UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GLORIA INVESTIGATION OF THE EXCLUSIVE ECONOMIC ZONE IN THE GULF OF ALASKA

MV FARNELLA CRUISE F6-89-GA
May 16 to June 11, 1989

by

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INTRODUCTION

Cruise F6-89-GA was the third survey in a 4 cruise multi-year program designed to image the Gulf of Alaska EEZ (Exclusive Economic Zone) using GLORIA (Geological Long Range Inclined Asdic), a long-range side-looking sonar (Somers et al, 1978, Swinbanks, 1986). The Gulf of Alaska study is part of a cooperative research program between the United States Geological Survey (USGS) and the British Institute of Oceanographic Sciences (IOS). The objective of this program is to produce an atlas that shows the geologic and morphologic features of the seafloor so as to better evaluate the economic potential, geologic hazards, and other possible uses of the Alaskan EEZ.

Cruises prior to F6-89-GA were F1-86-GA, which imaged a small area around Middleton Island, and F9-88-EG, which covered the EEZ between the Aleutians and Kodiak (fig. 1) that were carried out in June 1986 and August 1988 respectively. Cruise F6-89-GA covered an area southeast of Kodiak Island to Yakutat Bay, seaward to the 200 mile limit, from May 16 to June 12, 1989. The remainder of the Gulf of Alaska was covered by the subsequent cruise, F7-89-EG.

The GLORIA surveys are conducted from the M/V Farnella, a converted freezer-trawler that is under lease to the U.S.G.S. through IOS in Wormley, England. In addition to collecting GLORIA data, operations included collecting two-channel seismic-reflection profiles using an air-gun sound source, 3.5 kHz high-resolution profiling, 10 kHz echo-sounding bathymetry, magnetic and gravity potential-field measurements, and upper water column temperature profiles using expendable bathythermographs. The scientific and ship personnel are listed below.

Table 1. Scientific and support personnel, cruise F6-89-GA

U.S. Geological Survey

Paul Carlson	Co-Chief Scientist/Geologist
Dennis Mann	Co-Chief Scientist/Geophysicist
Kaye Kinoshita	Navigator/Watch Chief
Michael Hamer	Geologist/Watchstander
Rick Morgan	Watchstander
Larry Kooker	Electronic Technician

Institute of Oceanographic Sciences

Quentin Huggett	Co-Chief Scientist/Geologist
Derek Bishop	Chief GLORIA Engineer
Adrian Fern	Navigator/Computer Technician
Alan Gray	Airgun Technician
Andrew Harris	GLORIA Engineer

JMarr (Ships Crew)

John Cannan	Captain
William Wilson	Chief Officer
Albert Fuller	2nd Officer
Michael Baldwin	Chief Engineer
Lee Hussey	2nd Engineer
Arthur Green	3rd Engineer
Robin Searle	Electrician
Alan Thompson	Bosun
Gordon McFadyen	Chief Cook
Thomas Caughie	2nd Cook
Peter Appleyard	Seaman
Coleman Kenny	Seaman
Colin Bettison	Seaman
Anthony Zielinski	Messman

EQUIPMENT

GLORIA Side-scan Sonar System

The GLORIA instrument is towed at a depth of 40-50 m, at a distance of 300 m behind the vessel, and at a speed of 8 to 10 knots. The sonar array in the GLORIA fish consists of two rows of 30 transducers each, on either side of the fish. The transducers send a 4 sec burst of energy at 30 sec. intervals with frequencies of 6.3 and 6.7 kHz and 100-Hz bandwidth. Incoming signals from the port and starboard sides are recorded separately and the data are corrected for distortions due to slant-ranging and changes in ship's speed. The system can image features 20 cm high, features separated by 45 m in the direction perpendicular to the ship's track, and features on the order of 100 m long in the direction parallel to the ship's track. For more detailed information about the GLORIA system see Somers er al (1978) and Swinbank (1986). The data in digital format are amenable to computer-aided image processing and enhancement techniques. This cruise experienced more problems with the GLORIA system than any other cruises in the GLORIA-EEZ program. Thus, we have documented these problems in a summary of field operations that follows the equipment section.

Two-Channel Seismic Reflection System

The two-channel seismic reflection system employs a 2600 cm^3 (160 in^3) air-gun sound source and a two-channel streamer. The streamer's two 50 m long active sections were towed about 500 to 600 m behind the air gun. The air gun was fired every 10 seconds. Data were recorded on a MASSCOMP computer in SEGY format on 1600 bpi tapes, and a one-channel, six-second analog record was displayed on a Raytheon LSR (line scan recorder). Data tapes are digitally processed by the USGS using Digicon's DISCO seismic processing software on a VAX 11-785 computer system. Data quality is enhanced by editing of bad traces and muting of water noise, stacking, deconvolution, filtering processes, and migration of selected lines. The data are then re-displayed on an electrostatic plotter (fig. 2).

The two-channel seismic reflection system performed well during the survey. The airguns required little attention aside from routine maintenance at 5 day intervals. The Teledyne streamer required no attention with the exception that upon recovering the streamer on day 153 because of the storm, it was discovered that the weighted section had been omitted from the streamer. This was remedied immediately so the streamer would be ready to relaunch when the seas subsided. MASSCOMP malfunctions generally were a minor problem and required little attention. The few data gaps were mainly caused by watchstander errors.

3.5-kHz and 10-kHz Systems

The 3.5-kHz high-resolution reflection profiling system is on a tow fish and performed well with only routine maintenance throughout the course of the cruise. The precision-echo-sounding 10-kHz system was deployed in a tow fish similar to that of the 3.5-kHz system. The system worked flawlessly with down time restricted to routine maintenance.

Gravity Meter

The gravity meter, a LaCoste and Romberge S-53, functioned continuously throughout the cruise. Gravity ties to land stations were established at the start and end of the cruise. Data are recorded on both strip-chart and magnetic tape.

Magnetometer

The magnetometer was deployed throughout GLORIA data acquisition. The data are recorded on both strip-chart and magnetic tape, with the same digital recorder used for the gravimeter.

Shipboard Positioning Systems

The shipboard positioning systems performed well, using the Global Positioning System (GPS) network coupled with the addition of a real-time, rho-rho Loran positioning system. The system (described in Normark et al., 1987) also incorporates a real-time trackline display for the ships' bridge personnel, that displays ships position relative to the desired survey line.

The GPS system provided navigation about 15 hours per day. When GPS was unavailable we used the rho-rho Loran C with the Western Gulf of Alaska Chain which has stations at Tok (master), Kodiak (slave x), and Shoal Cove (slave y). The rho-rho performed satisfactorily.

Expendable Bathythermographs (XBT's)

The XBT probes were deployed as weather allowed to measure the thickness and temperature of the surface mixed layer, and the temperature profile within the thermocline. The system is incorporated with a micro-computer that handles recording, plotting, formatting and data transmission. Data transmission to NOAA (National Oceanographic and Atmospheric Administration) is accomplished via satellite. Successful XBT drops are as follows:

Day/Time	XBT	Depth Rating	Record Length	Latitude	Longitude
150/2228	T-04	460 m	Full	58° 21.9'N	143°56.1'W
151/2244	T-04	460 m	Full	55° 50.3'N	148°34.0'W
154/2342	T-04	460 m	Full	56° 48.0'N	146°03.4'W
156/2335	T-04	460 m	Full	54° 48.1'N	148°49.5'W
157/2322	T-04	460 m	Full	56° 18.0'N	145°23.7'W
158/2326	T-04	460 m	Full	56° 45.7'N	143°45.0'W
159/2330	T-04	460 m	Full	56° 44.1'N	142°59.5'W
161/2323	T-04	460 m	Full	58° 17.0'N	141°35.5'W

SUMMARY OF FIELD OPERATIONS

The following narrative of the F6-89-GA cruise is given in GMT (local + 8 hrs)

Day 136 (Tuesday, May 16)

1700: Sailed from Kodiak Harbor. Winds at gale force.
2100: Launched 10 kHz and 3.5 kHz fish,

Day 137 (Wednesday, May 17)

0400: Arrived at launch point. Winds and seas still high; GLORIA launch postponed until 1400 (daybreak).
1600: Commenced launch of GLORIA vehicle and geophysical gear.
1630: IOS technicians discovered short circuits in GLORIA sections 1, 2, and 4. Operation of GLORIA requires three adjacent sections, so all gear recovered while tracing cause of short circuits.
2100: Short circuits traced to cables linking GLORIA transducers to main junction box. Weather conditions worsening. Efforts to make repairs suspended. Steamed for shelter of Kodiak Island.

Day 138 (Thursday, May 18)

0200: Anchored in sheltered waters of Sitkalidak Strait off southeast Kodiak Island. Upon removal of faulty cables, discovered gland body was badly corroded underneath plastic molding. Affected all cables, not just those that shorted. Only enough spares to fix sections 1, 2, and 4, so vehicle was reassembled with corroded cables. Telexed IOS to send spare cables.
1830: Reassembly of GLORIA vehicle completed.
1900: Weighed anchor, transited to launch point.
2000: 10 kHz and 3.5 kHz relaunched.

Day 139 (Friday, May 19)

0100: Relaunched GLORIA vehicle near starting point. No other gear deployed while testing transducer arrays. Section 2 again shorted so transmission switched to sections 3, 4, and 5.
0350: GLORIA transmitting ok so turned toward start point of survey and deployed all gear.
0740: Started line 1, everything functioning normally.
1130: Section 5 shorted out, section 2 already out. Without three adjacent sections, survey was aborted.
1700: All gear recovered, steam for Kodiak to make major repairs. Enroute arrangements begun for workshop facilities at Coast Guard Base in Kodiak, a crane to offload vehicle, truck to transport it, van rental for transportation, pilot for entry to the harbor, etc.

Day 140 (Saturday, May 20)

0300: Anchored off Kodiak. Paul Carlson and Larry Kooker went ashore to continue necessary arrangements. Others prepared GLORIA vehicle for removal by crane.

Day 141 (Sunday, May 21)

0800: Farnella moved to container cargo dock for removal of GLORIA vehicle (midnight local time).

1800: IOS technicians took GLORIA vehicle to Coast Guard Base motor pool. Rest of scientific staff assisted changing towing cable. New transducer cables arrived from England via express air freight.

Day 142 (Monday, May 22)

1700: Work continued on GLORIA vehicle. Sections 1 and 2 recabled. New cables better designed and relatively easy to install.

Day 143 (Tuesday, May 23)

1700: Work continued on GLORIA, sections 3, 4, 5 and 6 completed. Continuity tests showed everything working. Arrangements made for returning vehicle to Farnella.

Day 144 (Wednesday, May 24)

2000: GLORIA re-loaded onto Farnella. Everything reassembled by 2400.

Day 145 (Thursday, May 25)

0200: Ship sailed from Kodiak.

0400: 10 kHz and 3.5 kHz fish launched.

1400: Reached launch point. GLORIA deployed for testing; calm seas, light wind. Sections 2, 3 and 4 set for transmitting.

1800: All other gear launched. Steamed to waypoint to restart line 1 (line 1A in logs).

Day 146 to Day 153 (Friday, May 26 to Friday, June 2)

No major equipment problems during this time. Recabled GLORIA vehicle performed well. Weather worsened on Thursday June 1; forecast 55 knot winds, 30 ft seas.

0228: Stopped logging GLORIA to haul in gear.

0300: All gear on board to wait out storm. During recovery of two-channel hydrophone streamer, discovered weighted section omitted behind first stretch section. Immediately fixed. Streamer ready for relaunch.

Day 154 (Saturday, June 3)

1600: Weather moderated. GLORIA nose cone removed, twist in tow cable removed.

1740: Relaunched GLORIA and other gear.

1838: Restarted line 17 (17A in logs).

Day 153 to Day 162 (Sunday, June 4 to Sunday, June 10)

No major problems for rest of survey.

2047: Ended main GLORIA survey. Recovered hydrophone streamer, airgun and magnetometer. GLORIA shorthauled for mini survey of Yakutat Valley on way into Yakutat Bay.

Day 163 (Monday, June 11)

0500: Mini survey ended in Yakutat Valley, all gear aboard by 0530. Final passes processed and printed for mosaic.

1630: Ship anchored in Yakutat.

PRELIMINARY RESULTS

About 183,000 km^2 of the Gulf of Alaska were insonified on leg F6-89-GA which covered 6027 km (3258 n. mi.) of track line (fig. 3). The shipboard mosaic created from the GLORIA images displays prominent geomorphic features of the Gulf of Alaska continental slope, rise and the northern portion of the Aleutian Trench, and the northern two-thirds of the Alaskan Abyssal Plain. Some highlights of these morphologies as provided by GLORIA imagery and associated acoustic data are described in the following preliminary cruise results.

Gulf of Alaska Continental Margin

GLORIA and other data show that the continental slope developing along this active margin is devoid of large submarine canyons, in spite of the presence of large glacially-formed sea valleys that extend to the edge of the continental shelf (Carlson et al, 1982; Hampton, 1983). Much of the slope is incised only by relatively small canyons and cut by intensive gullying (fig.4). Along the slope between Kodiak Island and Pamplona Spur discontinuous, actively growing deformation structures disrupt or divert the downslope transport of sediment into the Aleutian Trench . These subduction margin ridges result in the ponding of Quaternary sediment to thicknesses of several hundred meters in the interslope basins (Carlson et al., in press). Some of the ridges are breached or cut by sediment flow paths which wind around the ridges and reach the trench. Where these small canyons and gully systems debouch into the trench, small fans have developed (Carlson et al , in press). Between Middleton Island and Alsek Valley, where the areas of intensively gullied slopes are most common, the gullies often merge to form a small dendritic canyon system that extends to the abyssal depths. Between Middleton Island and Kayak Island these systems extend directly to the northeastern end of the Aleutian Trench. Southeast of Pamplona Spur the dendritic systems reach the base of the slope where they are feeders to extensive deep-sea channel systems (Bruns et al, 1989).

Aleutian Abyssal Plain

The major features imaged on the abyssal plain, by the GLORIA system on cruise F6-89-GA, are the Kodiak-Bowie Seamounts that extend in a northwesterly trend across the surveyed area and the Surveyor Channel system that extends southwesterly across the Aleutian abyssal plain and bends sharply northwesterly and extends into the Aleutian Trench (fig.3). Although both features, the seamount chain and the channel system, have been known for many years (Menard, 1964; Ness and Kulm, 1973; Stevenson and Embley, 1987), the GLORIA imagery permits continuous, more precise mapping of the channel and provides an improved coverage of the seamounts and surrounding abyssal features.

The Kodiak-Bowie Seamount chain consists of more than 30 seamounts that range in size from 50 km in long dimension for three (Giacomini, Pratt and Surveyor Seamounts) to small seamounts less than 5 km in diameter, including some with visible craters. Although the largest seamounts have been mapped and named, the GLORIA mosaic (including imagery collected on leg F7-89-GA) will allow us to map in detail all of the seamounts in the chain north of 53° 20' N latitude. The mosaic includes the most northerly seamount in the chain, Kodiak Seamount, which has entered the Aleutian Trench (fig. 3) and may be deforming as it encroaches on the deformation front along the landward wall of the trench.

The Surveyor Channel system originates at the base of the intensively gullied slope between Pamplona Spur and Alsek Valley, as the small slope gullies merge into three turbidity current channels, which in turn merge together 150 km south of the margin to form Surveyor Channel (fig. 3). The resulting well-defined Surveyor Channel meanders approximately 700 km from the margin to the Aleutian Trench. About 350 km from the margin, the channel encounters the structural oceanic-basement barrier formed by the Kodiak-Bowie Seamount chain. The channel crosses the barrier by Giacomini Seamount (figs. 2 & 5) and heads south for another 150 km where it bends northerly, perhaps influenced by the oceanic basement relief effect of the nearby Patton Seamounts. The now deeply entrenched channel is up to 2 km wide and 800 m deep, and continues in this northerly trend for about 200 km where it empties into the Aleutian Trench, some 700 km from the Yakutat margin.

South of Surveyor Channel, the GLORIA imagery revealed evidence of two other, previously unnamed channels. One channel, is partially filled, is older than Surveyor Channel based on overlapping levee deposits, and is traceable only by using seismic reflection data in conjunction with the GLORIA data. The second, still active, we have informally named the Chirikof Channel System (Bruns et al., 1989). We first recognized parts of these channels near the southern portion of our cruise area where their courses too, were influenced by the Kodiak-Bowie Seamount chain. The older channel meanders through a gap in the seamount chain between Quinn and Giacomini Seamounts (fig. 6) and eventually bends northwesterly. This channel may have carried turbidity currents to the Aleutian Trench prior to the advent of the modern, active Surveyor Channel, or, may be the now dead former course of Chirikof Channel.

The Chirikof Channel bends around Pratt Seamount and then winds through a gap between Surveyor and Quinn Seamounts (fig.7) and splays into a fan-like form on the abyssal plain southwest of the seamount chain. Leg F7-89-GA obtained imagery of the remainder of this channel which originates at the base of the continental margin between Alsek and Yakobi Valleys (Bruns et al., 1989).

Summary and Conclusions

The GLORIA system has provided new perspectives on the deep-sea floor in the GULF of Alaska EEZ. The wide-range (up to 60 km total width per pass) of this side-scan sonar system has allowed us to survey the entire Gulf of Alaska EEZ from the shelf break to the 200 n mi boundary, an area of about 760,000 km^2, in about 3 months time. The major features observed on these images include: 1) continental margin deformation features and their effects on a variety of types of continental slope sediment transport pathways, and 2) extensive abyssal plain submarine-channel systems and their interaction with seamounts of the Kodiak-Bowie chain.

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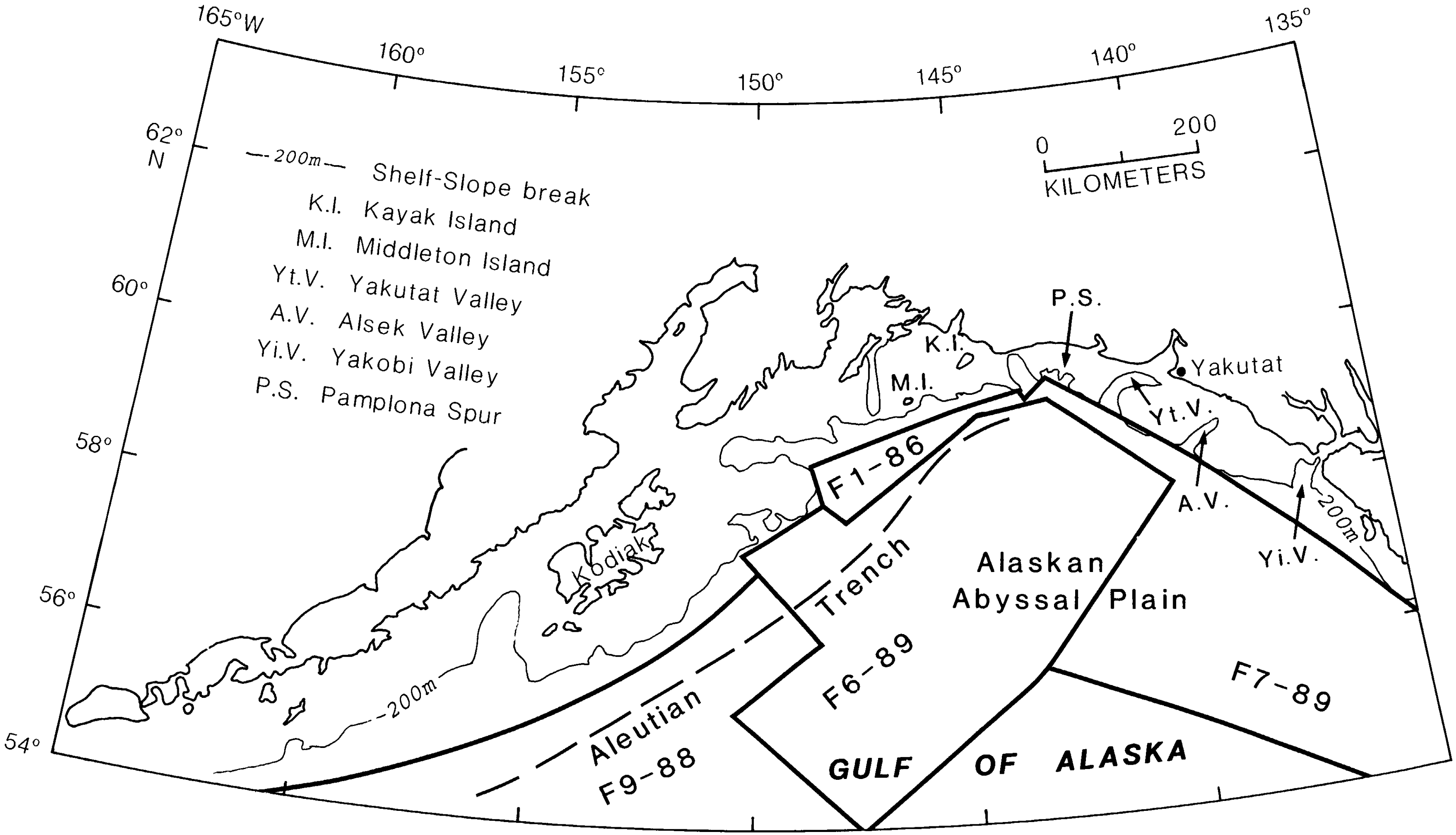

Figure 1. Location map of Gulf of Alaska. GLORIA cruise boundaries (F1-86, F9-88, F6-89, and F7-89) are outlined by heavy solid lines. Lambert conformal conic projection.

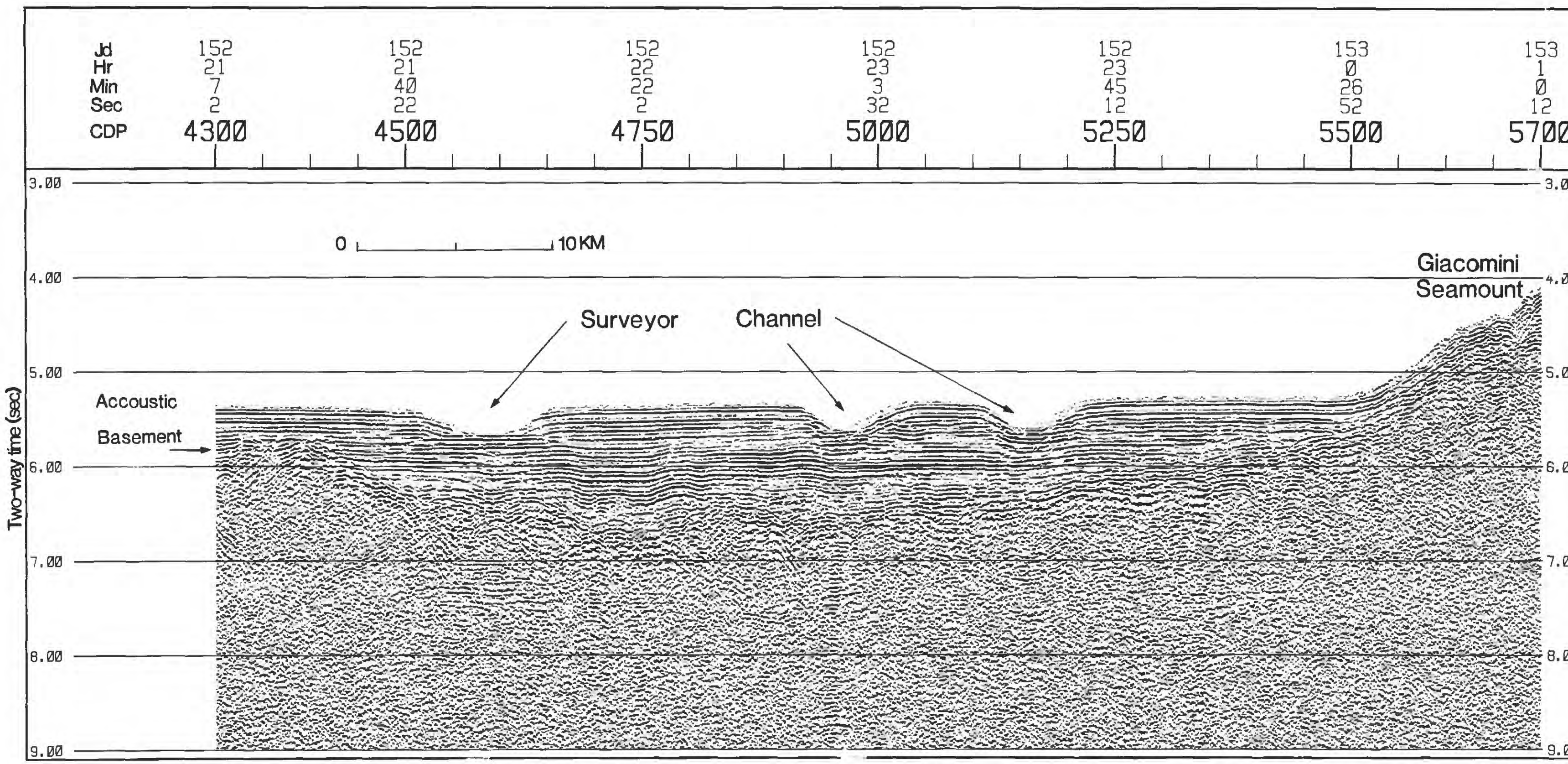

Figure 2. Processed two-channel seismic-reflection line 17-89 across meandering Surveyor Channel west of Giacomini Seamount. The two closely spaced channel crossings are shown as the tight meander on figure 5 between 152/2300 and 153/0000.

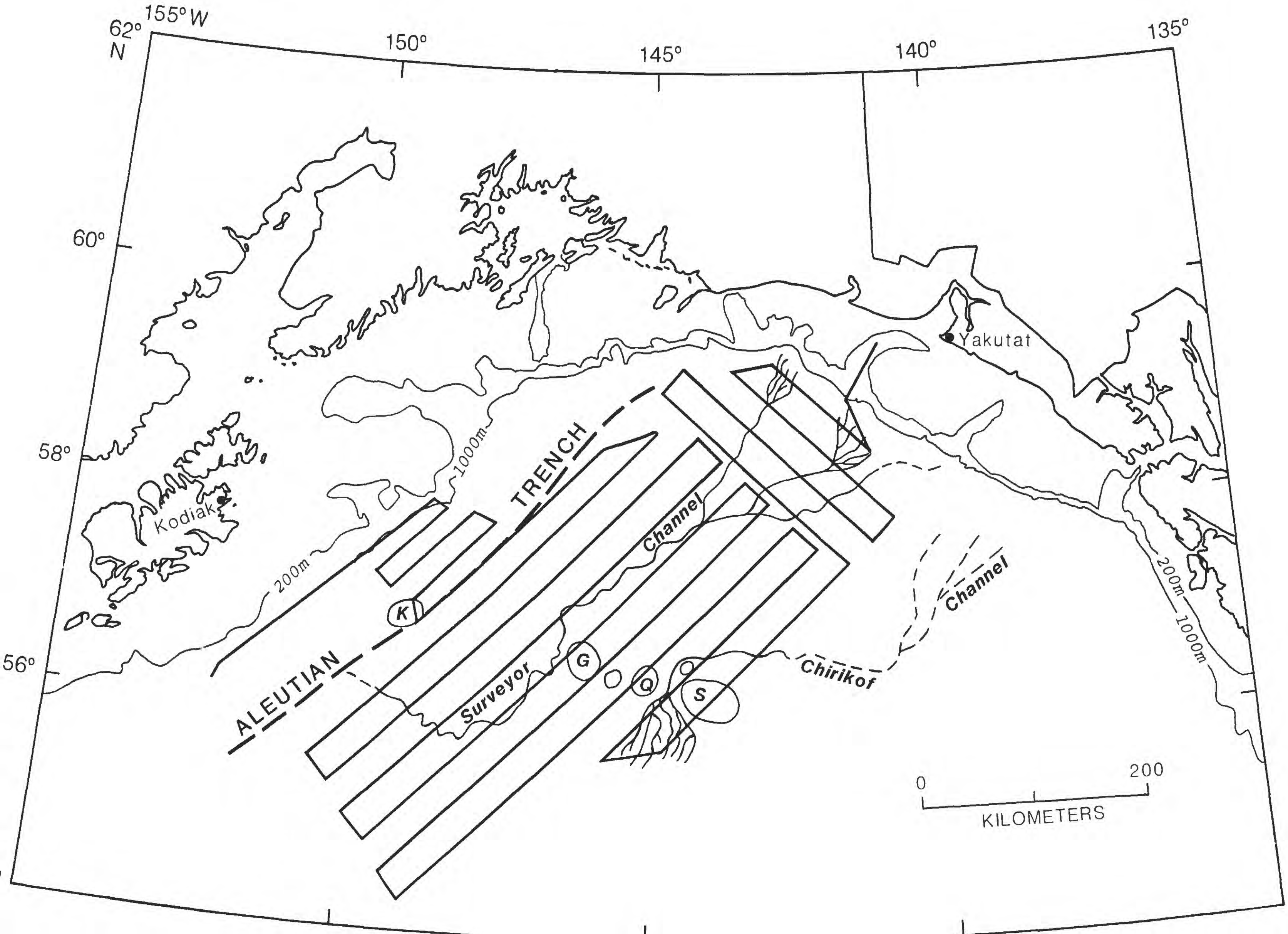

Figure 3. Trackline map of leg F6-89-GA in the northern Gulf of Alaska overlain by generalized sketch showing relations between deep-sea channels, Aleutian Trench, and seamounts (K=Kodiak, G=Giacomini, Q=Quinn, and S=Surveyor). Lambert conformal conic projection.

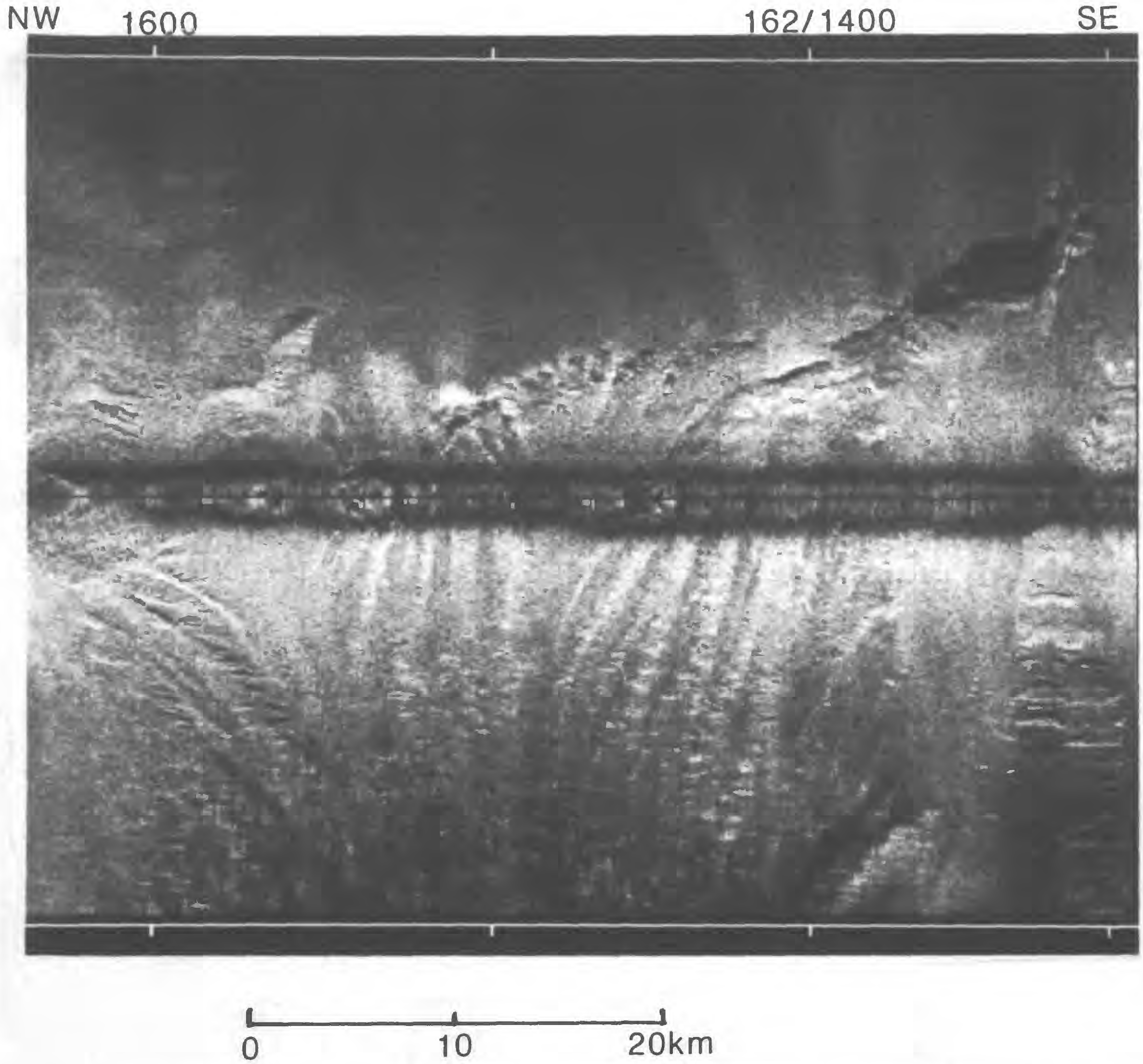

Figure 4. GLORIA image showing extensive gullying of continental slope near Yakutat Valley. White is high reflectance on this and subsequent GLORIA figures.

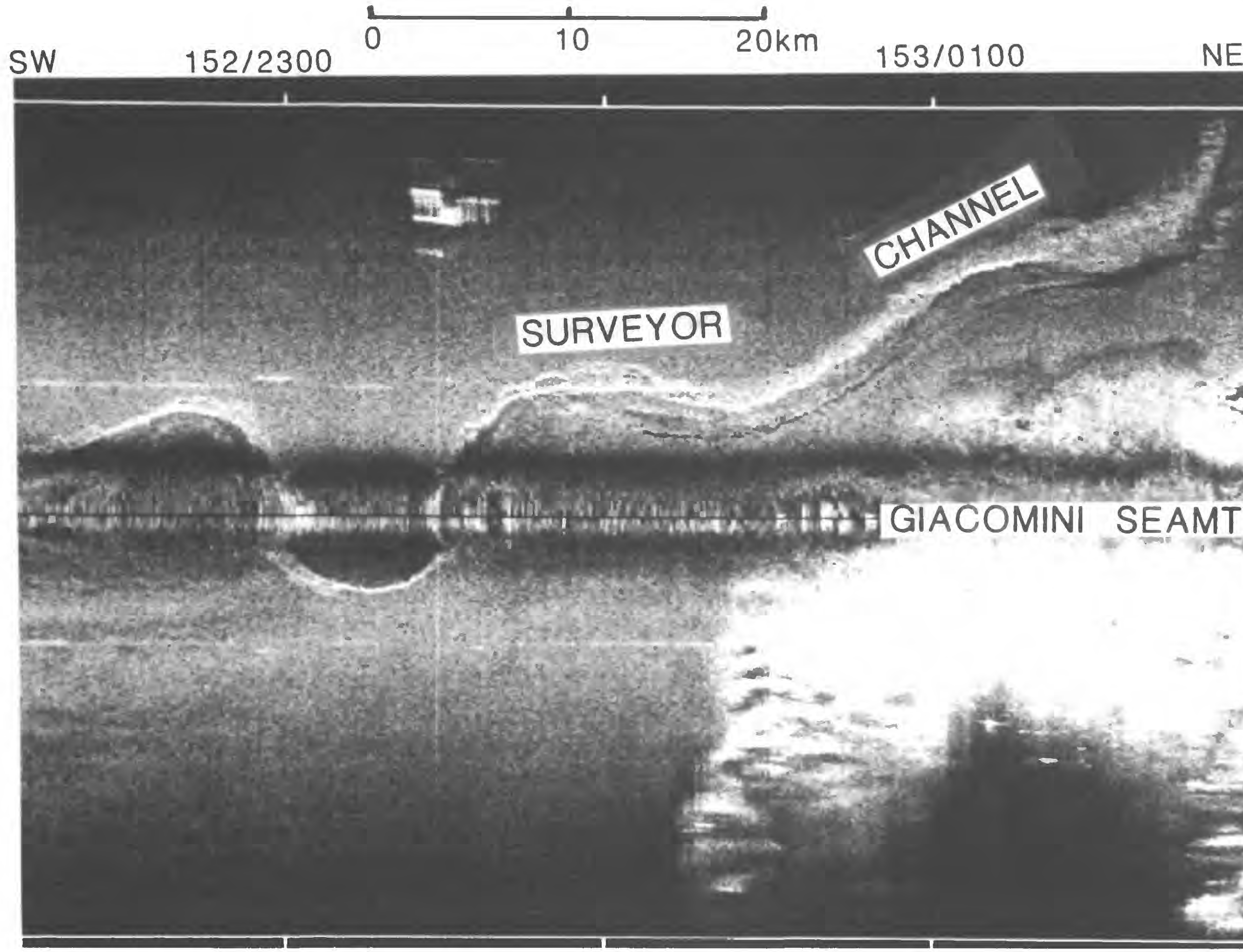

Figure 5. GLORIA image showing meandering Surveyor Channel winding around Giacomini Seamount.

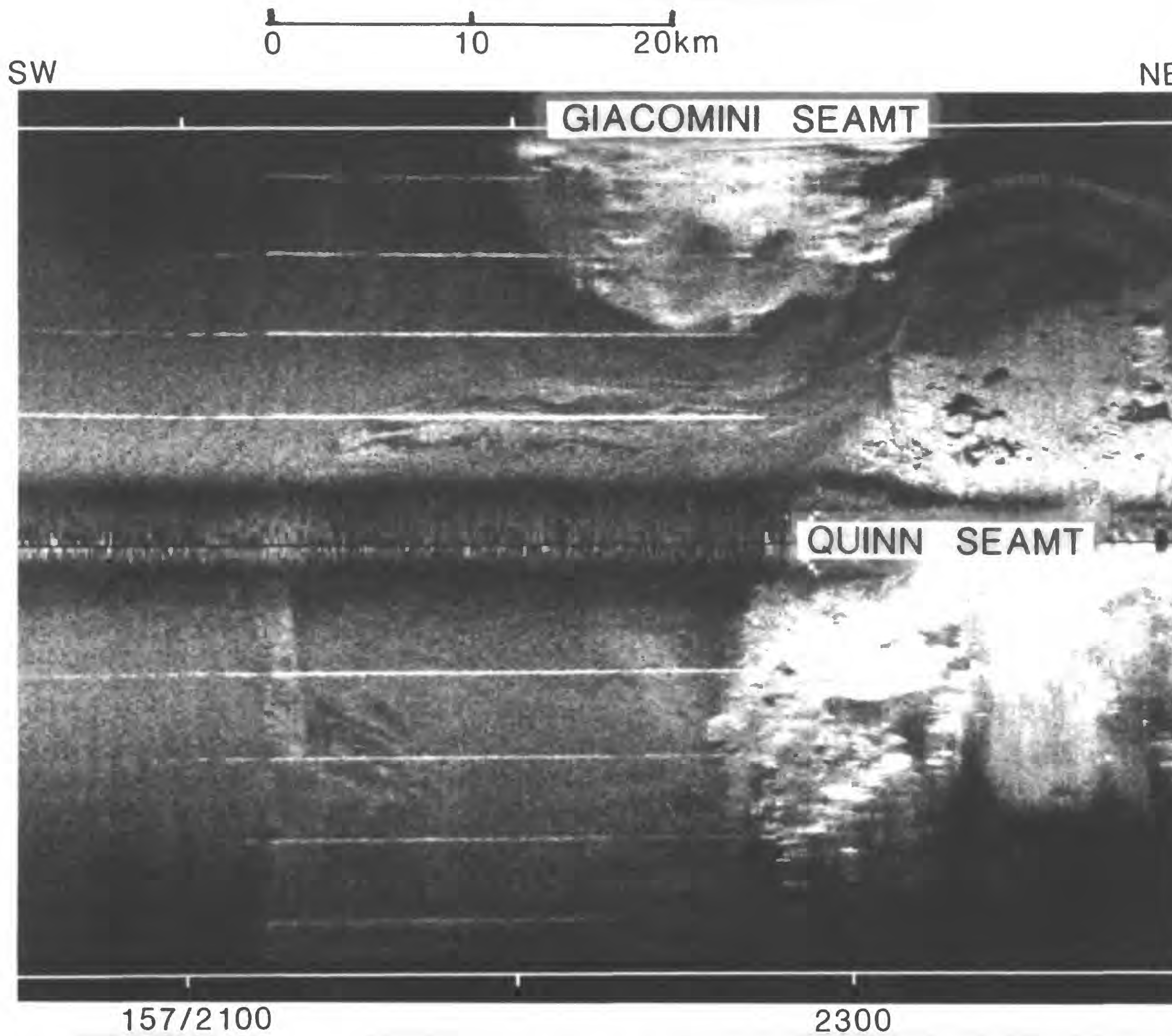

Figure 6. GLORIA image showing partially filled channel crossing seamount chain between Giacomini (top) and Quinn Seamounts (bottom).

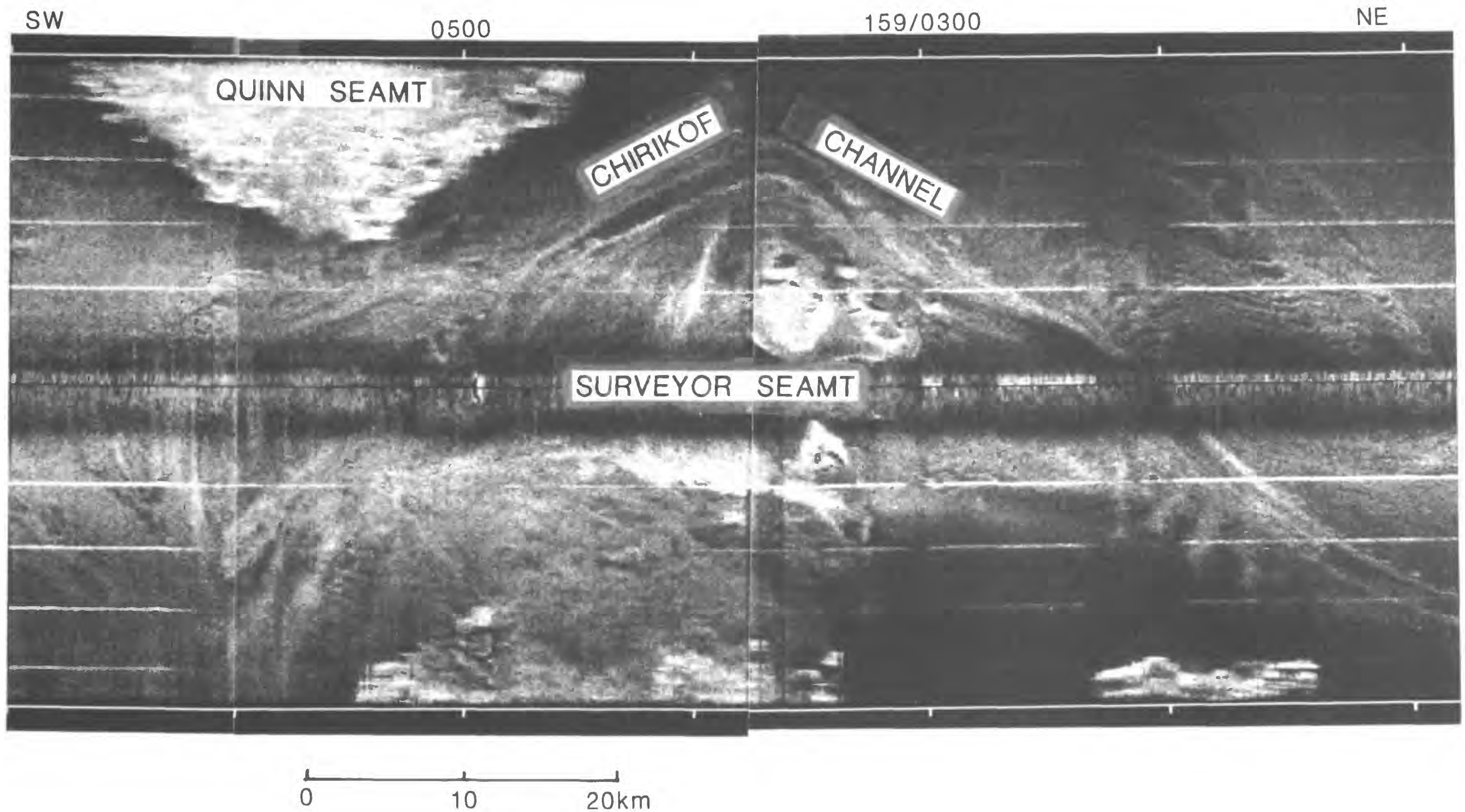

Figure 7. GLORIA image showing Chirikof Channel extending through gap between Surveyor (bottom) and Quinn (top) Seamounts.