ANSMET'S GUIDE TO

Recovering Antarctic Meteorites

First Edition, Dec. 2010

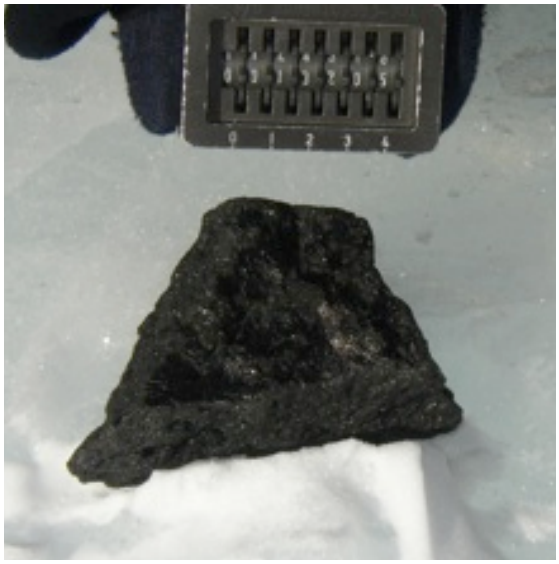
2010-2011 FIELD SEASON

The ANSMET Meteorite Dance

CONTENTS

APPENDICES

Why Meteorites Are Important



Above: MIL 03346, a representative of the Nakhlite group of meteorites thought to originate on Mars

Left: Most meteorites are 4.56 billion years old and represent material relatively unprocessed since the solar system first formed.

Meteorites are a unique scientific resource

There are two basic ways to characterize the value of Antarctic meteorites. First, sources of extraterrestrial material are rare; after meteorite recoveries, the only other source of recovered non-microscopic extraterrestrial material is the Apollo collection of moon rocks. Delivered to Earth by gravitational interactions in space, meteorites are our only source of macroscopic samples of other bodies such as asteroids, Mars or even Mercury.

Second, if science can be characterized as a search for origins, you can't go further back than meteorites. Most meteorites remain little changed since our solar system was born; and unlike astronomical observations subject to interpretation from remote distances, meteorites can be studied with the full power of earthbound laboratories.

ANSMET

Among the many meteorite recovery efforts supported by governmental agencies and private groups, the Antarctic Search for Meteorites program (ANSMET) is unique. All the specimens collected by ANSMET are made available to researchers without fee and without regard to nationality or funding status. 100% of all recovered specimens are made available within 3 years of arrival in the US; descriptions of newly available specimens are published biannually in the Antarctic Meteorite Newsletter and requests for material to study are made year-round. This is in contrast to privately recovered meteorites, of which only a small fraction is typically available to science (usually to the highest bidder).

Since 1976 NSF and NASA have supported the ANSMET program, ensuring a continuous supply of these important research materials. The US Antarctic Program strongly encourages researchers to keep their eyes open for meteorites during field work; this publication has been designed to serve as a guide to meteorite identification and recovery.

NEXT

Where to find meteorites (likely hiding places).

Where Meteorites Are Found

Above: The best place to find meteorites is high-altitude blue ice. If you spot a rock that's uphill and inland of any terrestrial rock source, it's very likely to be a meteorite.

Left: Moraines near high-altitude blue ice often harbor meteorites, but they're also much harder to recognize in that setting.

Meteorites can be anywhere

There's no magical connection between Antarctica and meteorites; just some favorable natural circumstances. Low rates of weathering, sedimentation and snow accumulation mean meteorites survive longer and make up a higher percentage of the stuff piling up on local surfaces. In addition, glacial motion can concentrate meteorites in some favorable settings.

Blue Ice

Blue ice areas form when enhanced localized sublimation leads to exposure of deep glacial ice. This natural removal of the ice, although slow, can go on for hundreds of thousands of years, and the result can be a lag-deposit of meteorites. Only a small proportion of blue ice areas harbor meteorite concentrations; typically those moving slowly and at higher altitude on the edge of the East Antarctic Plateau. But in some areas, number densities can reach a thousand meteorites per square kilometer.

On blue ice regions far from any source of terrestrial rock, almost any rock you find is likely to be a meteorite. Meteorites can also be found on blue ice closer to bedrock where they may be mixed in with terrestrial rocks.

Moraines

Moraines formed where ice interacts with bedrock often contain meteorites; typically smaller specimens moved by the wind or simply sliding downhill. Meteorites can be highly concentrated in such areas making moraines valuable locations for searches, but the abundance of terrestrial lithologies can create a daunting background.

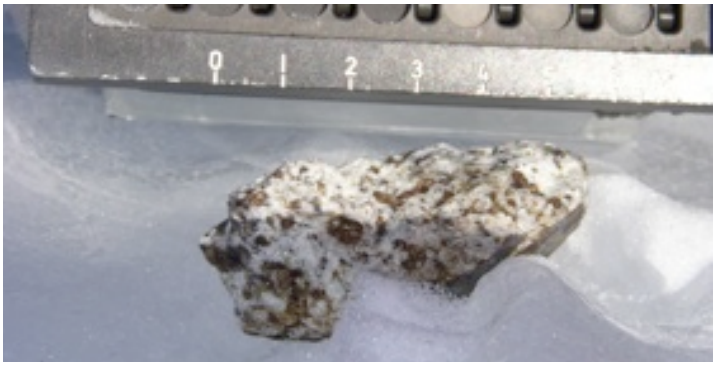
Old Surfaces

Antarctica abounds in non-ice surfaces that have seen little sedimentation on timescales approaching millions of years. These old surfaces offer decent potential for meteorite discovery, particularly if the local terrestrial rocks and sediment aren't too confusing.

NEXT

How to identify a potential meteorite (what to look for).

Identifying Meteorites



Above: The majority of Antarctic meteorites are at least partially covered by fusion crust, a dark burned- or glassy-looking layer of melted rock distinct from interior lithologies. Left top: some meteorites develop a unique shiny or metallic patina. Left bottom: Others may have little fusion crust, or strangely colored fusion crust.

Fusion crust

The most distinctive feature of meteorites and the one that most often distinguishes them from terrestrial rocks is fusion crust. On their way to the ground, meteorites develop a thin shell of melt as 20 km/s of momentum is turned into thermal energy within the Earth's atmosphere. The resulting layer of melt, once solidified, is called fusion crust. With notable exceptions, fusion crust is notably distinct from a meteorite's interior and much darker than the weathering rind common on native Antarctic rocks. It often shows flow lines and oozy features characteristic of a semi-liquid state; and is rarely more than a few mm in thickness. Fusion crusts can range from a matte black, polygonally-fractured surface reminiscent of a charcoal briquet to a smooth glassy black like furnace slag. Fusion crust is almost always black, but can vary in color depending on the minerals being melted; grey, green and even yellowish fusion crust has been noted on some unusual specimens.

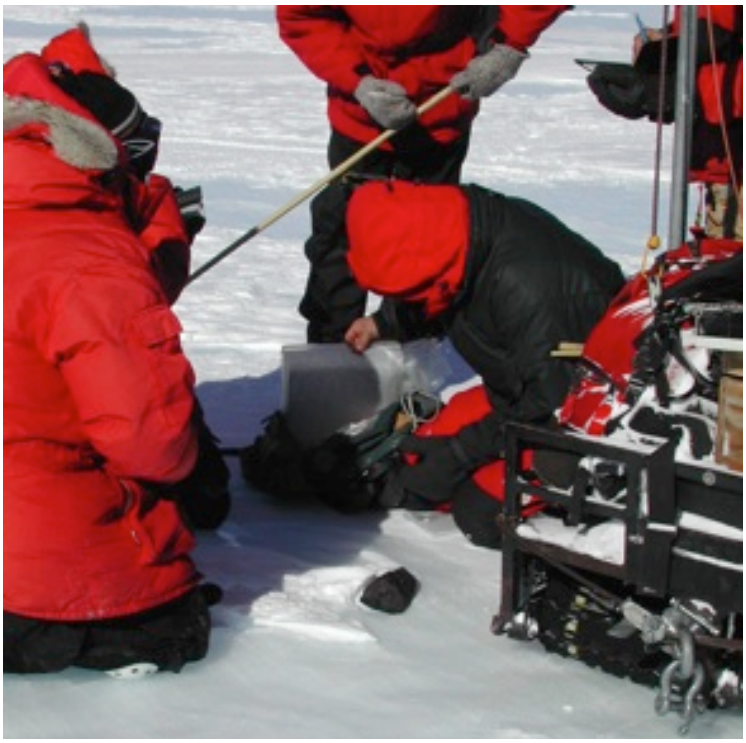
Other clues

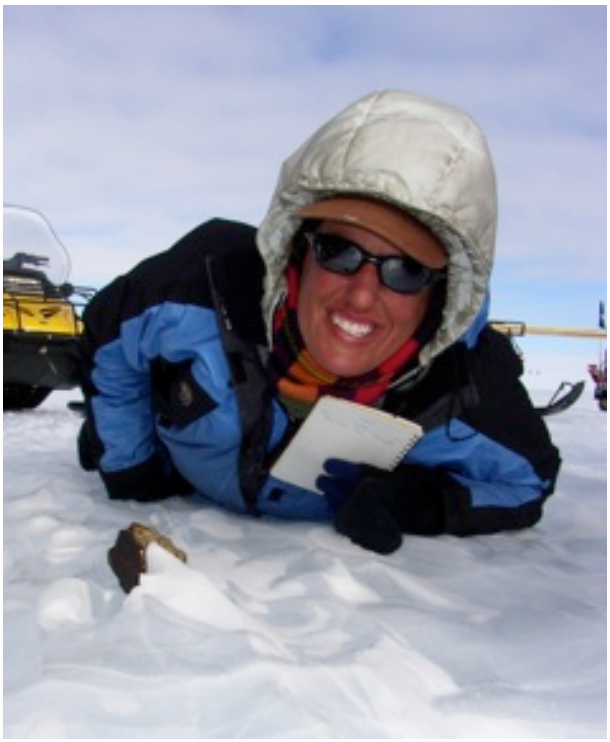
In the absence of fusion crust, other clues can help one recognize meteorites. Meteorites are often well-rounded in comparison to their terrestrial neighbors, different in size and can show significant spots of rust (many meteorites contain native metal that oxidizes very easily). Meteorite lithologies are distinct from most terrestrial lithologies, so any rock that just "looks different" has potential, whether or not you're a trained geologist. ANY rock suspected of having fusion crust is worth recovering; and if you spot something that just seems exceptionally out of place, don't leave that behind either.

NEXT

How to collect a potential meteorite (procedures).

How to Collect a Meteorite





Above: Researchers are preparing to bag the specimen while preparing to photograph the find, plant a flag to mark the site and collecting the latitude and longitude by GPS. Right: Document your finds with a smile! More information is good.

Procedures NSF regulations specify strict procedures for meteorite collection by formal recovery expeditions; luckily, less strict protocols apply to serendipitous meteorite discoveries. Here's a summary of procedures designed to retain as much scientific value as possible.

Examine it Anthropogenic contamination is the bane of meteorite geochemists; so if you encounter a possible meteorite, avoid touching it. If you need to roll it over for a closer look, do so with a chunk or ice or nearby rock. Make sure your nose doesn't drip on the specimen and gloves or sunglasses don't fall on it. Inadvertent contact happens, so don't stress over it; but document any contamination that might occur.

Document it Give the find a unique name or number that clearly distinguishes it from other finds. Include this name on your written notes and in or on the specimen bag.

Photograph the meteorite *in situ* if possible. Pictures that reveal the setting of the find are key. If you can include a scale and the sample name, even better!

Mark the find site with a flag or cairn if possible so ANSMET can revisit the site. If a GPS is available, the latitude and longitude of the find greatly facilitates a return visit.

Field notes including the above data and anecdotal observations such as snow and ice adhering to the specimen, similarity to other specimens, or inadvertent contamination, are extremely valuable if you can provide them. Don't forget your own contact information!

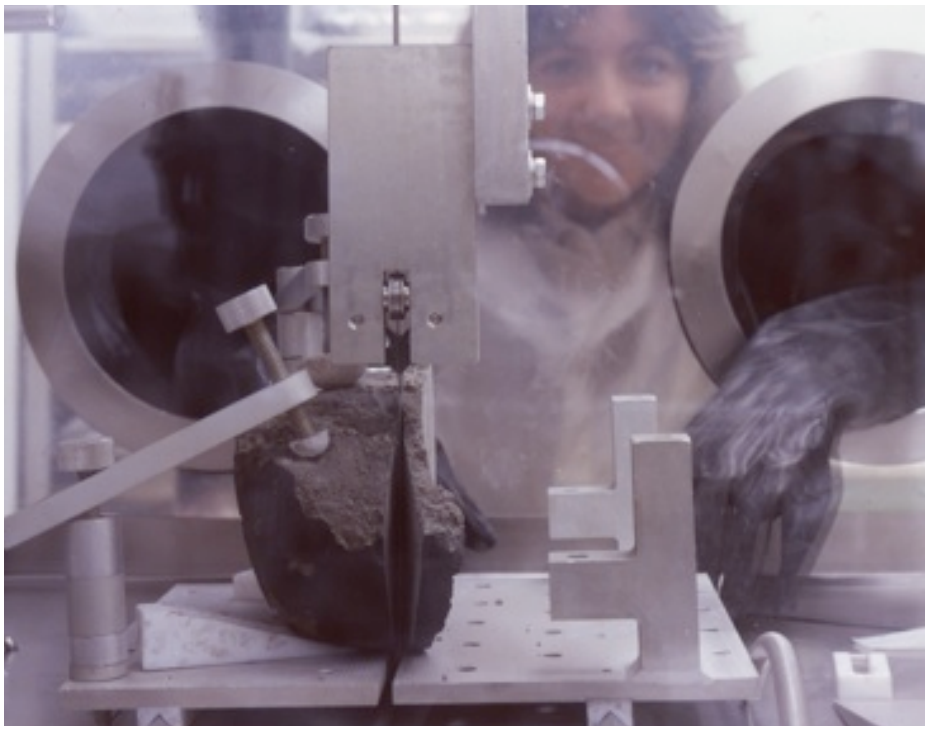
Bag it When a field party knows they'll be visiting possible meteorite sites, ANSMET can provide collection kits including steel forceps, clean plastic bags, sealing tape, identification tags, and a notebook with scalebar. If you have these, use them! But in their absence, any clean plastic bag or foil will do. Try not to touch the meteorite with dirty tools; often you can put an open bag over the specimen and pick it up without your hands touching the meteorite. If a specimen appears friable, wrap it in crumpled foil or a second bag. Include all the fragments in the same bag. Try to shake out any loose snow, and then seal the bag to prevent further contamination. If you include a tag with the meteorite name or ID, try to put it in a fold of the bag that won't touch the specimen.

Store it The ideal way to store a recovered meteorite is under ambient conditions: keep it frozen if you can. Please don't leave a meteorite sealed in a bag sitting in the sun; the miniature greenhouse created will lead to secondary mineral formation and leaching within the rock.

NEXT

What to do after recovering the meteorite.

What to do with a recovered meteorite



Left: the Antarctic Meteorite receiving lab at the NASA Johnson Space Center. Above: a good day's haul, ready for McMurdo.

Storage

By virtue of having been kept in a natural deep-freeze, Antarctic meteorites preserve significant chemical information lost in finds from other regions. Ideally meteorites should be kept frozen at all times.

It's probably a good idea to keep the meteorites in a secure place, and not overtly labelled. People are naturally curious about meteorites and sometimes the desire to handle them can overwhelm their sense of responsibility. This is particularly a problem once you're in McMurdo; a box in a cargo yard labelled "METEORITES" can be hard for many to resist.

In McMurdo

The Crary Lab is prepared to receive any meteorites you may have found. If possible, deliver your specimens to a Crary lab supervisor in person, and they will make sure they are stored in an appropriate freezer. Otherwise alert Science Cargo that you have "Keep Frozen" samples for delivery during your pull-out from the field. The container holding the meteorite specimens should be prominently labelled "For G-058". ANSMET is typically one of the last field parties to leave Antarctica in the season, which allows your specimens to be shipped home within our existing containers and procedures.

Where do they go?

The meteorites are sent home by ship, and kept frozen until they reach their final destination, the Antarctic Meteorite Receiving Lab at NASA's Johnson Space Center. There they are carefully thawed in dry nitrogen, sectioned, and characterized. Scientists from the Smithsonian Institution add to the description of the samples. This characterization process has been carefully designed to help classify the specimen to a minimal level only, leaving significant potential for discoveries by subsequent researchers.

Can I learn more about the specimens I recovered?

It takes a minimum of about 6 months for the specimens to be made available to science. A web-based publication called The Antarctic Meteorite Newsletter is published twice yearly and contains initial descriptions of all newly-available samples. Scientists around the world use this newsletter as a guide to requesting samples for their own work. All of the samples are renamed during the characterization process; but the Antarctic Meteorite Curator or ANSMET PI can help you follow your specimens through the system. Contact information is available on page 12.

NEXT

Field portraits of selected Antarctic meteorites.

Misc. field portraits of Antarctic Meteorites

Clockwise from upper left: lunar gabbro; aerodynamically-shaped ordinary chondrite; rounded ordinary chondrite; typical H-chondrite, strongly resembling Ferrar Dolerite but with fusion crust; achondrite with shiny fusion crust; unique achondrite.

Misc. field portraits of Antarctic Meteorites

Clockwise from upper left: ordinary chondrite; weathered and evaporite-bearing carbonaceous chondrite; typical ordinary chondrite; ordinary chondrite in moraine, showing contrast with Ferrar cobbles; achondrite with glassy black fusion crust; heavily-weathered ordinary chondrite.

Appendix 1: Federal Regulations regarding Antarctic Meteorite Recovery

(NSF regulation 45 CFR Part 674, RIN 3145-AA40; from the Federal Register, Vol 68, No. 61, p.15378)

Antarctic Meteorites
AGENCY: National Science Foundation (NSF).
ACTION: Final rule.
SUMMARY: NSF is issuing a final rule that authorizes the collection of meteorites in Antarctica for scientific research purposes only. In addition, the regulations provide requirements for appropriate collection, handling, and curation of Antarctic meteorites to preserve their scientific value. These regulations implement Article 7 of the Protocol on Environmental Protection to the Antarctic Treaty and are issued pursuant to Section 6 of the Antarctic Conservation Act, as amended by the Antarctic Science, Tourism and Conservation Act of 1996.
DATES: The rule is effective April 30, 2003.
FOR FURTHER INFORMATION CONTACT: Anita Eisenstadt, Office of the General Counsel, at 703–292–8060.
SUPPLEMENTARY INFORMATION: On August 27, 2002, the NSF published a proposed rule authorizing the collection of meteorites in Antarctica for scientific research purposes only. NSF invited public comments on the proposed rule. NSF received nine comments on the proposed rule. All of the commenters were supportive of the proposed rule.
One of the commenters suggested that NSF revise § 674.5(3)(ii) to recognize that in some cases, a meteorite will not belong to any well-established classification. NSF agrees with this comment and has revised the language accordingly.
Another commenter requested clarification whether or not meteorites are considered mineral resources. As noted in the preamble to the proposed rule, the authority for this rule derives from Article 7 of the Protocol on Environmental Protection to the Antarctic Treaty which states that ''any activity relating to mineral resources, other than scientific research, shall be prohibited.'' These regulations implement this provision of the Protocol with respect to meteorites.
The same commenter raised concerns that the definition of expedition would enable U.S. citizens to avoid application of the rule by organizing expeditions to Antarctica in a foreign country. NSF notes that the restriction in § 674.4 against collecting meteorites in Antarctic for other than scientific research purposes applies to any person subject to the jurisdiction of the U.S. This provision would extend to U.S. citizens collecting meteorites in Antarctica, regardless of the location from which the expedition is organized. Consistent with other regulations implementing U.S. obligations under the Antarctic Treaty, the more detailed requirements for preparation and plans and submissions of information to NSF are limited to expeditions for which the United States is required to provide advance notification under the Antarctic Treaty. NSF believes that this obligation is appropriately apportioned.
Another commenter expressed concern that the exception for serendipitous finds could result in meteorites ''fall[ing] through the regulatory cracks before arriving at a curation site.'' Section 674.7 provides that serendipitous finds must be handled in a manner that minimizes contamination and must otherwise be documented in accordance with the requirements of § 674.5. This approach recognizes that serendipitous finds will occur and assures that the opportunity to collect these specimens for scientific purposes is not lost. NSF believes that the requirement for documenting and curating serendipitous finds provides an appropriate mechanism for adequately and accurately tracking Antarctic meteorites.
Another commenter suggested technical revisions to the handling requirements in Section 674.5 (b)(1) to reflect current research laboratory practices. These revisions have been adopted in the final regulation. All other comments were appropriately considered in the promulgation of this final rule.
Determinations
NSF has determined, under the criteria set forth in Executive Order 12866, that this rule is not a significant regulatory action requiring review by the Office of Information and Regulatory Affairs. The rule is not a major rule under the Congressional Review Act. The Unfunded Mandate Reform Act of 1995 (Pub. L. 104–4), in sections 202 and 205, requires that agencies prepare analytic statements before proposing any rule that may result in annual expenditures of $100 million by State, local, Indian Tribal governments, or the private sector. Since this rule will not result in expenditures of this magnitude, it is hereby certified that such statements are not necessary. As required by the Regulatory Flexibility Act, it is hereby certified this rule will not have significant impact on a substantial number of small businesses. The Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.) and its implementing regulations, 5 CFR part 1320, do not apply to the rule because there are less than ten U.S. entities which annually organize expeditions to Antarctica for the purpose of collecting meteorites. Finally, NSF has reviewed this rule in light of section 2 of Executive Order 12778 and I certify for the National Science Foundation that this rule meets the applicable standards provided in sections 2(a) and 2(b) of that order.
List of Subjects in 45 CFR Part 674
Antarctica, Meteorites, Research.
Dated: March 24, 2003.
Amy Northcutt,
Deputy General Counsel, National Science Foundation.

For the reasons set forth in the preamble, the National Science Foundation is adding 45 CFR part 674 to read as follows:
PART 674—ANTARCTIC METEORITES
Sec.
674.1 Purpose of regulations.
674.2 Scope and applicability.
674.3 Definitions.
674.4 Restrictions on collection of meteorites in Antarctica.
674.5 Requirements for collection, handling, documentation and curation of Antarctic meteorites.
674.6 Submission of information to NSF.
674.7 Exception for serendipitous finds.
Authority: 16 U.S.C. 2401 et seq.
§ 674.1 Purpose of regulations.
The purpose of the regulations in this part is to implement the Antarctic Conservation Act of 1978, as amended by the Antarctic Science, Tourism and Conservation Act of 1996, (16 U.S.C 2401 et seq.), and Article 7 of the Protocol on Environmental Protection to the Antarctic Treaty done at Madrid on October 4, 1991. Specifically, this part is designed to ensure meteorites in Antarctica will be collected for scientific research purposes only and that U.S. expedition organizers to Antarctica who plan to collect meteorites in Antarctica will ensure that any specimens collected will be properly collected, handled, documented and curated to preserve their scientific value.
§ 674.2 Scope and applicability.
This part applies to any person who collects meteorites in Antarctica. The requirements of § 674.5 apply to any person organizing an expedition to or within Antarctica for which the United

Appendix 1: Federal Regulations (continued)

States is required to give advance notice under Paragraph (5) of Article VII of the Antarctic Treaty where one of the purposes of the expedition is to collect meteorites in Antarctica. The requirements in this part only apply to the collection of meteorites in Antarctica after April 30, 2003.

§ 674.3 Definitions.

In this part:

Antarctica means the area south of 60 degrees south latitude.

Expedition means an activity undertaken by one or more persons organized within or proceeding from the United States to or within Antarctica for which advance notification is required under Paragraph 5 of Article VII of the Antarctic Treaty.

Incremental cost is the extra cost involved in sharing the samples with other researchers. It does not include the initial cost of collecting the meteorites in Antarctica or the cost of maintaining the samples in a curatorial facility.

Person has the meaning given that term in section 1 of title 1, United States Code, and includes any person subject to the jurisdiction of the United States.

§ 674.4 Restrictions on collection of meteorites in Antarctica.

No person may collect meteorites in Antarctica for other than scientific research purposes.

§ 674.5 Requirements for collection, handling, documentation, and curation of Antarctic meteorites.

(a) Any person organizing an expedition to or within Antarctica, where one of the purposes of the expedition is to collect meteorites in Antarctica, shall ensure that the meteorites will be properly collected, documented, handled, and curated to preserve their scientific value. Curation includes making specimens available to bona fide scientific researchers on a timely basis, in accordance with specified procedures.

(b) Expedition organizers described in paragraph (a) of this section shall develop and implement written procedures for the collection, documentation, and curation of specimens which include the following components:

(1) Handling requirements. Handling procedures shall ensure that the specimens are properly labeled and handled to minimize the potential for contamination from the point of collection to the point of curation. At a minimum, handling procedures shall include:

(i) Handling the samples with clean Teflon or polyethylene coated implements or stainless steel implements (or equivalent);

(ii) Double bagging of samples in Teflon or polyethylene (or equivalent) bags;

(iii) A unique sample identifier included with the sample;

(iv) Keeping the samples frozen at or below ¥15 ¢XC until opened and thawed in a clean laboratory setting at the curation facility; and

(v) Thawing in a clean, dry, nonreactive gas environment, such as nitrogen or argon.

(2) Sample documentation. Documentation for each specimen, that includes, at a minimum:

(i) A unique identifier for the sample;

(ii) The date of find;

(iii) The date of collection (if different from date of find);

(iv) The latitude and longitude to within 500 meters of the location of the find and the name of the nearest named geographical feature;

(v) The name, organizational affiliation, and address of the finder or the expedition organizer;

(vi) A physical description of the specimen and of the location of the find; and

(vii) Any observations of the collection activity, such as potential contamination of the specimen.

(3) Curation. Make prior arrangements to ensure that any specimens collected in Antarctica will be maintained in a curatorial facility that will:

(i) Preserve the specimens in a manner that precludes chemical or physical degradation;

(ii) Produce an authoritative classification for meteorites that can be shown to belong to a well-established chemical and petrological group, and provide appropriate descriptions for those meteorites that cannot be shown to belong to an established chemical and petrological group;

(iii) Develop and maintain curatorial records associated with the meteorites including collection information, authoritative classification, total known mass, information about handling and sample preparation activities that have been performed on the meteorite, and sub-sample information;

(iv) Submit an appropriate summary of information about the meteorites to the Antarctic Master Directory via the National Antarctic Data Coordination Center as soon as possible, but no later than two years after receipt of samples at the curatorial facility;

(v) Submit information on classification of the meteorite to an internationally recognized meteorite research catalog, such as the "Catalogue of Meteorites" published by the Natural History Museum of London or the "Meteoritical Bulletin" published by the Meteoritical Society;

(vi) Specify procedures by which requests for samples by bonafide scientific researchers will be handled;

(vii) Make samples available to bonafide scientific researchers at no more than incremental cost and within a reasonable period of time; and

(viii) In the event that the initial curatorial facility is no longer in a position to provide curation services for the specimens, or believes that the meteorites no longer merit curation, it shall consult with the National Science Foundation's Office of Polar Programs to identify another appropriate curatorial facility, or to determine another appropriate arrangement.

§ 674.6 Submission of information to NSF.

A copy of the written procedures developed by expedition organizers pursuant to § 674.5(b) shall be furnished to the National Science Foundation's Office of Polar Programs at a minimum of 90 days prior to the planned departure date of the expedition for Antarctica. NSF shall publish a notice of availability of the plan in the Federal Register that provides for a 15 day comment period. NSF shall evaluate the procedures in the plan to determine if they are sufficient to ensure that the meteorites will be properly collected, handled, documented, and curated. NSF shall provide comments on the adequacy of the plan within 45 days of receipt. If NSF advises the expedition organizer that the procedures satisfy the requirements of § 674.5 and the procedures are implemented, the expedition organizer will have satisfied the requirements of this part.

§ 674.7 Exception for serendipitous finds.

A person who makes a serendipitous discovery of a meteorite in Antarctica which could not have been reasonably anticipated, may collect the meteorite for scientific research purposes, provided that the meteorite is collected in the manner most likely to prevent contamination under the circumstances, and provided that the meteorite is otherwise handled, documented and curated in accordance with the requirements of § 674.5.

Contact Information:

If you are in Antarctica, and have either found a meteorite or want a collection kit:

Contact the Antarctic Search for Meteorites program (G-058-M) via MacOps or the Crary Lab. Meteorites should be kept frozen and delivered to an ANSMET representative or the Crary lab.

In the civilized world:
Ralph Harvey, Principal Investigator of ANSMET
Dept. of Geological Sciences
Case Western Reserve University
Cleveland OH 44106-7216
phone: 216-368-3690
E-mail: ANSMET@case.edu

For information on meteorites you recovered:
The Antarctic Meteorite Newsletter is published twice a year and can be found at:

http://curator.jsc.nasa.gov/antmet/amn/amn.cfm

If you need help locating a specimen within the JSC databases, contact:
Kevin Righter
Antarctic Meteorite Curator
Mail Code KT, NASA
Lyndon B. Johnson Space Center
2101 NASA Parkway
Houston, Texas 77058-3696
Phone: (281) 483-5125
FAX: (281) 483-5347
E-mail: kevin.righter-1@nasa.gov

Rewards:

Unfortunately, federal law prohibits private ownership of Antarctic meteorites, so we can't let you keep one or part of one as a souvenir. But your contribution of specimens to the ANSMET program will be formally recognized by the Meteorite Working Group. The samples you collect, altruistically provided to the world's planetary materials research community, could play a key role in understanding the history of our solar system. And if you're lucky, someday a meteorite you recovered will show up in a publication or a news article, and you'll be able to say "I found that!"

Oh, and swag. Recovering an Antarctic meteorite means you're an honorary member of G-058. Contact the PI of ANSMET for a team patch and bumper sticker.

In the event you find an alien life form

Stay Calm

Hollywood is clear on this issue; first contact between an alien race and humans is most likely to take place in Antarctica. As an Antarctic scientist you owe it to humanity to have a plan for what could be the defining moment in the total of human history.

If the alien is clearly dead

It's not. No matter how inactive or seemingly damaged, it's not. It's dormant, or healing itself, or sporing, or simply waiting for a new host. Do not thaw it, warm it, bring it into your tent or vehicle. Do not attempt to enter its vehicle, if one is evident. Document the alien with a photograph and GPS location, and move away. Quickly.

If the alien is clearly not dead

Any alien that reaches Earth knows of the presence of humans. Logically, a live alien encountered in Antarctica indicates they are avoiding contact with our species and have no desire to interact with us. Again, your best course of action is passive observation- attempts to communicate or draw attention to yourself are clearly at odds with the alien's wishes. Please do not irritate the alien.

If you feel the alien wishes to communicate

Get over yourself. You probably ate a can of brown bread that was way past expiration date. Aliens that want to communicate with a species thousands of years more primitive than they are either going to eat you, "probe" you, hunt you as prey, ask you to carry their gear, or convert you to their religion.

If the alien has proven hostile intent by eating/occupying/enslaving/probing your field assistants

USAP has a tradition of preparedness that goes back 50 years. Each field party is equipped with a glass-fronted case containing a fully prepped and loaded flamethrower and an assortment of machine guns. Smash the glass and show those aliens whose planet this really is.

You did check one of those out from the BFC, didn't you?

When the encounter is over

You'll probably be dead. But as you die, perhaps slowly digesting in the belly of the alien, reassure yourself with the knowledge that by having carefully documented the encounter, you have earned a legacy as one of THE most important humans to have ever lived. In truth, the pictures on the camera you leave behind will be inexplicably blurry, your notebook taken to be the ravings of a madman, and your family disgraced. No one will believe you. Sorry about that.