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IGY to IPY: The U.S. Antarctic oversnow and airborne geophysical-glaciological research program from 1957 to 1964 from the view of a young graduate student

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Abstract When 12 countries established scientific stations in Antarctica for the 1957-58 (IGY), the Cold War was at its height, seven countries had made claims in Antarctica, and the Antarctic Treaty was in the future. The only major field project of the U.S. IGY Antarctic program was series of oversnow traverses, starting in 1957, making seismic reflection ice soundings (and other geophysical measurements) and glaciological studies. The U.S.S.R. and France made similar traverses coordinated through the IGY. Although geology and topographic mapping were not part of the IGY program because of the claims issue and the possibility of mineral resources, the oversnow traverse parties did geologic work, during which unknown mountains were discovered. The oversnow traverses continued through 1966 and resulted in an excellent first approximation of the snow surface elevation, ice thickness and bed topography of Antarctica, as well as the mean annual temperature of that era and snow accumulation.

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Introduction

The "scientific era" in Antarctica was ushered in by the International Geophysical Year (IGY) 1957-58. My first experiences in Antarctica were from November 1956 to March 1958, November 1958 to March, 1959, and October 1960 to March 1962. My personal accounts of these expeditions are documented in Behrendt (1998, 2005) and include perspectives on the science, logistics and geopolitics of these science explorations. Here, I relate some of these experiences and review some of the early science results.

The Antarctic Treaty was negotiated and signed in 1959 and entered into force in 1961, largely as the result of the peaceful cooperation and scientific success of the IGY. The only ostensible purpose of the 12 countries' Antarctic expeditions during IGY was the peaceful coordinated scientific study of the ice covered continent. There were, of course, the hidden agendas of the Cold War, existing claims of seven countries and the territorial interests of the U.S. and the USSR.

When we young scientists first went to Antarctica to participate in the mission-oriented directed research of the IGY and in the U.S. Antarctic Research Program (USARP) in the early 1960s, the world was quite different from the undirected proposal-driven U.S. Antarctic Program (USAP) of the 1980 to 2007 period. The Cold War was at its height, and the U. S. Navy and participating researchers accepted safety risks that would not be tolerated today. Fifty years later, the U.S. Antarctic Program has altered dramatically, as has my perspective as a researcher "on the ice" in each of six decades. Most notable changes are the presence of women, and, in descending order, greater safety, availability of reliable maps, mail (more than once a year), transportation (in the IGY we had to spend 15 months in Antarctica to get a three month field season), fresh food during the summer, and of course technological advances particularly in electronics, communication, computers, satellites, and navigation.

Fifty years ago, large areas of Antarctica, which we studied in the period described here, were totally unmapped, and had not even been seen from the air. Even the coastline was not completely mapped. The extent of the Filchner Ice Shelf was unknown, although exploratory flights in 1956 had discovered the "Grand Chasm", a large rift of then unknown length in the ice shelf (Behrendt, 2007). In IGY, all traverse members had to be explorers as well as geophysicists and glaciologists. The IGY resulted in much new data about Antarctica and polar regions (e.g., Sullivan, 1957, 1961), the thickness and characteristics of the Antarctic Ice sheet and ice shelves (e.g., Thiel, 1962; Bentley, 1964; Behrendt, 1962; Neuburg et al., 1959; Thiel and Behrendt, 1959) and the crustal structure of Antarctica (Bentley, 1964,1965; Oliver, 1998).

During the IGY, Albert P. Crary had overall responsibility for the U.S. oversnow traverse program, which included three U.S. Antarctic field projects, each of which operated for several seasons. These IGY traverses were: 1) the Ross Ice Shelf (1957-58) and Victoria Land (1958–59), headquartered at Little America Station on the Ross Ice Shelf; 2) the Little America-Byrd (1957) and Sentinel Mountain (1957–58) operating out of Byrd Station on the West Antarctic Ice Sheet; and 3) the Filchner Ice Shelf Traverse (1957–58) and the Ellsworth–Byrd Traverse (1958–59) that were both out of Ellsworth Station on the Filchner Ice Shelf.

In this paper, I concentrate on the Filchner Ice Shelf Traverse, based on my personal experience. All of the U.S. traverses used the same equipment and techniques; however, the experience of each was unique. Our primary objective was the measurement of the snow-surface

Figure 1. Traverse at intermediate station. Behrendt reading magnetometer at left. Walker and Aughenbaugh making snow hardness measurement left background. Thiel on track of Sno-Cat after making a gravity measurement. Crevasse detector visible on leading vehicle.

configuration, the ice thickness, and the depth to underlying bedrock, using seismic reflection and gravity methods. We would measure snow accumulation, average annual temperature, and other glaciological characteristics of the ice sheet, make observations of the earth's magnetic and gravity fields, study the geology of any mountains we encountered, and make other scientific observations as opportunities were presented.

Filchner ice shelf traverse, 1957–58

On 28 October, 1957, our five man party left Ellsworth Station on the Filchner ice front with two Sno-Cats (in contrast to the usual three on the other U.S. traverses) each pulling a 2.5 ton sled filled with fuel, food, explosives, (Figure 1) and all of our scientific and other equipment. For the next 81 days we made a geophysical-glaciological reconnaissance of the Filchner-Ronne Ice Shelf area, and made the first geologic observations of the Dufek Massif.

The logistics of the traverse oversnow traverse program were dictated by the fact that state-of-the-art electronics at the time depended on the vacuum tube, rather than the solid-state electronic microcircuits available today. The hundreds of tubes in our seismic system required large amounts of battery power. The power requirements, in turn, required two 250 amp-hour batteries weighing 80 kg each to produce the 24 volts necessary for operation. The only recording system was the heavy oscillograph "camera" with its tanks of photographic solutions. Altogether the seismic Sno-Cat carried a total load of about 500 kg of electronic equipment, gravimeter, magnetometer, and seismic batteries. Each Sno-Cat used about 3 liters of fuel per km or about 200 kg for a 50-km day for two vehicles. This fuel determined how frequently we needed to be resupplied by the single-engine Otter aircraft available. These planes could only carry a few barrels of fuel in one trip, the number depending on our distance from Ellsworth Station.

Navigation over the course of a day's travel was by dead reckoning, using a gyrocompass mounted in the lead Sno-Cat. A few years later the U.S. traverses changed to magnetic compasses mounted in the Sno-Cats, which were an improvement because of the fragility of the gyrocompasses. About every 40-60 km, Hugo Neuburg, our navigator and traverse co-leader, measured the exact position of the sun using a theodolite. He determined the time with a chronometer checked with a time signal from the U.S. National Bureau of Standards radio station WWV, which we received well. He then calculated our position using a slide rule (pocket calculators did not exist) to better than 200 m accuracy using a nautical almanac. The small-scale weaving of the snow-cat track averaged out to straight tracks on a larger scale. Therefore, we could correct our dead reckoning position every day that we stopped for station work, using the accurate position obtained from the sun shots.

The lead vehicle had a crevasse detector, mounted on it, projecting about 6 m ahead of the vehicle (Figure 1), however, it was never of much use. About 10 km out of Ellsworth Station, the sled behind the lead vehicle broke through a snow bridge into a crevasse, and sank about a

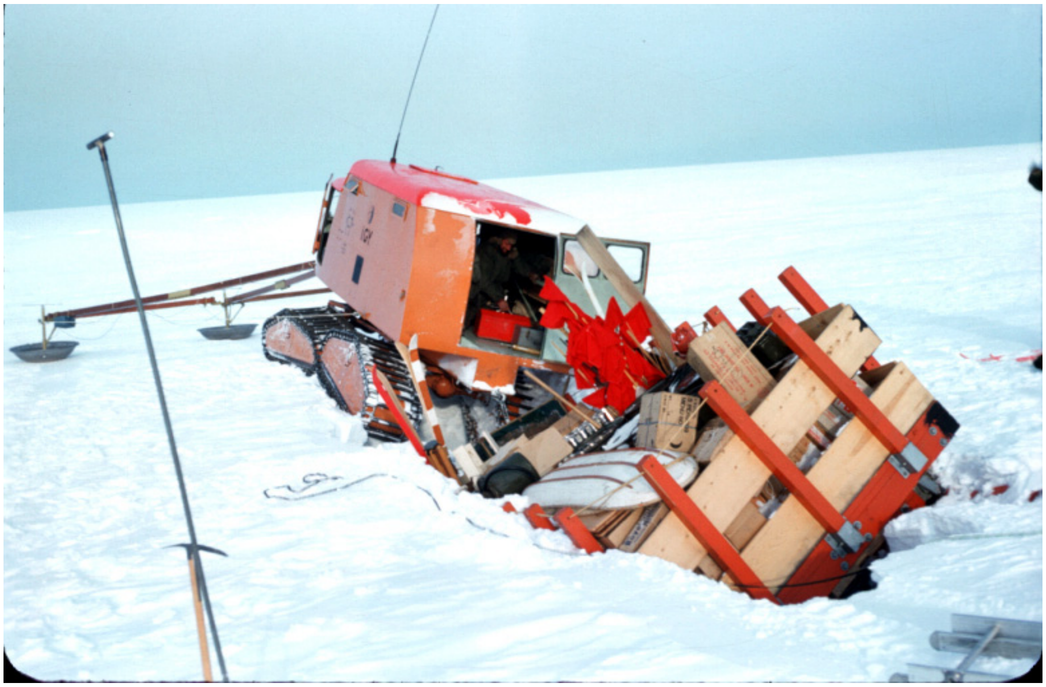

Figure 2. Sno-Cat and sled broken into hidden, bridged crevasse. Note T-handled probe, ice-axe, and crevasse detector extending forward of Sno-Cat.

meter, but was pulled out by the Sno-Cat without stopping. This minor incident set the pace for the entire 2100 km-long oversnow traverse. This small crevasse was probably about 20 m deep, pinching out at the bottom, but we generally could not see the bottom of crevasses when looking down. The extreme case on our traverse was the Grand Chasm, which extended entirely through the ice shelf, which was 700-m thick at that location.

Although we commonly saw open crevasses on the traverse, the ones that gave us the most trouble were bridged with snow and could not usually be seen from the surface as we drove along (Figure 2). Sometimes we could safely drive across snow bridges, but other times we broke through. The Sno-Cats were nearly as safe as a man on skis because of their relatively low weight and four wide tracked pontoons. It is much easier to see bridged crevasses from the air, but this method is severely limited, even when a plane is flying directly over crevasses. We traveled in crevasse country most of the 81 days of the traverse and had a number of incidents of vehicles and sleds breaking through. One man fell in about 10 m , but was rescued safely.

We spaced seismic-glaciology stations at about each day's travel distance (~50-60 km). The measurements at the stations consisted of a seismic reflection sounding to measure the depth to bedrock; seismic measurement of the increase in sound velocity (and thus snow density) with increasing depth; and a two- or three-meter snow pit to measure snow accumulation and other glaciological parameters such as density and temperature. We would lay out our 330 m seismic cables in an L shape, which we unrolled from chest reels. We would then hand drill a 2 to 8 meter deep shot hole at the apex of the L. We fired a small explosive charge of 0.5-2 kg of ammonium nitrate detonated with an electric blasting cap and a 0.5-kg high explosive primer charge. The sound waves penetrated to the ice-water contact (in the case of the floating ice shelf) and to the water-rock (or ice-rock) contact and reflected back to the surface where they were picked up by the geophones. Each of the 24 geophones was attached to one of the channels in the cables. The seismic signals were amplified and recorded on photographic paper that spewed into my hand at 1 meter per second. On a few occasions the wet paper record froze in my hands as I wrote the data on the back. There was some hazard associated with laying out the cables when we were working in crevassed areas. In these cases we skied, which offered some protection. We also used skis when we were not in areas of known crevasses, if the snow was soft.

In addition to digging a snow pit where snow stratigraphy was measured to determine snow accumulation, Neuburg and Walker would hand drill a hole 9 m deep and place an electrical-resistance temperature probe on a cable in the bottom. This would come to equilibrium "overnight," and the average annual temperature of the surrounding area was obtained.

We made gravity, magnetic and altitude measurements every 8 km (Figure 1) to study the variations in density and magnetic properties of rock beneath the ice, and therefore to make inferences about the ice-covered geology. We also used the gravity data to determine the depth to bedrock between the seismic reflection stations.

Airborne and aerogeophysical measurements

Starting in 1958 and continuing to 1964 the oversnow traverses were complemented by an airborne geophysical program comprising widely spaced landings for seismic reflection ice sounding and 75,000 km of widely spaced aeromagnetic and snow surface elevation profiles. The airborne profiles were concentrated over the West Antarctic Ice Sheet (WAIS) and along the length of the Transantarctic Mountains, and approximately defined the vast extent of a geophysically inferred Oligocene-Recent volcanic province beneath the WAIS associated with the then unknown West Antarctic rift system. There were numerous hazardous events encountered using these U.S. Navy planes of opportunity. These included denting a wing while flying by a mountain hidden in the clouds, and an airplane crash that killed the geophysicist (Edward Thiel) and four others. There was an aircraft death rate of 3.8 deaths per year in the U.S. program from 1955-66.

Conclusions

What we geophysicists and glaciologists set out to do in the IGY had only the very general objective of determining the three-dimensional configuration of the Antarctic ice sheet and, ultimately, of discovering whether it was increasing or decreasing in size. These pioneering studies laid the groundwork and provided focus for much of the future geophysical and geological work that continues to this day. Some of our major accomplishments included discovering that the area of the Filchner-Ronne Ice Shelf was >400,000 square km (5 times larger than previously known); mapping a 1200-1700-m-deep trough beneath the Filchner Ice Shelf (i.e., the Thiel Trough); making hundreds of seismic, gravity, magnetic, glaciological and surface-temperature measurements; and doing a geologic reconnaissance of the Dufek Massif which is part of a large mafic intrusion.

The inductive method used in IGY has probably resulted in the greatest geological and geophysical discoveries, but it is no longer in fashion. Now we use the deductive method, which begins with a specific hypothesis or problem and then searches -- not broadly, but narrowly -- for evidence to support or reject the hypothesis. At the beginning of the twenty-first century, the deductive method is necessary for writing scientific proposals to funding agencies for very expensive research programs with shrinking funds.

The inductive approach to research planning appears to be no longer viable. Because of the large number of excellent scientists competing for limited resources in Antarctica and elsewhere, careful attention must be paid to the specific problem being investigated and its importance relative to other competing and more-or-less equally significant proposals. Much of the excitement of heading into the unknown, which we experienced in the IGY, is missing today. During that era when Antarctica was still largely unexplored, we sampled and mapped *everything*. Although sharply focused research is possible today because of our results 50 years ago, there is, for example, still much geophysical "exploration" needed using modern techniques to define the crustal geology beneath the ice. The IGY transects laid a solid groundwork for today's geoscience studies and the young scientists that conduct them.

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