ON THE CURRENT LOCATION OF THE BYRD "SNOW CRUISER" AND OTHER ARTIFACTS FROM LITTLE AMERICA I, II, III AND FRAMHEIM

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Charles —
let's bring it back!
Ted Scambos

Abstract: Analysis of maps, sightings, satellite images, and aerial photos indicates that a ~105 km² section of the eastern side of the Bay of Whales, containing the buried remains of several bases from the "heroic era" of Antarctic exploration, calved away around late 1961. A small iceberg from this event (or closely spaced events), with the remains of Little America III exposed in the ice face, was sighted in February 1963 near the western Ross Ice Shelf front. Satellite observations of more recent calving events show that most small icebergs from the Bay of Whales area drift westward and repeatedly impact the shelf, fragmenting as they move. This implies that a number of artifacts from the bases, such as the 1939–1941 Snow Cruiser, are likely strewn along the seabed near the 1962 ice-front position. Major Ross Ice Shelf calvings of 2000 and 2002 have removed the ice cover from parts of the 1962 front area for the first time since that period. Thus a search for the artifacts is technically more feasible for the next few years until shelf ice flow re-covers the area.

INTRODUCTION AND HISTORY

In the satellite era, our understanding of the evolution of ice shelves, rifting, and iceberg drift has greatly improved, and has allowed us to recognize an underlying cyclicity and repetitiveness of these processes at the decade to century scale (e.g., Jacobs et al., 1986; Lazzara et al., 1999; Fricker et al., 2002). This permits a re-evaluation of less-complete observations from the past against the template of modern patterns. Here we investigate the glaciological history of the Bay of Whales and the calving of a particular small iceberg upon which a great deal of history has transpired.

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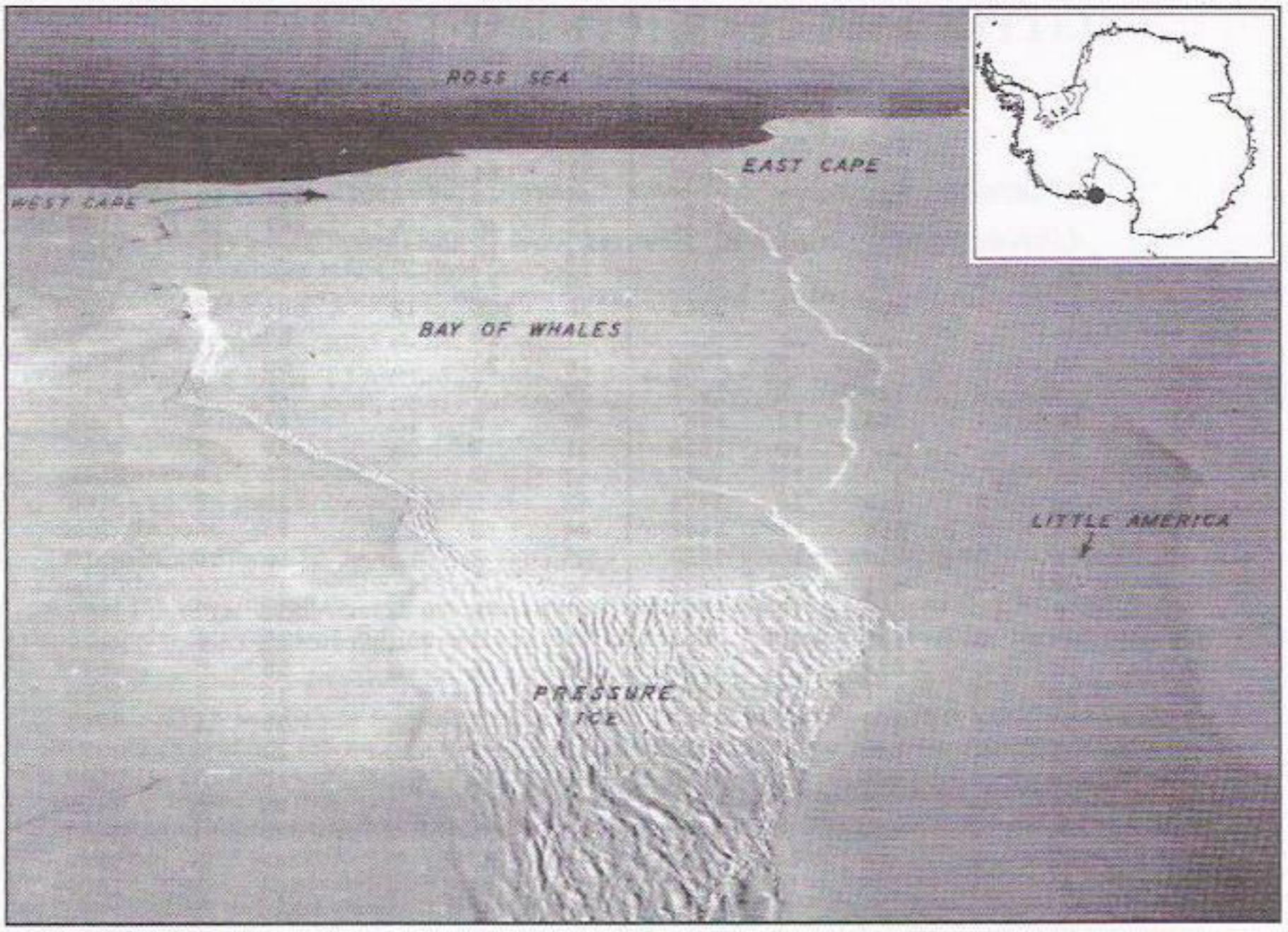

Fig. 1. Annotated oblique aerial photo of the Bay of Whales acquired in December 1934, looking northeast, altitude 12,000 feet, or ~3660 m. From Poulter (1947a). Inset: location of the Bay of Whales.

The Bay of Whales is arguably the most important site for Antarctic exploration in the years 1900 1955 (Figs. 1 and 2). It is a persistent, though evolving, indentation in the Ross Ice Shelf edge formed by the bifurcation of ice flow around the Roosevelt Island ice dome just to the south. The bay was first mapped by Ross in 1842, and first exploited by Carsten Borchgrevink in 1900 as a temporary harbor while he trekked southward (the first overland "furthest south," at 78°50' S; Crawford, 1998). It was mapped again by Scott's "Discovery" expedition in 1902, and by Shackleton in 1908. Both Scott and Shackleton noted that the bay was farther south than McMurdo Sound, but were dissuaded from building a base there by the indications that the Bay was formed by floating shelf ice that calved frequently. Amundsen was not discouraged, and established his base "Framheim" on its eastern flank, convinced that the Bay was comprised of ice resting partly upon land, and thus stable (Amundsen, 1912; p. 169-174). Priestly, who visited the bay and Framheim in the *Terra Nova* about a month after Amundsen arrived, concluded again that the ice flanking the bay was entirely floating (Cherry-Garrard, 1922; p. 130-132). Priestly's assessment is closer to the present understanding of the geography, but as events showed, the Bay shelf ice was stable enough for Amundsen's purposes.

The success of Amundsen, and the Bay of Whales' far southern and eastern location, prompted Richard Byrd in 1928 to select the site for his first Antarctic base, Little America I. This was the first of four major U.S. bases and one university research camp on the eastern flank of the Bay of Whales. The "easternness" of the

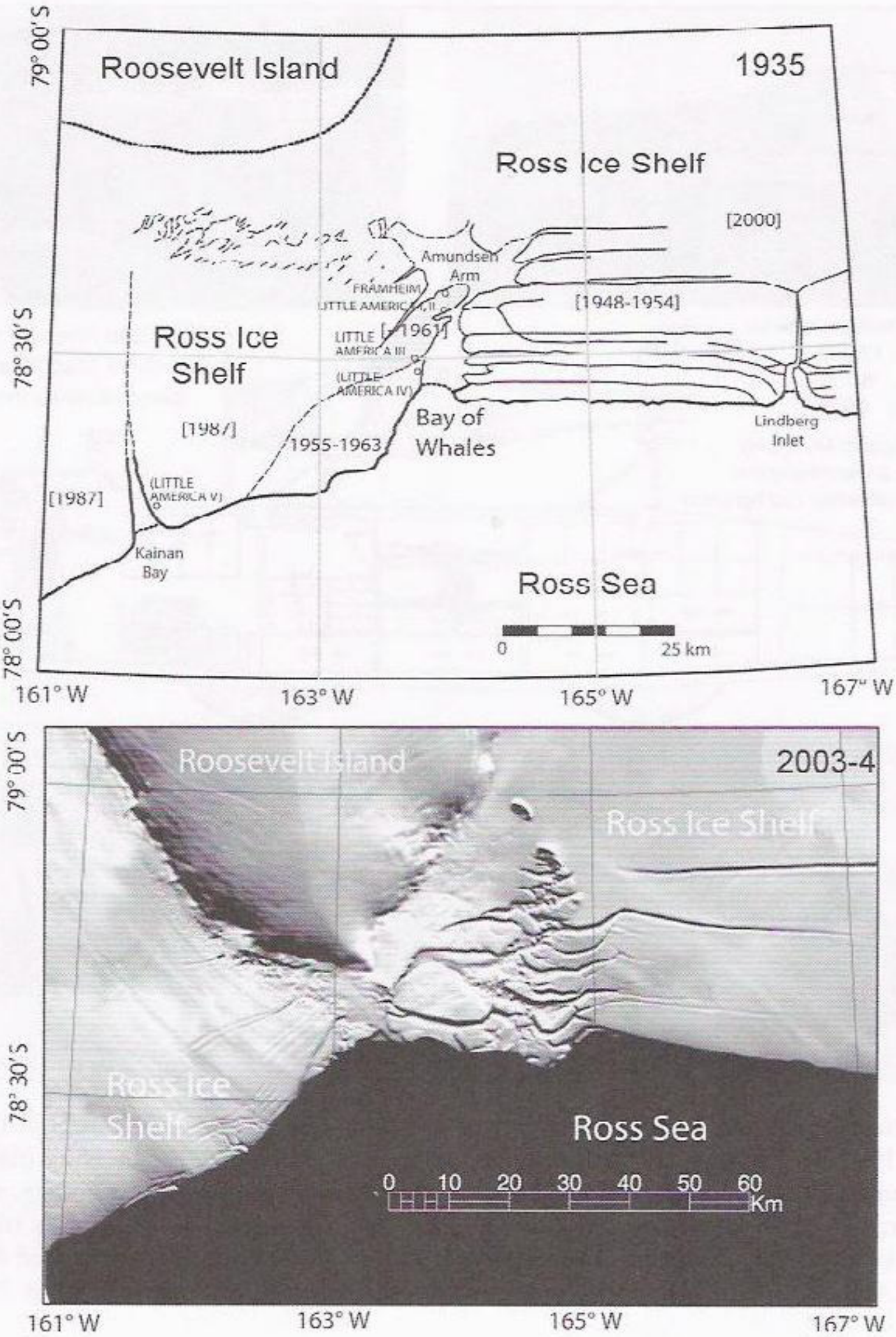

Fig 2. A. Map of the eastern Ross Ice Shelf region in 1935 (derived from Poulter, 1947b). B. Composite satellite image of the Bay of Whales region in 2003–2004 (Scambos et al., 2006).

Bay was of interest because of its proximity to a large unclaimed section of Antarctica between 90°W and 150°W. Byrd returned in 1934, and built Little America II at the same location. In 1940, the U.S. Antarctic Service Expedition, Byrd's third foray, established Little America III as its "West Base" a short distance north of the first two. This was followed by Little America IV in 1947, a major camp of the "Operation Highjump" aerial mapping program, still farther to the north. The last significant

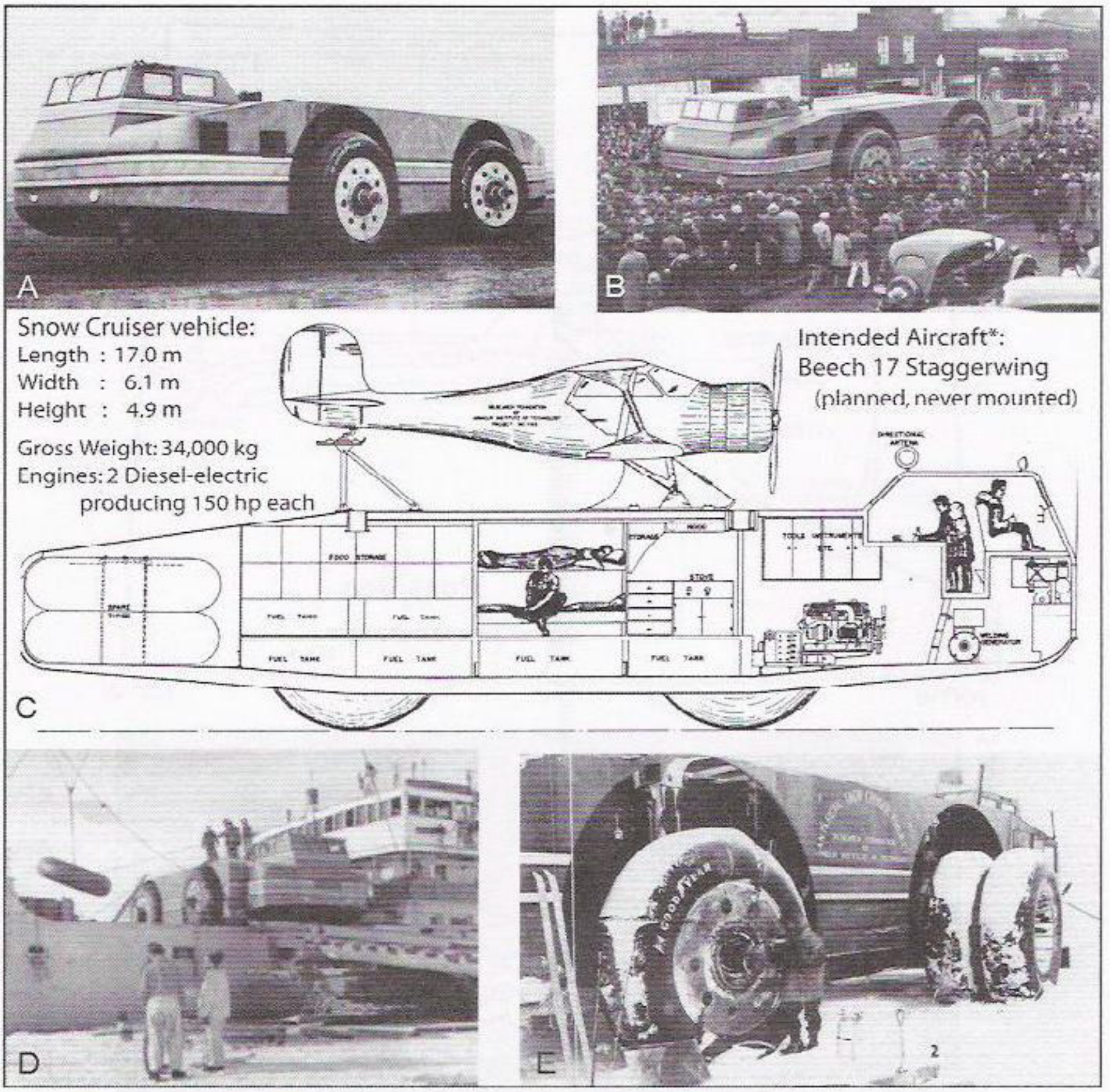

Fig. 3. Images and specifications of the Byrd Snow Cruiser. A. The Snow Cruiser in Indiana in October 1939. B. En route to Boston at Barberton, Ohio, 1939. C. Engineering plan for the Snow Cruiser from the Research Foundation of the Armour Institiute of Technology, where the vehicle was built. D. Unloading the Snow Cruiser from the *North Star* at the Bay of Whales, January, 1940. E. Repairing frozen bearings near Little America III. Images scanned from U.S. National Archives Record Group 126 and from *Special Interest Autos*, June 1995, p. 70–76.

camp in the area was "Camp Michigan," a research camp established in 1957 as part of the International Geophysical Year (Zumberge, 1974).

Little America III included an over-snow vehicle of immense size, capable of carrying an aircraft on its back, and having a designed range of up to 5000 miles (Fig. 3). With living quarters, labs, and workshops for a crew of five, the Snow Cruiser (nicknamed "Penguin I" or "the Penguin") was intended to explore the far interior of the ice sheet, and perhaps reach the South Pole. It was conceived and built within a period of just eight months (March–October 1939) by Dr. Thomas Poulter and the Armour Research Institute of Chicago (Freitag and Dibbern, 1986). The vehicle included

several engineering innovations, such as four-wheel steering and a retractable axle system designed to allow it to cross crevasses up to 4.5 m wide by sliding on its belly near the retracted axle. Its most successful journey (although not without incident) was a shakedown drive across sand dunes in Indiana, followed by a highly publicized road trip from Chicago to Boston in October 1939 to deliver the vehicle to the *North Star*, the ship Byrd used to transport his expedition. Although the first several miles of Antarctic travel on firm sea ice were promising, the Snow Cruiser bogged down upon reaching the soft snow of the ice shelf. Poulter had measured the bearing strength of shelf snow at low total pressures during Little America II, but the mass of the Snow Cruiser was enough to break the hard upper wind-pack crust. With the upper surface broken, softer depth hoar below was incapable of supporting the heavily loaded wheels, or provide sufficient traction for the vehicle (Freitag and Dibbern, 1986). Through dogged persistence, the Snow Cruiser was coaxed through several short Antarctic journeys totaling about 10 miles. All accounts (e.g., Little America III map by Berlin and Butler, 1941, and personal communication from the late Colonel Ted Petras in 2004) indicate that the Snow Cruiser was left very close to the Little America III camp, completing its difficult, abbreviated traverse on January 6, 1941. The camp was abandoned on February 1, 1941.

ICE FLOW AND 20TH CENTURY EVOLUTION OF THE BAY OF WHALES

Ice flow in the Bay of Whales is convergent, with the eastern flank moving westward and the western flank flowing north (Poulter, 1947b; Thomas et al., 1984). Interaction with small ice rises off the western grounding line of Roosevelt Island, and shear margins on either side of the dome, create large rifts on both flanks of feature. These rifts gradually extend, leading to large tabular iceberg calving events (e.g., Lazzara et al, 1999; Keys et al., 1990).

Ross's 1842 map of the Bay of Whales showed an indentation in the "barrier" front of 16 km in both width and length, shifted about 23 km northeastward of its late 20th century mean location (U.S. Naval Hydrographic Office, 1943; see also Jacobs et al., 1986). This shift may have been due to higher ice flux from Kamb Ice Stream along the western flank of Roosevelt Island. Kamb Ice Stream, a major outlet glacier of the Siple Coast, was active until about 1865 but has since slowed to near-zero speeds (Retzlaf and Bentley, 1993). In February 1900, Borchgrevink's *Southern Cross* expedition found the embayment much smaller but still shifted northeast by about 20 km. Scott's *Discovery* expedition of 1902 found two embayments, each roughly 8 by 10 km. "Discovery Inlet," to the west, was a wide ice rift that led to an unobserved calving a few years later; the eastern bay was deemed the probable 'heir' to the earlier Bay of Whales. Shackleton's visit in 1908 found the Bay of Whales area was now one large shallow indentation.

Amundsen, sailing in the *Fram*, found the Bay of Whales in January 1911 to be an 18 × 18 km single indentation in the Ross front. He sited the "Framheim" hut on a protected south-facing edge on the eastern wall (Fig. 4, upper left). The length of the bay, and sea ice–free conditions soon after he arrived, allowed *Fram* to sail to 78° 41' S on February 15, the record "furthest south" of any ship until the 2005/2006 season (small boats from the *Kapitan Khlebnikov* exceeded the record by a fraction of a

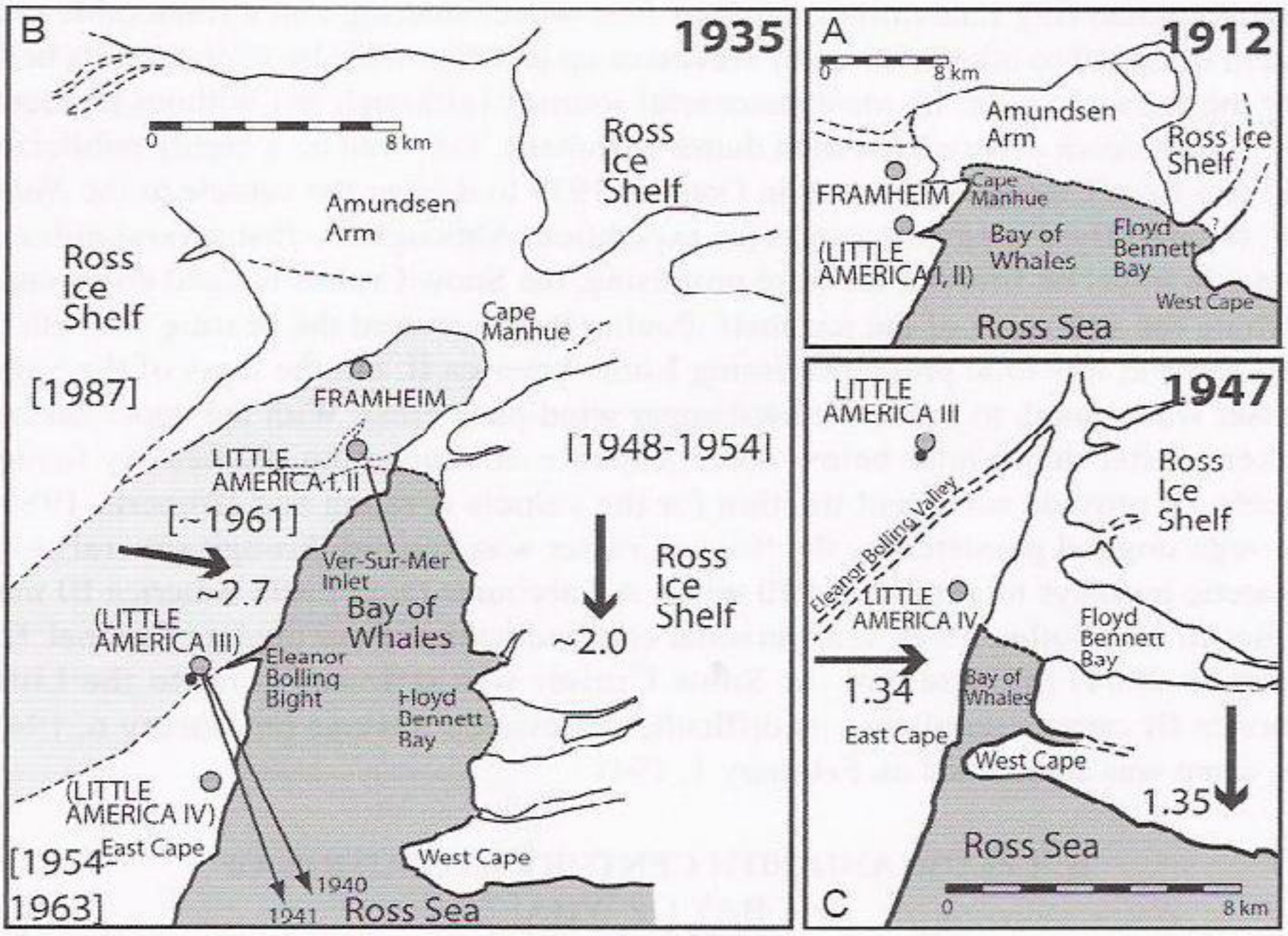

Fig. 4. Evolution of the Bay of Whales, 1911–1947, showing exploration camps in their positions relative to ice features. A. From Amundsen's map of the bay based on the 1911 and 1912 visits by the *Fram* (Amundsen, 1912). B. 1935 configuration, with two vectors from 1940 and 1941 toward the West Cape ice feature from Little America III (Berlin and Butler, 1941; Poulter, 1947b); ice motion vectors of eastern and western bay flanks are shown as heavier arrows (derived from aerial photos and survey markers; Poulter, 1947b); black dot shows position of Snow Cruiser relative to Little America III camp (Berlin and Butler, 1941); lightly shaded area indicates the ice block containing the majority of 1911–1935 artifacts; the year of likely calving is shown for each section of the ice shelf. C. 1947 configuration for northern section of the bay (Siple, 1947), again showing ice motion vectors derived from surveys. Note that scale changes for each panel. See also Sullivan (1957, p. 221).

minute on February 3, 2006). The camp was located about 1.6 km east of an ice promontory Amundsen named "Cape Manhue," or "Man's Head Cape" (Fig. 3A). Amundsen's map shows several features, such as Man's Head and West Cape, that persisted for at least the following 35 years.

Ice flow had reshaped the Bay of Whales by the time of Byrd's visit in 1928, closing the front to just 12 km between East Cape and West Cape. Furthermore, the rear section of the bay, which Byrd called the "Amundsen Arm," was now permanently ice covered with thick fast ice that was deforming under convergent ice flow (Fig. 1, foreground). Byrd's station site was constrained by this blockage to be farther north, and somewhat more exposed, on the east flank of the Bay at a location he named "Ver-sur-Mer Inlet."

Byrd returned to the site in 1934–1935, and established Little America II at the same location. The lead scientist for the Little America II expedition, Dr. Thomas Poulter, used aerial photographs from both 1930 and 1935, supported by ground

surveys, to map in detail the ice features and determine the ice movement of the Bay (Poulter, 1947a, 1947b). This map identifies a single ice block, bounded by deep rifts and the bay edge, that contains both Framheim and the first two Little America bases (Figs. 1 and 3). It is bounded on the north by a small inlet and rift named Eleanor Bolling Bight, on the south by a large NW-trending rift in the Amundsen Arm, and its southwestern tip is Cape Manhue. At the time of Poulter's map, the two flanks of the bay had very different ice flow directions: the eastern bay features moved westward at 2.5 to 3 m per day (bearing 280 ± 5°); and the western margin moved at 2 m per day due north. Poulter noted that this meant that the Bay was closing, and would likely be smaller in future years (i.e., for future expeditions to the Bay of Whales).

This was indeed the case in 1940, when the *North Star* returned to establish Little America III. The bay had shrunk to 3 km width ("about 1.5 miles"; Siple, 1947, 1959), and continued to close during the expedition's stay (Berlin and Butler, 1941; see "1940" and "1941" arrows in Fig. 4). Persistent fast ice in the southern bay area forced Byrd to establish the new camp still further north, at 10 km from Little America I and II (5.4 nautical miles at bearing 207.3°; Berlin and Butler, 1941). The small Eleanor Bolling Bight had become a narrow shelter just large enough to permit unloading of the cargo and Snow Cruiser. An extensive multi-building base was established.

By 1947, during Operation Highjump, the Bay had narrowed to just ~300 m ("less than 1000 feet"; Siple, 1947). Due to the narrowness and fast ice conditions, the large air photography and mapping camp, Little America IV, was established north of Eleanor Bolling Bight and 3 km from Little America III. Siple inferred that the bay had actually completely closed in the previous winter, i.e., that West Cape had been in contact with the eastern flank, and a small area ("one-half mile"; Siple, 1947) of the West Cape tip had been knocked away. A re-measurement of ice flow on either side of the Bay indicated that ice flow speed had slowed considerably ("4.37 feet per day . . . westward" and "northward at a rate of 4.4 feet per day"; or 1.33 and 1.34 meters per day, respectively; Siple 1947), but flow directions were the same as in 1935. Siple predicted that a major calving event would occur in the years following 1947 as the "jaws" of the Bay of Whales closed completely.

POST-1947 EVOLUTION OF THE BAY OF WHALES AND EASTERN ROSS ICE SHELF FRONT

For the period 1948–1954 there were no mappings of the Bay of Whales area. In late 1954 and early 1955, the USS *Atka* visited with the intent of establishing a base in the bay for the International Geophysical Year (IGY), and contributed an ice front survey to a new map by New Zealand's Lands and Survey Department (Dick, 1957). The new ice front mapping, and sightings from the *Atka*, revealed a large area had indeed calved away along the western flank of the Bay, 20 km wide and extending at least 150 km to the west, leaving a new, much broader Bay of Whales. However, helicopter inspection on January 14, 1955 from the *Atka* provided visual evidence that the Little America I-II camp and Little America III camp were still present on the eastern Bay of Whales shelf ice (Sullivan, 1957, pp. 302-303). Little America IV was cut by the calving front, with the majority gone and artifacts dangling from the shelf ice (Sullivan, 1957, p. 304; see also his maps on p. 221).

Siple also flew over the Little America camps, in late December 1955, and described the visible remains as follows (Siple 1959, p. 118):

> "... three steel radio towers I had helped erect at Little America I barely protruding above the surface, although they had originally stood some seventy feet high. All that remained of the second Little America were the tips of five once-high telephone poles, while the tent village we had established as Little America IV had partly disappeared as a result of the Barrier's calving."

Siple refers to Little America III as the "second Little America" because both Little America I and II were established on the same site, and used some of the same structures; Little America III was the second site.

A snow pit dug on January 29, 1958 to the Snow Cruiser shows that the vehicle, well preserved, was still a part of the eastern Bay of Whales ice flank at that time (Goldthwaite, 1958). A few visits at this time and in the weeks before the following winter represent the last times anyone has seen the Snow Cruiser (to the knowledge of the authors).

Sometime subsequent to these inspections, the eastern Bay of Whales ice front began to calve the ice block that contained the first three Little Americas and Framheim. Figure 5 shows an orthorectified version of one of the earliest satellite images of the Ross ice front, acquired by the "Argon" defense intelligence satellite project on October 29, 1963 (Bindschadler and Seider, 1998; Kim et al., 2006). Superimposed on the images is the trace of ice feature edges from Poulter's 1935 map (Poulter, 1947b), and an ice front map from February 1957 (Wexler, 1960; U.S. Hydrographic Office, 1957) and 1962 (U.S. Naval Oceanographic Office, 1966; AGS, 1971). In addition, the ice feature–referenced locations of Framheim, Little America I–II, Little America III, and Little America IV relative to Poulter's 1935 map are shown.

Although ice flow measurements in the immediate vicinity of the Bay of Whales flanks show large variations (Fig. 4), regionally the ice shelf should show more constant rates of flow, since overall shape, divergence, and thickness do not vary greatly. The ice front should on average move forward at these rates, modified by calving events. Some idea of the timing of these calving events can be inferred from changes in the front shape and its relative position. Recent analyses of ice front movement and evolution show this is generally the case for the Ross (Jacobs et al., 1986; Lazzara et al., 1999), and it is indeed what we observe for the Ross front on either side of the bay in Figure 5.

The relationship of the coastlines, coupled with regional ice motion vectors of the mid-1970s (Thomas et al., 1984) indicate that southern areas on the east side of the Bay of Whales must have calved away in the period 1957-1962; northern areas calved between early 1962 and October, 1963 (Fig. 5). These southern sections contained the remains of Little America I –II, Little America III, the Snow Cruiser, and Framheim. On the western side of the bay, the RIGGS vector (scaled to equal 30 years of motion in Fig. 5) suggests that a major rift identified by Poulter in 1935 (he called them "tide cracks" on his map) was the calving front for the major berg that detached between 1948 and 1955 (see Dick, 1957).

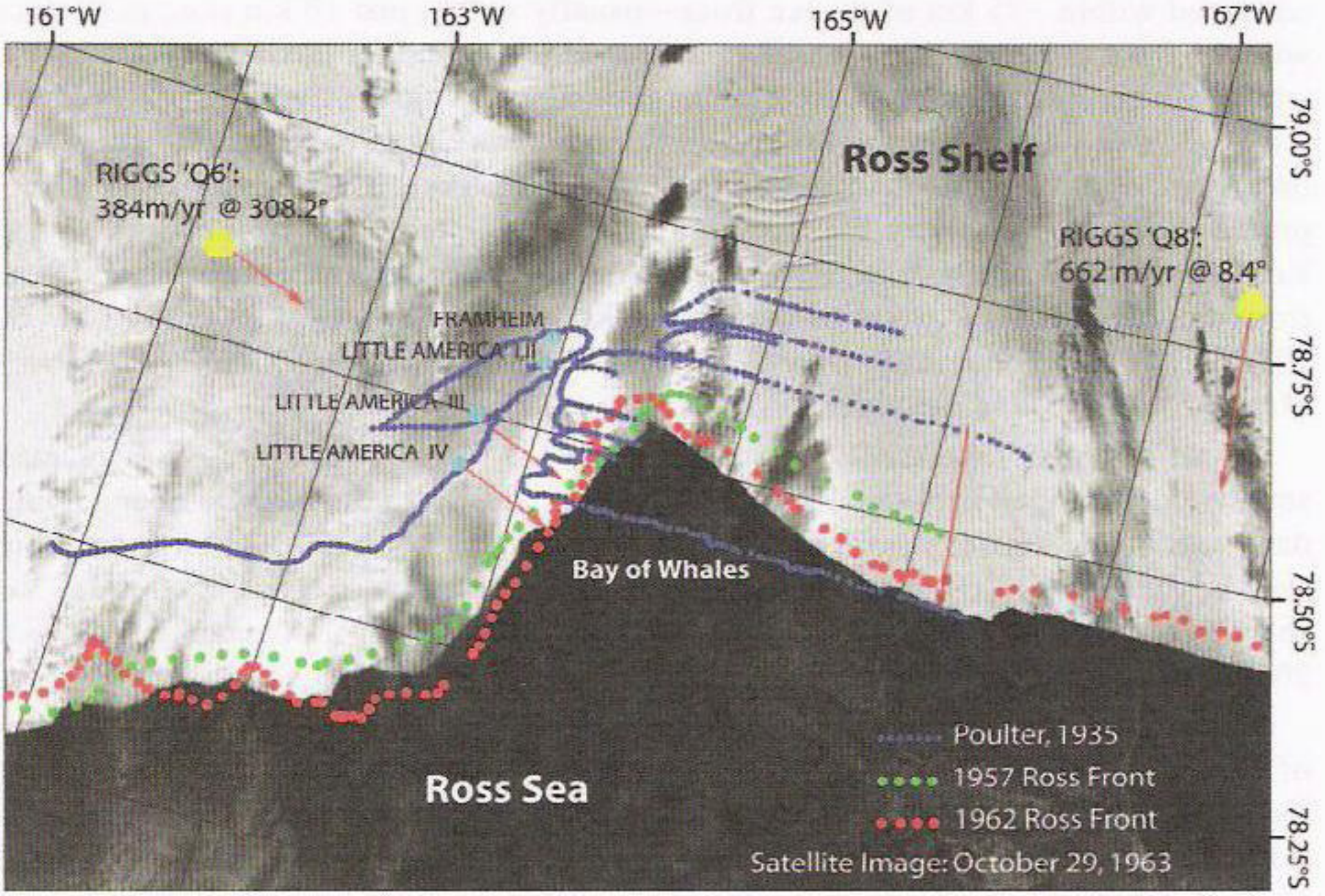

Fig. 5. Evolution of the eastern Ross Ice Front, 1935–1963. Base image is a subscene from a coastline image map derived from declassified early defense intelligence satellite photographs (Kim et al., 2006). This section of the map, derived from image DS09059A065MC083 (USGS Earth Explorer archives), was acquired on October 29, 1963 (Bindschadler and Seider, 1998). Overlain on this image are coastlines and ice features from earlier ice front mappings in early 1962 (AGS, 1971; red dotted line), 1957 (U.S. Naval Oceanographic Office, 1966; see also Wexler, 1960; green dotted line), and 1935 (Poulter, 1947b; blue dotted line). The nearest measured ice flow vectors from the RIGGS project of the mid-1970s are shown by yellow markers (Thomas et al., 1984). Vector arrow lengths are scaled to 30 years of ice motion. A copy of the 30-year vectors are shown placed at Little America III, Little America IV, and on the western flank of the bay. Note that ice front relationships imply calvings between 1957 and 1962 for the southeastern Bay of Whales, and further calvings between 1962 and the 1963 image in the northeastern flank.

ICEBERG CALVINGS AND ICEBERG DRIFT TRACKS ALONG THE ROSS ICE SHELF FRONT

We now consider the probable drift track of any small bergs formed in the 1957–1962 calving(s), and their likely rate of drift, by looking at similar recent events from the same area. In October 1987 a large iceberg (named B9 by the U.S. National Ice Center) and many smaller bergs calved from the shelf region just east of the Bay of Whales—in fact, this is the ice immediately behind the Little America–Framheim–Snow Cruiser ice block identified from Poulter's 1935 map. Keys et al. (1990) described in detail the drift of B9 (154 × 35 km) and five much smaller (~2–10 km long) icebergs calved from the new shelf front. Drift paths of the smaller pieces were very similar, and unlike the path of the large berg. Small pieces drifted westward and

remained within ~75 km of the ice front usually within just 10 km (i.e., in contact with the front or nearly so). A similar pattern was observed for the huge B15 iceberg, which calved in late March 2000. The berg remained in close proximity or in contact with the front, lodging in the McMurdo Sound area (Lazzarra et al, 2000; see also image series at http://nsidc.org/data/iceshelves_images). Keys et al. (1990) interpreted the strong tendency for the smaller B9 associated bergs to remain near the Ross edge as being due to a narrow front-parallel westerly current. Current flow from moorings within 10 km of the ice front (site Γ in Keys et al., 1990; 78.11° S, 175.52° W) showed westerly flow that averaged 4 km/day during summer (October–March), but slowed to near-zero during winter months.

The drift transit time across the western Ross Ice Shelf front for the B9-associated smaller bergs ranged between 132 and 152 days, timed from the mid-October calving date of B9 (i.e., during austral summer; Keys et al., 1990). Satellite image tracking showed an average drift rate of 6 12 km/day, ranging between 2 and 25 km/day for short periods. B-15 transited a shorter distance in ~270 days, between late March 2000 and early January 2001 (i.e., spanning the winter period).

From these observations we infer that small calving events from the eastern Bay of Whales flank implied by the front retreat between 1957 and 1962 would most likely have drifted very close to the Ross shelf front of that period. They likely collided with the front repeatedly, as did the smaller B9-associated bergs, and fragmented. Furthermore, the transit time across the Ross shelf would be rapid during austral summer, but might be considerably slower during an austral winter.

SIGHTING OF LITTLE AMERICA III REMAINS BY THE *EDISTO* IN 1963

On February 25, 1963, the *USS Edisto* sighted a small tabular iceberg with "telephone poles" upon it as it was conducting oceanographic survey work near the western Ross Ice Shelf front (Fig. 6; see the *Edisto* log, from National Archives; ret. Cpt. Ron Jesberg, personal communication; and Third Little America, 1963; see also Zumberge, 1974). A helicopter flown by Jesberg for a closer inspection of the iceberg face showed exposed boards, tarpaulins, and other artifacts of a camp. The camp was identified as Little America III. The berg was approximately 400 m long and 100 m wide and located at 77.36° S, 174.3° E, approximately 18 km from the 1962 Ross front.

Aerial photos of the berg from that day reveal four thick "telephone" poles atop the berg near the ice front, and camp artifacts and a building interior in the berg face. A survey of camp photographs of Little America III (U.S. National Archives Record Group 126) shows that several such poles were placed near the aircraft winter hangars (with guy wires, consistent with the 1963 photograph in Fig. 6, lower right). Siple's note of "the tips of five once-high telephone poles" (Siple, 1959, p. 118) as the only remaining artifact on the surface further supports the Little America III identification, and also suggests that one pole had already detached from the berg. Moreover, the relative position of the aircraft hangars, poles, and Snow Cruiser (Berlin and Butler, 1941) make it almost certain that the Snow Cruiser had separated from the *Edisto* berg at some earlier time.

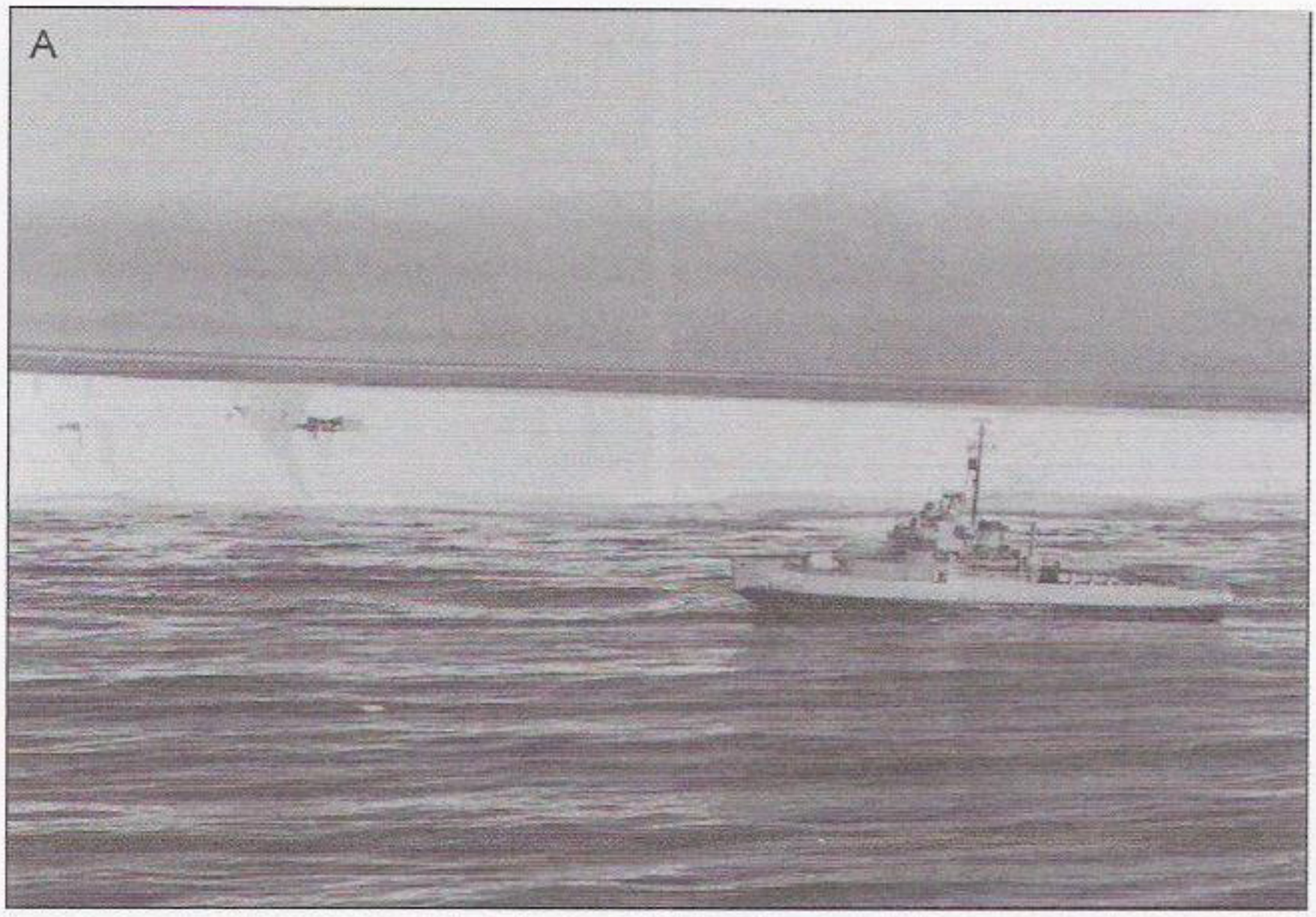

Fig. 6. Images of Little America III remains in the face of a ~400 meter-long iceberg in the western Ross Sea, February 25, 1963. A. Aerial photograph of *USS Edisto* icebreaker near the front of the iceberg (image provided by R. Jesberg). B. Aerial photograph showing remains and four tall poles on upper surface of berg. C. Photograph of A. Schroeder next to pole on surface of the berg (Third Little America, 1963).

REMAINING LARGE ARTIFACTS OF THE EXPEDITIONS

Given the above discussion, we review the historical literature to identify items that were left with the bases on the Framheim Little America ice block. Some of these are items likely to be present along the 1962 ice-front line on the Ross Sea seabed. A collage of pictures of the main items is shown in Figure 7.

Framheim

Amundsen (1912, p. 289) spoke of the great iron stove that the cook Lindstrom used to make pancakes, and of many wood-working implements. However, it is

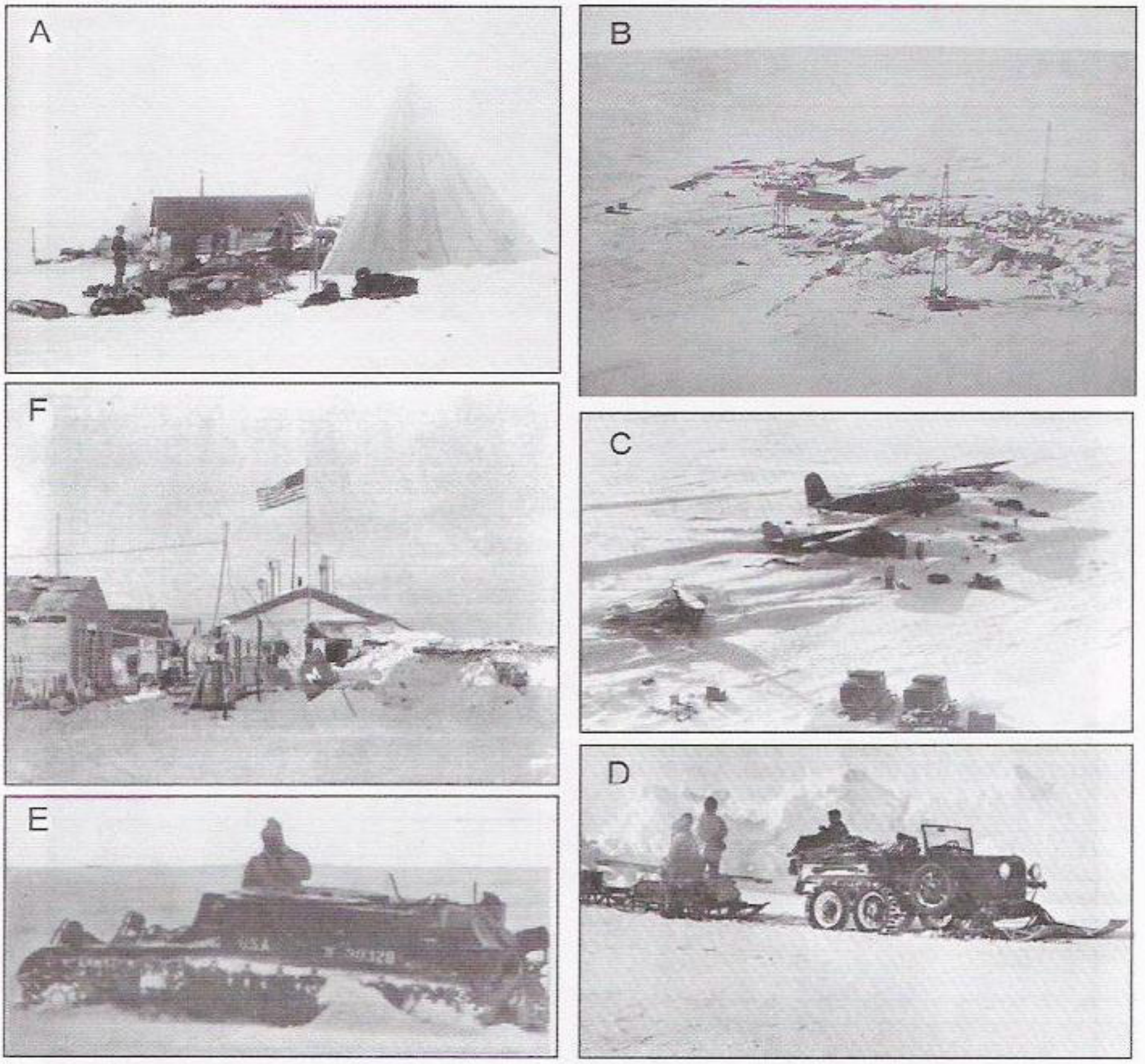

Fig. 7. A sampling of the major artifacts (in addition to the Snow Cruiser) left behind at the Framheim, Little America I, Little America II, and Little America III bases. A. Framheim hut (Huntford, 1987, p. 85); B. Steel radio towers dominated the camp at Little America I and II (U.S. National Archives image 306-NT-547-1). C. Aircraft and tractors at Little America II. The two aircraft at the top of the image, a Condor and Fokker, and one of the two tractors at the bottom, both Citroëns, were left behind in 1930 (NA image 306-NT-548-16). D. Two Ford snowmobiles of this type (NA image 306-NT-548-14). E. A small military tank, as well as several buildings steel drums, machinery, poles, wire, etc. were left at Little America III (F; NA image from record group 126, dated March 17, 1939).

unclear which if any of these were left behind on January 30, 1912. Because the hut and several workshops were entirely buried within 2 months of the building of Framheim (Amundsen, 1912), we expect that the hut itself was not recovered (Fig. 7A). Although a 1934 location for Framheim of 1.6 nm due south of Little America II is attributed to Poulter (1947a, 1947b; see Zumberge, 1974 and Wexler, 1960), we could not find such a statement in the Poulter (1947) texts. It is therefore uncertain if the Framheim hut was revisited, or what artifacts might have been seen in 1934.

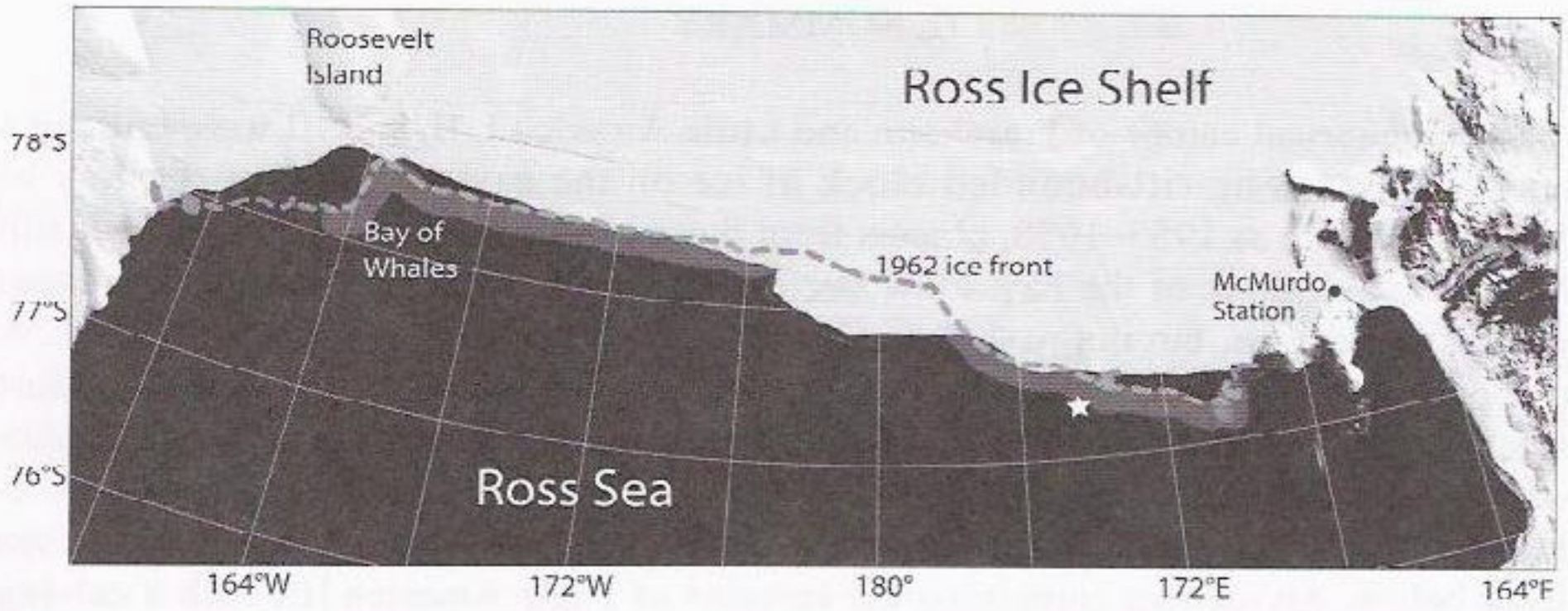

Fig. 8. Ice front of the Ross Ice Shelf (from MODIS Mosaic of Antarctica, or MOA; Scambos et al., 2006) compared with the ice edge as mapped in 1962. *USS Edisto* location during the 1963 iceberg sighting is shown as a star symbol. Light shaded area along part of the ice front indicates surface-accessible region of potential 1911-1957 historical artifacts (as of ~1 January 2004).

Little America I and II

The camp was dominated by three ~70 foot-tall derrick-like steel radio antennas (Fig. 7B). As late as 1956, two of the towers still protruded roughly 4 feet above the shelf surface (Siple, 1959, photos after p. 96), confirming that the towers and the underlying camp were still attached to the ice shelf. At the end of the Little America II expedition, during the final phases of re-loading the ships, bad ice conditions and weather forced Byrd to leave behind two large aircraft (a Fairchild Condor and a Fokker) and several tractor vehicles a short distance from camp (Bertrand, 1971). The vehicles are a Cletrac and Citroen tractor, and two Ford snowmobiles modified from Model A automobiles (Figs. 7C and 8D).

Little America III

Little America III was a huge camp by previous standards, and included numerous vehicles, buildings, and many barrels of fuel. It included a substantial machine shop, large food stores, and three large wood and metal buildings. Among the vehicles was a small U.S. Army tank (Fig. 7E), and several tractors and bulldozers. However, the most recognizable large artifact was the Snow Cruiser.

Little America IV

This huge camp calved somewhat earlier, beginning before 1955, and it is unclear where the western Ross front was during the period 1948–1954. However, the pattern of calving for this camp appears to have been different, crumbling away in many smaller pieces. A huge number of artifacts are potentially distributed along the Ross Ice Shelf front, possibly very close to the 1948–1954 Bay of Whales ice front, beginning with 9 RD-4 aircraft (Sullivan, 1957).

SUMMARY

The historical camps of Framheim and Little America I, II, and III were built on a single 16 km-long rift-bounded block of ice on the eastern flank of the Bay of Whales. As late as 1955–1958, objects from these camps were sighted or visited, still on the eastern flank of the bay. Flow vectors of nearby ice are consistent with these objects being near, but not past, the calving front of the Ross as mapped in 1957. A mapping in 1962 indicates that this area calved away between the two periods. Most small icebergs calved from this region drift westward along the Ross ice front, repeat edly impacting it. Iceberg-shelf collisions lead to erosion of the ice masses (via collapse of "push mounds"; e.g., Ross et al., 2004) and loss of the artifacts to the sea floor below. An iceberg containing the remains of Little America III, with a calving face orientation that strongly implies that the Snow Cruiser was *not* aboard at the time, was sighted in late February 1963. Drift rates for bergs across the Ross Ice Shelf front suggests that the calvings must have occurred very late in the 1957–1962 range, probably just months before the 1962 mapping. An October 1963 satellite image confirms the general accuracy of the 1962 mapping. Therefore, it is likely that at least some artifacts from Framheim and the three Little Americas, including the Snow Cruiser, are strewn along the seabed beneath the 1962–1963 front.

The recent major calvings of the Ross front (B-15, March 2000; C-19, May 2002) have now removed shelf ice covering the sea floor beneath the 1962–1963 shelf fronts for the first time since that period (Fig. 8). Approximately 50% of the front area is now accessible from the surface. Moreover, this strip of sea floor has never been surveyed with modern marine sensing and sampling equipment (e.g., side-scan sonar, magnetometer, piston corers). Water depth across the ice front is 400–800 m.

These historical artifacts could be located and identified by a survey of the Ross Ice Shelf front, using modern subsurface remote sensing techniques. At the same time, such a survey could analyze a new strip of sea floor sediments, not measured previously, and determine glaciologically important parameters in understanding the history of the Ross-draining glacier systems and the mean location of the Ross Ice Shelf front.

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