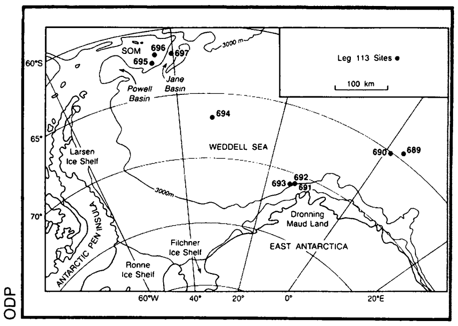
# Leg 113: Drilling into Antarctica's past



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Scientists know from fossil evidence that the climate of the entire earth was once temperate and nearly uniform. The winds and ocean circulation were relatively weak because there were no great temperature contrasts between the poles and the equator. Now, of course, with its ice-capped poles and tropical equator, the earth presents a very different climatic picture.

"The question is exactly how and when did we go from a very homogeneous, warm planet to the [climatically] diverse planet we have today," says Suzanne O'Connell of Texas A&M University in College Station, the staff scientist on the Ocean Drilling Program's recent Leg 113. "We think the answers to that question lie around Antarctica, because it is considered to be the anchor of climate today." The temperature difference between the cold southern pole and the hot equator causes the air above the ice and water below it to sink and move northward. This then drives most of the planet's wind patterns and ocean flow.

In spite of Antarctica's importance to the earth's climate, scientists have had relatively little geologic information on the region. So on Leg 113, the drillship *JOIDES Resolution* spent most of January and February taking cores in Antarctica's Weddell Sea. These cores, which O'Connell says are the first continuous, high-resolution, hydraulic-piston cores obtained in Antarctica, offer the most detailed record yet of Antarctica's glacial history over the last 70 million years. They also hold some clues about the causes of a mass extinction far in the past, as well as some hints about the effects of "greenhouse" warming on the planet in the future.

Leg 113 confirmed that East Antarctica was once a relatively warm, ice-free continent. The cored sediments older than about 38 million years contain pollen from beech forests, fern spores, freshwater diatoms that had been blown to sea from inland lakes, and clays that were formed by chemical weathering. In sediments from about 38 million years ago, however, the appearance of silica-rich sediments, clays made by physical weathering and other clues indicate that the continent was cooling down. By 15 million years ago a stable ice sheet had formed over East Antarctica, says James P. Kennett, Leg 113's co-chief scientist, from the University of Rhode Island in Narragansett.

According to Kennett, West Antarctica went through the same process of cooling and ice sheet formation, but these steps occurred later; the West Antarctic ice sheet is thought to have begun to form about 6 million years ago. This is not unexpected, says Kennett, considering that the East Antarctic ice sheet rests on land, whereas the West Antarctic ice sheet lies mainly on seawater. The salt in the seawater lowers the melting point of the overlying ice.

What is surprising, he notes, is the stability of the West Antarctic ice sheet over the last 4.8 million years. Because it's marine-based, scientists had speculated that it would be very vulnerable to temperature changes and that, like the Northern Hemisphere glaciers, it would have gone through cycles of melting and freezing. But, says Kennett, "our geological evidence from the cores suggests very high stability – that it formed as a permanent feature of the earth 4.8 million years ago and it's been quite stable since, including times that have been warmer than the present day."

"That's very comforting," comments O'Connell, "because right now the biggest water reservoir in the world is the Antarctic ice sheets." Some scientists have worried that future "greenhouse" warming of the planet, due to the burning of fossil fuels, would raise the temperature enough to rapidly melt the Antarctic ice sheets and cause dramatic sea level rises.

"We're not saying that [the ice sheets] don't contribute at all to sea level changes," says O'Connell, "but by and large they appear to be fairly stable."

Because the East Antarctic ice sheet is land-based and less susceptible to temperature changes, Leg 113 scientists were not surprised to find that it, too, has a very stable history. But this finding contradicts the work of other scientists who recently discovered pieces of wood that they think are traces of a forest that grew close to the South Pole 3 million years ago (SN: 3/8/86, p.148). Forests growing that far inland would imply that at least half of the East Antarctic ice sheet had melted away, says Kennett. So shipboard scientists had their eyes out for evidence of a major oscillation in the ice sheet.

"We found no evidence of that whatsoever," says Kennett. He doesn't know how to reconcile the two different results, but suggests that the wood is much older than what is claimed.

One of the most powerful tools geoscientists have in unraveling the temperature and ice history is the ratio of oxygen isotopes in calcarious microfossils. According to O'Connell, Leg 113 will provide the first Antarctic deep-sea cores for oxygen isotope work. These cores, by containing oxygen isotopes from times when there were no ice sheets, will also give scientists a reference point for calculating temperatures and ice volumes around the globe. Because the continuous cores also contain many types of microfossils, she says, they will enable biostratigraphers to precisely date and correlate the core sections.

Not all of the important discoveries during Leg 113 are directly related to glaciation and climate. For example, Kennett says the scientific party obtained two "very interesting" cores that are continuous across the sedimentary boundary marking the end of the Cretaceous (K) period and the beginning of the Tertiary (T) period – a transition time in which 75 percent of life on earth perished.

Since iridium, an element found in relative abundance on asteroids, has been found in high levels at K/T boundaries elsewhere on the globe, some scientists have postulated that an extraterrestrial body caused the mass extinction by slamming into the earth. Scientists have yet to analyze the content of iridium and other elements on Leg 113 cores. But according to Kennett, the researchers did find that there is volcanic material mixed in with the K/T boundary sediments, an observation that may support a competing theory that holds that intense volcanic activity was responsible for the mass extinctions (SN: 4/18/87, p.248).

Leg 113 scientists also discovered in their Cretaceous sections some of the highest concentrations of organic sediments ever obtained by scientific drilling in the deep sea. This suggests to Kennett and O'Connell that during the early Cretaceous, the Weddell Sea area was an extensive, enclosed and oxygen-depleted basin in which organic matter was able to accumulate. While no oil or hydrocarbons were found, the discovery suggests that the Weddell area may be an important source of hydrocarbons.

O'Connell says another unusual aspect of the cruise was that in addition to the usual microfossils, researchers recovered macrofossils, including ammonites, which look like nautiluses, and squid-like belemnites.

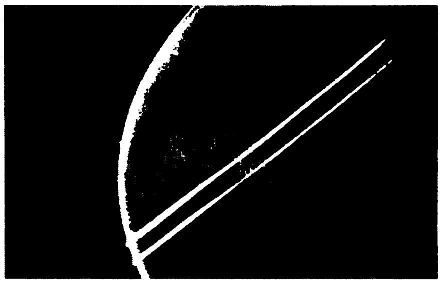
The cruise was a success technically as well. A big problem with working in the polar regions is icebergs – as the Leg 113 ice observer reportedly joked, the sound of the drill string is a mating call for icebergs. That problem was solved by an accompanying Danish ship, which was contracted to tow the icebergs with ropes or push them away with water spewed from its propellers.

One of the consequences of having Antarctic ice sheets is that large thermal gradients between Antarctica and latitudes farther north make for some of the worst weather in the world around 50°S.

Unfortunately, that's where the *JOIDES Resolution* is now, on Leg 114, which is supposed to address some of the same questions of Leg 113 but in a slightly warmer climate. According to O'Connell, the *Resolution* is battling 50- to 80-knot winds and rolling 25°. "It's just horrendous," she says. "They probably have a whole ship full of sick people."

*– S. Weisburd*

# Supernova: High on understanding


NASA

*Ultraviolet spectrum of the supernova. Two slanted bands show how the spectrograph spreads out the ultraviolet light. The wiggly line is a graph of ultraviolet brightness vs. wavelength.*

Supernova 1987A in the Large Magellanic Cloud is inspiring a growth industry in scientific papers. Particularly satisfying to a scientist is to have predicted something before or immediately after the appearance of 1987A that now comes true in the ongoing development of the phenomenon. At last week's meeting of the American Physical Society (APS) in Crystal City, Va., this attitude was parodied by Michael Turner of the University of Chicago, who made the facetious claim that on Feb. 22, the day before the supernova, he had written a paper stating that superstring theory predicted a supernova in the Large Magellanic Cloud: "Six of my friends signed the cover to witness that I did it on the 22nd." Turner got a good laugh – because, although superstring theory apparently has nothing to do with supernovas, many serious predictions *are* coming true.

As a result, astrophysicists are beginning to understand a good deal: "We understand what makes a type II supernova," says Stirling A. Colgate of Los Alamos (N.M.) National Laboratory.

This claim of understanding fits in well with other descriptions of supernova euphoria: "more exciting than Woodstock" (John N. Bahcall of the Institute for Advanced Study in Princeton, N.J.); "first time we've actually caught a core collapse of a star" (Adam Burrows of the University of Arizona in Tucson); "uniting a wide group of people who ordinarily pass each other in halls with polite grunts" (Robert P. Kirshner of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass.).

The current situation is something of a turnaround from the days of early March, when confusion over what star had exploded was giving astrophysicists a boxed-in feeling (SN: 3/14/87, p.65). Now observers seem to agree that it was a rather unusual blue giant star that exploded – Sanduleak -69° 202. As astrophysicists take into account the characteristsics of this star, things begin to fall into place.

In the first few days after the Feb. 23 discovery of the supernova, observers thought it was Sanduleak -69° 202 that had exploded. Then data from the International Ultraviolet Explorer satellite, supervised by Kirshner, seemed to show the blue giant star still there. Now a reexamination of those data show that of the three stars known to be in the immediate area before the supernova, the two on either side of Sanduleak -69° 202 remain, but it has vanished.

Neutrinos from the supernova have gained a great deal of attention in recent weeks (SN: 3/21/87, p.180; 4/11/87, p.231; 4/18/87, p.246). Well they might, as they involve a fantastic amount of energy. Burrows estimates it at $10^{53}$ ergs. Trying to put this into a human perspective, Alfred K. Mann of the University of Pennsylvania in Philadelphia translates it to a power of $10^{45}$ watts and calculates that a million power plants producing 1,000 megawatts of electricity each would still be $10^{30}$ times short of the amount. So, he says, the explosion is "$10^{30}$ times larger than anything human beings would ever dream of."

All this means, as Burrows puts it, that "[the visible flash of] the supernova is a sideshow compared with the main event, which is the formation of a neutron star." The neutron star forms as the core of the exploding star collapses. Neutrinos are produced, as Colgate points out, by the "deleptonization of this core" – that is, particles of the lepton class, primarily electrons, disappear as everything turns to neutrons.

Burrows estimates that about $10^{58}$ neutrinos are produced and, after being trapped in the core for a short while, eventually diffuse out and fly off into the universe. He estimates that about 1 kilogram (in mass-energy equivalent) of neutrinos passed through the earth, and says neutrinos probably passed (harmlessly) through the bodies of some 8 million people. On this basis Colgate suggests that many supernovas are not seen – they expend nearly all their energy in neutrinos and other unseen radiation. He estimates there is one supernova a second in the whole universe.

Gravity waves are another form of radiation expected from supernovas. The case for neutrinos is relatively certain, being based on simultaneous observations by detectors in Japan and Ohio. The case for gravity waves is almost nonexistent, but nevertheless there are some tantalizing data.

Gravity waves are gravity's analog to radio waves. Cyclic disturbances of gravitational forces that propagate themselves through space, they carry energy and therefore information. For astronomers they could be a completely new way of getting data about the universe. Gravity waves should produce microscopic vibrations in large massive objects. Several detectors around the world occasionally see rumbles that could be gravity waves, but a positive claim to their discovery will require two or more detectors seeing the same vibration at the same time.

A detector at the CERN laboratory in Geneva, Switzerland, operated by physicists from the University of Rome, reported events at the time of the supernova. And at the APS meeting, Joseph Weber of the University of Maryland in College Park showed a spike – a vibration stronger than background – in one of his detectors, but he commented: "I am reporting an observation. I am not claiming to have discovered anything."

Radio waves also come from supernovas, and those from supernova 1987A prompted an attempt to measure the size of the exploding volume by the technique of very long baseline interferometery, which uses simultaneous observations by widely separated telescopes. Norbert Bartel of the Harvard-Smithsonian Center for Astrophysics told the meeting that if optical astronomers thought they had a hard time getting telescope time in a hurry, they should have been in on the 58 hours of telephoning it took to arrange simultaneous observations by the two radiotelescopes in the Southern Hemisphere capable of this work, which are located at Hartebeesthoek, South Africa, and Tidbinbilla, near Canberra, Australia.

The effort did not succeed in measuring the actual supernova – though the observers still hope for a more positive result as they continue to refine their data analysis – but it did determine that the supernova was no bigger than two-thousandths of an arcsecond across. To put that in perspective, says Bartel, if someone held up a penny in Boston, to an observer in Washington, Lincoln's head would be about two-thousandths of an arcsecond wide.

A successful measurement of the supernova's width would give astronomers, who already know the distance of this one, a size/distance ratio for a supernova. They could then hope to use this on supernovas in more distant galaxies, as an independent way of measuring the distances of such galaxies and so checking on the expansion of the universe and other cosmological parameters.

*– D.E. Thomsen*