue is worked out before hand.

In this document we provide some detail on the data analysis at NOSAMS and limits to the precision of the results.

The graphite derived from each of your samples is compressed by our target press and inserted into the cathode of the ion source. After acceleration and removal of electrons, the emerging positive ions are separated and the C-12 and C-13 ions are measured in Faraday Cups where a ratio of their currents is recorded. Simultaneously the C-14 ions are recorded in a gas ionization counter, so that instantaneous ratios of C-14 to C-13 and C-12 are recorded. These are the raw signals that are ultimately converted to a radiocarbon age.

From a contemporary sample, about 150 C-14 counts per second are collected. It is expected then, for a 5,570 year (one half-life) or 11,140 year old (two half-lives) sample that 75 or 38 counts per second would be obtained. (The mass-specific activity scales as $(1/2)^{n}$ where n is the number of half-lives.) Although one can simply measure older samples for longer times, they are constantly being consumed by the ion source, so there are practical limits to the minimum sample activity that can be measured, depending on how much material you have. At the present time, this limiting age is ten half-lives, or 55,700 years, set not only by the sample size but also by blanks. The blanks (for inorganic samples we use Carrara marble) contain small but measurable amounts of C-14 from contamination introduced during chemical preparation or other handling techniques during sample collection. Organic materials, which require the most processing, are limited to younger ages by their corresponding blanks. Since it is always necessary to subtract the counts due to blanks from the counts due to samples and standards, it becomes a statistical problem of measuring the differences between small numbers.

The fraction-modern is computed from the expression:

$$F_m = (S - B) / (M - B)$$

In the equation, B, S and M represent the C-14/C-12 ratios of the blank, the sample and the modern reference, respectively. When the statistical error in the fraction-modern begins to exceed the fraction-modern value itself, we quote a limiting age. Standard practice is to limit reporting ages to fraction-moderns which are at least two standard deviations from the blank, or background levels. At the other end of the scale, we measure many seawater samples for C-14 concentrations which are close to the values of the oxalic acid standards. These do not have a blanks problem, but the fraction-moderns are closer to unity, i.e. more sensitive to uncertainties in the standard values.

Aside from the normal statistical errors intrinsic to the counting of C-14 events, there are additional statistical errors from the several corrections and adjustments that are necessary for us to arrive at a reportable result for you. We measure the deltaC-13 value, both on the AMS machine and off-line on a stable isotope mass spectrometer for each sample, unless you, the user have already measured it in advance. This is necessary for us to correct each result for natural fractionation, as is customary, to -25 per mil. The correction, which varies between zero and 5%, has its own uncertainty of 0.1%. The added benefit of measuring the deltaC-13 online during AMS C-14 measurements is that we can correct for any machine fractionation effects. These have turned out to be small, and can be minimized by proper tuning techniques, which ensure that there is no isotopic shift between sample and standard. The overall AMS system stability contributes about 0.2% and the sample preparation contributes 0.25%. As an example of a typical analysis, consider a case where the counting statistics is 0.35%. When all these are added in quadrature, the total error in the measured fraction-modern averages about 0.5% for a wide range of our samples. This is what we refer to as the precision of our results.

- Counting statistics (sigma).....0.35%
- AMS system stability.....0.20%
- Sample processing.....0.25%

DOI 04349

● deltaC-13 correction.....0.10%

● **Total Error.....0.48%**

In the above table the error introduced by sample processing was inferred by subtraction from the observed total error. It includes many contributions, such as inhomogeneity of the graphite, varying hydride content, and yield-dependence that have not been completely established. Any of these error contributions can be minimized to reduce the overall precision. For example, the counting statistics can be reduced by counting a sample for a longer period of time. With special data-analysis methods, the system drift or instability can be removed from the data. The highest precision which we have obtained to date is 0.3%, for a group of seawater samples. Seawater samples, which make up most of our output, are reported by DeltaC-14, the concentration of C-14 in parts per thousand relative to the modern standard at the time of sample collection. Other samples are reported by their radiocarbon ages, which result from taking the log of the fraction modern:

$$\text{Age} = -8033 \ln (F_m)$$

The error in the age is given by 8033 times the relative error in the F_m . Therefore a 1% error in fraction-modern leads to an 80 year error in the age.

Finally, the errors reported to you are the larger of the intrinsic counting statistics or the total error as measured by the standard deviation among the several measurements we make on each sample. For example, we may measure each target up to 9 times over the course of a 2-day period. The error in each of the individual 5-minute measurements may be dominated by the C-14 counting statistics. Long term instabilities and other systematic errors may show up in repeated measurements at longer intervals. We look at the distribution of all the measurements on a sample and compare the standard error to the standard deviation of the mean.


DOI 04350

Fees for Radiocarbon Analyses

National Ocean Sciences Accelerator Mass Spectrometry Facility

Fees charged at NOSAMS are currently under review. The amounts listed below for federally sponsored research are unchanged from previous levels and are not expected to change. Those for all other investigations are provisional. They represent a 5% increase over the previous maximum fees.

Costs can be estimated precisely using the formula given below. Alternatively, the following values can be used for constructing budgets. For federally funded projects, **approximate per-sample fees** are \$125 for samples in the form of graphite, \$205 for samples in the form of CO₂, \$275 for samples of carbonate minerals, and \$300 for samples of organic carbon, seawater DIC, or soils. Projects that are not federally funded are not eligible for the NSF subsidy, and these costs should be doubled.

The *fee-estimate calculator*  incorporates the equation below. Please review [Collection and Handling of Samples for Analysis by AMS](#). For information on pressed graphite samples click [here](#).

Cost per sample, dollars = $X(120 + 40/n + C + P + A + D)$

Where

X = Multiplier to account for eligibility for NSF subsidy

- 1.0 for federally funded projects
- 2.0 otherwise

\$120 = basic charge for administration, curation, and AMS analysis of graphite

$\$40/n$ = order processing charge, where n = number of samples submitted in a single batch

C = fee for converting raw samples to graphite.

Please confer in advance regarding submission of CO₂ or graphite.

- \$80 for CO₂
- \$140 for carbonate minerals requiring acid hydrolysis
- \$140 for organic matter requiring combustion only (ready to burn; $P = 0$)
- \$165 for dissolved inorganic carbon in seawater

P = fee for preparation, if required, of samples that are not ready for routine processing

\$25 per hour, call for further information if needed

- typically one hour for sediments, plants, charcoal, or other mixtures of organic and inorganic materials
- typically more for samples requiring conferences with investigator

Parallel processing of batches of samples can yield per-sample times of less than 1.0 hour

A = fee for supplementary analyses, if required

- \$15 for determination of ¹³C
- \$20 for elemental analyses (% OC determination)

D = \$45 fee for dilution if required to obtain sample 500 microgram C (*fee includes Delta C13 Analysis*)

Notes

This pricing structure is intended to reflect actual costs and thus to be fair to all members of the user community and to encourage submission of samples that can be processed more efficiently (CO₂, graphite). The facility is obligated to recover 60% of its operating costs from user fees.

Samples are processed in the order received. During the past two years, turnaround times have ranged from three to seven months. The slow turnaround was a transient, and users can expect that turnaround times will be down to four months or less by 30 June 1997. **Fast turnaround** (one month or less) is available for small numbers of samples based on scientific need rather than extra payment.

Because NOSAMS seeks to build a database documenting the quality of its analyses, clients who submit from six to twelve samples are invited to add one **duplicate** sample to their submission (thus yielding a total of seven to thirteen samples). The extra sample must duplicate one of the other samples. When the client identifies the duplicates after the analyses have been completed, no charge will be assessed for the duplicate. If more than 12 samples are submitted in single batch, two blind duplicates can be included (*i. e.*, a batch of 13 samples could yield 15 submissions). This policy will be discontinued after a representative sampling of replicates has been obtained.

Research Initiatives

Proposals are sought for projects that will expand the range and applications of radiocarbon analyses in global-change and ocean-science research. There are no deadlines for submission of proposals. Approximately one project is approved each month. Evaluation is based on the scientific significance of the proposed work and on the likelihood that a given project will lead to further, funded research. Interested investigators should begin by sending a three-to-five sentence description of their initiative to jhayes@who.edu. Inquiries will be held in confidence and reviewed only within NOSAMS.

Fees for Radiocarbon Analyses

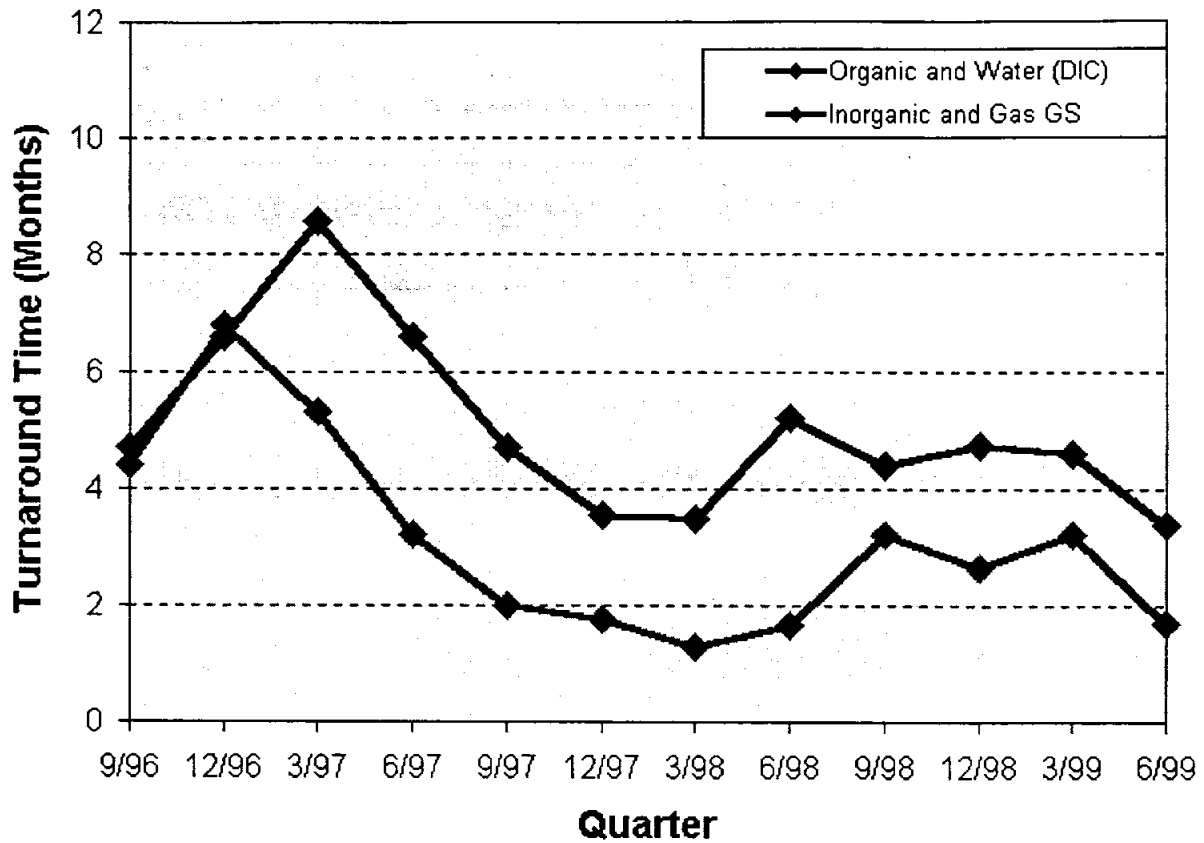
National Ocean Sciences Accelerator Mass Spectrometry Facility

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DOI 04353

NOSAMS Turnaround Time (Average)



The times shown reflect the average of all submission-to-report intervals for routine analyses during each of the indicated quarters. Much faster turnaround is available for samples submitted in the form of graphite and for samples in the quick-turnaround queue.

The NOSAMS Facility

The National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) facility is one of the most sophisticated and technologically advanced radiocarbon-dating laboratories in the world. It is funded by the National Science Foundation and operated within the Department of Geology and Geophysics at the Woods Hole Oceanographic Institution (WHOI). This facility is dedicated largely to serving the U.S. ocean sciences community. Presently, seventy percent of all samples run are seawater collected as part of the WOCE Hydrographic Program.

Since the early 1980's, scientists have been using Accelerator Mass Spectrometry (AMS) as an ultra-sensitive method to detect ^{14}C , the isotope required for radiocarbon dating. In AMS, a high-energy beam of carbon ions is produced, separated and directed to a detector where individual carbon atoms are counted. The ratio of radiocarbon to stable carbon atoms detected is used to calculate the radiocarbon age of the material. This method permits the dating of samples several thousand times smaller than conventional radiocarbon analysis in which beta-decay electrons are measured. The physical half-life of radiocarbon is 5730 years.

The NOSAMS Facility has an on-site preparation laboratory capable of analyzing a wide variety of materials containing carbon. AMS permits the most precise analysis currently available for investigations of many natural processes in which carbon plays a central role. A few of these include: ocean circulation, the occurrence and duration of warm or cold periods and ice ages, sea level changes, atmosphere/ocean exchange processes and carbon cycling in the oceans. Knowledge acquired from such studies is used to understand the ocean's role in global climate change.

In order to achieve high through-put the accelerator mass spectrometer has dual ion sources allowing for continual operation. Two stable isotope mass spectrometers are also utilized to obtain high precision measurements of $^{13}\text{C}/^{12}\text{C}$ ratios. In the sample preparation laboratory, carbon is extracted from each sample in the form of carbon dioxide.

The primary mission of the facility is to serve the ocean sciences community. Therefore, seawater, seafloor sediment, and organic material are the most common samples handled. Nevertheless, the facility welcomes samples from other discipline areas, as any material containing carbon has the potential to be analyzed.

The ultimate goal of the facility is to provide the oceanographic community with a large number (up to 4300 per year) of high-precision radiocarbon analyses. This includes rapid and appropriate dissemination of the results of these analyses to the user and scientific community. Several strategies have been implemented in order to achieve this goal. The first is a commitment to automation throughout the facility, including: sample preparation, analysis, and data reduction. The second is a commitment to the quality assurance made possible by a comprehensive relational database and bar-coding system which tracks every sample and every process performed at the facility.

Sample Preparation

The Sample Preparation Laboratory is designed to prepare graphite targets from carbon extracted from a wide variety of natural and anthropogenic sources. More than half of the samples prepared for analysis are seawater that is purged of CO_2 by bubbling N_2 gas through an acidified sample. This CO_2 is collected, its volume measured, and is transferred to the graphite preparation line. The gas is then split and can be concurrently analyzed for ^{13}C to a precision of 0.01‰ (parts per thousand). A portion of the gas is converted to graphite for ^{14}C analysis and any remaining gas is sealed and archived.

The process of converting CO_2 to graphite is automatically performed using a catalytic reduction method at high temperature. A robotic weighing system has been used to measure out precise amounts of catalyst. In order to preserve sample quality and integrity, computers are used to control the operation of valves and ovens, and record temperatures and pressures on the sample preparation lines. Once the

sample has been reduced, the graphite catalyst mixture is pressed mechanically into a solid pellet, which becomes the sputter target for the AMS ion source. The process of mechanically pressing targets has also been automated to insure consistency.

The Accelerator Mass Spectrometer & Sample Analysis

The milligram-sized sample of graphite is pressed into an aluminum cartridge (target) and placed into a 59 position carousel which is then loaded into the ion source of the AMS. Carbon atoms are sputtered from each target as negative ions by bombarding the target with cesium ions. In the first stage of the recombinator region, the negative ion beam is separated into its individual masses magnetically. The middle stage of the recombinator removes those masses higher or lower than 12, 13, and 14. In the final stage of the recombinator, the three ion beams are combined and injected into the first accelerator region where they are accelerated to 2.5 megavolts (MV) and passed into the argon stripper canal where four electrons are removed and any molecular fragments decompose into atoms. Now triple-positively charged, the ions pass into the second 2.5 MV accelerator region and exit into the analyzer region with a kinetic energy of 10 MeV (a velocity of 4% the speed of light). The beam is again split at the 110° analyzing magnet; the 12C and 13C are detected in Faraday cups while 14C atoms pass through additional filtering and into the ultrasensitive gas ionization detector where the 14C atoms are individually counted. With the NOSAMS accelerator, targets of more than 0.5 mg (40-80 mmol) of carbon can be analyzed to a precision of better than 5%.

Samples:

The following chart is a guide to the various types and typical sizes of samples that can be analyzed by the NOSAMS facility. Please contact us regarding the analysis of sample types not listed.

| Material | Suggested Sample Size |
|---|----------------------------|
| Gas | 40-80 umol CO ₂ |
| Seawater (inorganic carbon) | 500 ml |
| Carbonate Shells | 10-20 mg |
| Wood or Plant material | 5-20 mg |
| <p>Sediment: The sample size required varies greatly depending on the organic or inorganic carbon content of the sediment.</p> <p>a) organic matter: For a sediment that is 2% organic carbon by weight, we require 100-200 mg material.</p> <p>b) inorganic matter: If the sediment is 40% CaCO₃, we require 20-40 mg sediment.</p> <p>Specialty organics (e.g., bone or mollusc): Since these samples can require special procedures, please contact us regarding the dating of this type of material.</p> | |

The entire AMS system is designed to meet a specification of 3‰ precision for carbon 14/12 ratios after any fractionation corrections are determined from the 13/12 ratios. At present (1995), samples of modern age (i.e., most sea water samples) yield 14C count rates of about 130 counts per second and 0.5% counting statistics in five minutes. Overall accuracy is better than 1% for measurement times of 30

minutes.

Machine and sample backgrounds (blanks) are approximately 64,000 and 50,000 years BP, respectively. This residual ^{14}C can affect the accuracy of materials older than 45,000 years but has no effect on materials less than 10,000 years old. In samples younger than 10,000 years it is possible to measure the radiocarbon content with an overall precision of 5‰. At present, we routinely work with samples containing 0.5 - 1 mg of carbon depending on the material analyzed. Samples containing less than 500 micrograms of carbon require special handling techniques and must be discussed beforehand.

The VG Isotech Prism stable isotope ratio mass spectrometer (IRMS) provides baseline measurements to check the performance of the $^{13}\text{C}/^{12}\text{C}$ -ratio measuring capability of the AMS instrument for ^{13}C corrections to the AMS data and for stand-alone ^{13}C and ^{18}O measurements of scientific interest. It has the capability to measure the carbon $^{13}/^{12}$ and oxygen $^{18}/^{16}$ ratios to better than 0.01‰. The AMS machine measures individual atoms from a solid sample to measure the isotope ratios, whereas the IRMS uses molecules in a gaseous state.

Sample Submittal

Prospective users of the facility are urged to contact Susan Handwork, Administrative Assistant, to receive an official **Sample Submittal Form**; or may obtain one by accessing the NOSAMS home page. If there are any questions about the material to be analyzed, please contact Kathryn Elder, Quality Assurance Coordinator. Because user demand for radiocarbon analyses exceeds the ability of all AMS facilities to quickly satisfy that demand, samples at NOSAMS are assigned to one of three queues according to the following criteria.

First queue: During the initial years of operation, 70% of the sample capacity has been dedicated to global change samples; (*e.g.*, World Ocean Circulation Experiment [WOCE], or Joint Global Ocean Fluxes Study [JGOFS]). It is anticipated that during the active sample collection phase of the WOCE program (projected 1990-1998) seawater samples will comprise a majority of the analyses in this queue. Seawater samples from the WOCE and JGOFS programs received by the facility are processed in an order determined by an *ad hoc* WOCE AMS Users Panel. Results are reported quarterly to this program.

Second queue: Samples submitted by individual investigators and independent users comprise up to 20% of the NOSAMS capacity. Samples are placed into this queue upon receipt. Results are reported to the investigator, usually no longer than four months after receipt. A receipt number is assigned to each sample accepted for analysis and can be used to check the status of your samples (refer to Sample Status Information below)

Third queue: The remaining ten percent of sample capacity is reserved for high priority samples, at the discretion of the Director of the Facility. Submitters are encouraged to write a letter which details the need for high priority AMS analyses.

User Fees

Fees for analyses are assessed based on sample types, quantities and special processing requirements. Please see our [fee calculator](#) to obtain a cost estimate for your samples.

Sample Status Information

The status of samples in process and submittal information for new samples may be obtained by addressing the Woods Hole Oceanographic home page at <http://www.who.edu/> through which you can access the NOSAMS home page. By using the receipt number issued for the sample, its status may be obtained.

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Selected References

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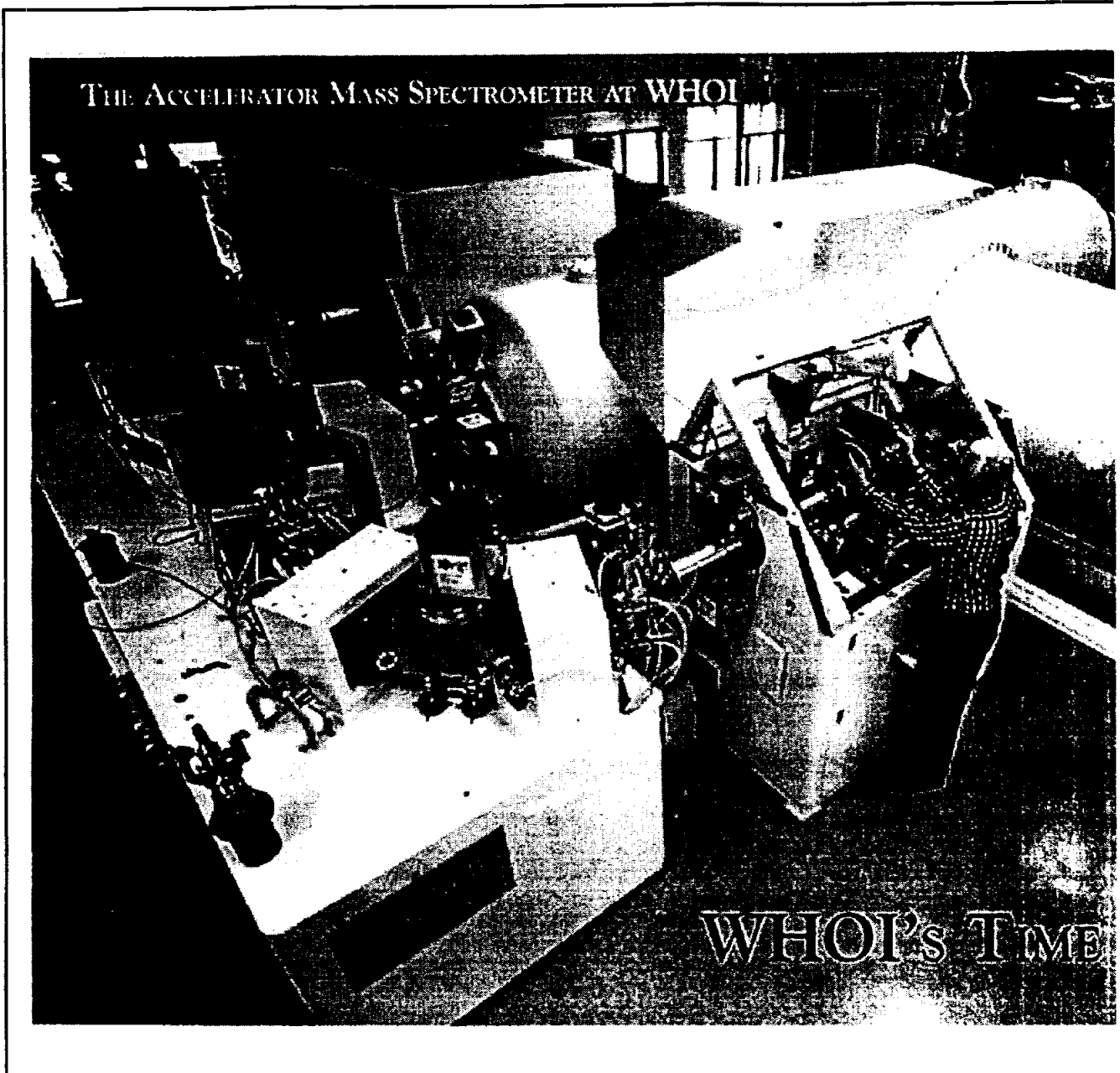
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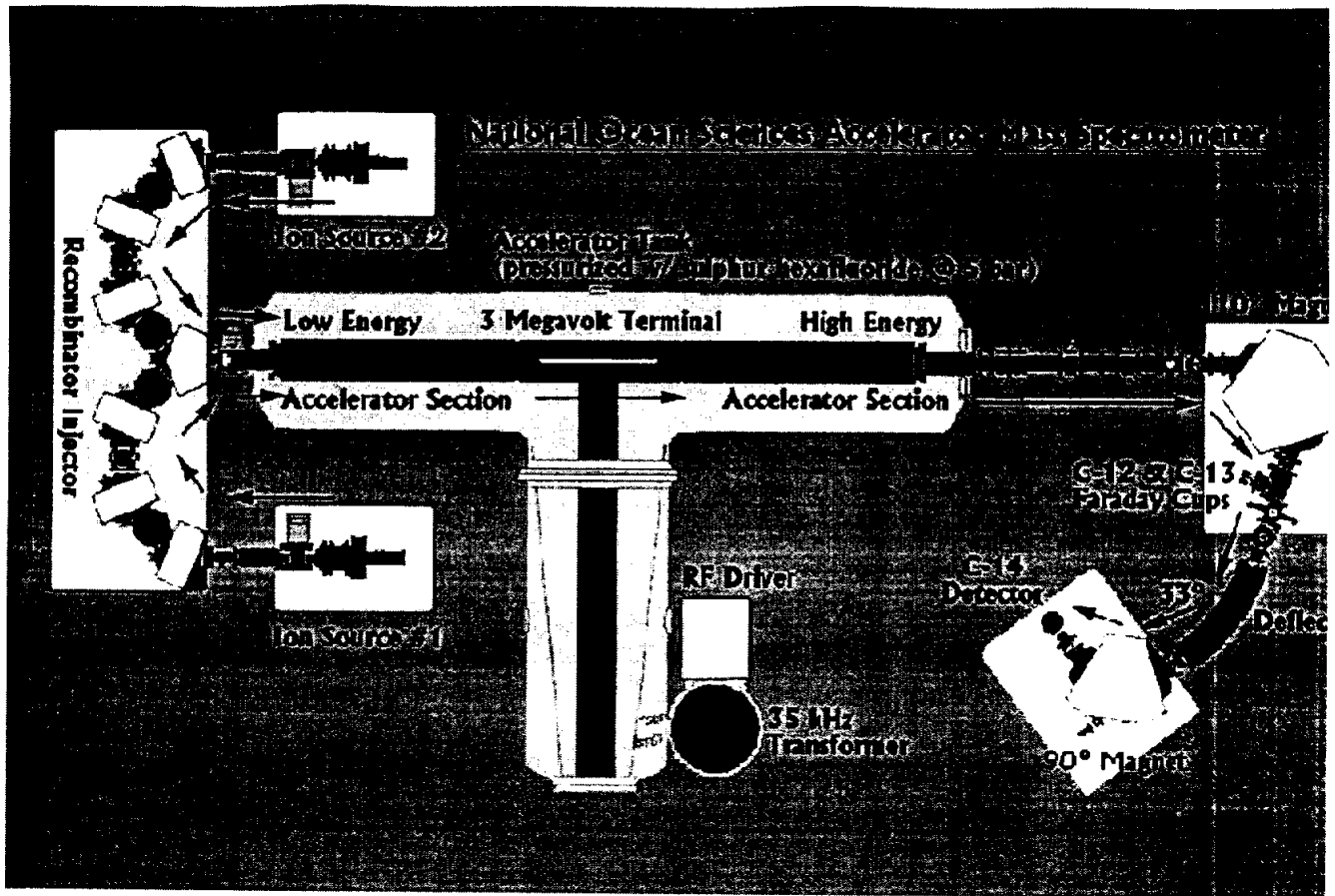
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Click [here](#) for a schematic overview and description of the NOSAMS system.





of the carbon isotopes. Two cesium sputter ion sources with automatic 59-sample changers allow a fast turn-around of sample analyses, with virtually continuous alternating operation of the sources. Black arrows next to the vacuum beam line indicate the ion beam path through the system. The negative carbon ion beams are extracted from the ion sources at 40 keV energy into the recombinator injector section (left). In this symmetric 4-magnet section the three isotopes of carbon ($A=12,13,14$) are magnetically dispersed into separate beams for pre-acceleration mass filtering. In the symmetry plane (after the first two magnets) ions with masses smaller than 12 and larger than 14 are stopped on aperture plates. In addition, the predominant C-12 beam is chopped to about the same intensity as the C-13 beam by a slotted rotating disk. Now the three separate ion beams are recombined in the remainder of this section for subsequent injection into the accelerator. The first stage of this tandem system accelerates the negative ion beams to 2.5 MeV kinetic energy. At the positive high-voltage terminal a 1-m long, 12-mm diameter tube is filled with a small amount of argon gas which acts as electron stripper: the electrons on the negative ions pick up energy during encounters with the argon atoms, and, as a result, several electrons are lost. Our system is tuned to analyze ions in the 3+ charge state (i.e., 4 of the 7 electrons are stripped from the incoming negative carbon ions). From the terminal these carbon-3+ ions are now further accelerated (pushed) to the high-energy end of the system, acquiring a kinetic energy of 10 MeV (about 4% of the speed of light). Now the ions are ready for the final high-precision mass analysis. A double focusing spectrometer magnet with a 110° bending angle disperses the ions and the beam currents for the abundant isotopes C-12 and C-13 are measured in Faraday cups in the focal plane of the magnet. The radioactive C-14 ion beam is too small to be measured in a Faraday cup, and must be analyzed with a nuclear particle detector,

counting individual ions. Two additional devices help avoid the misidentification as C-14 of particles that mimic the kinematic properties of the C-14 ions, but are products of complicated processes involving molecules of C-12 and C-13. First, there is a 33° electrostatic deflector which transmits only particles with the correct energy and charge. Second, another momentum-selecting spectrometer magnet with a 90° bending angle removes any remaining stray particles. The isotope specific nuclear stopping power in the gas ionization detector provides the final identification tool for the C-14 ions. The estimated background suppression of the high-energy section of the NOSAMS system is 10,000,000,000,000,000 to 1 (10 to the power of 16). Ratios of the three carbon isotope beam intensities represent the final result.