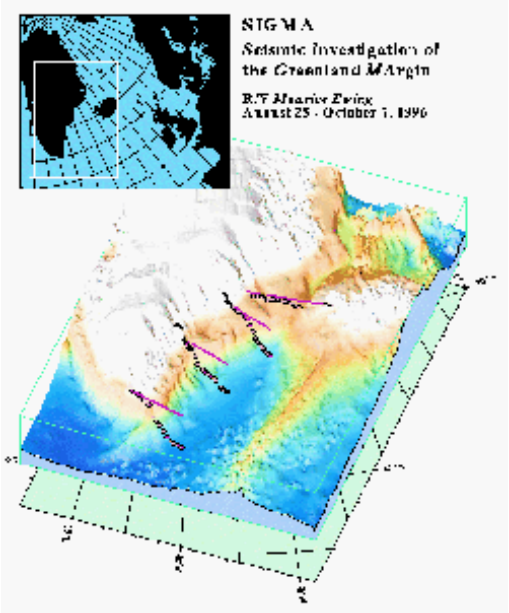
Seismic Investigation of the Greenland Margin (SIGMA)

Cruise Report for R/V Maurice Ewing EW-9607



Based on WHOI cruise report by
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Summary

R/V Maurice Ewing cruise EW-9607 formed the major data acquisition phase of SIGMA (Seismic Investigation of the Greenland MArgin), a joint U.S.-Danish investigation of the deep crustal structure of the Southeast Greenland continental margin. Previous seismic data indicate that Southeast Greenland is a volcanic rifted margin that contains significant thicknesses of mafic igneous material emplaced during early Tertiary continental breakup. The purpose of the SIGMA survey was to provide critical missing information on (1) the thickness, velocity structure, and composition of the Tertiary igneous crust; (2) variations in these properties both across the margin and along the margin at increasing distance from the Iceland plume track; and (3) the detailed structure of the continent-ocean boundary. This was achieved by acquiring seismic data along four margin-crossing transacts, one along the Greenland-Iceland Ridge and three at successively increasing distances of 200-1100 km from the presumed plume track. The Ewing fired over 33,000 shots from its 20-gun tuned airgun source into an array of offshore and onshore seismic receivers: the Ewing`s 4-km-long multichannel streamer, eleven Woods Hole Oceanographic Institution ocean-bottom hydrophones (OBH), eight U.S. Geological

Survey ocean-bottom seismometers (OBS), and 35 Reftek portable seismometers deployed on two transacts in Greenland and one in Iceland. Despite several gales, two storms, heavy fog, cold water, and numerous icebergs, the operational goals of the experiment were largely attained. Sixty-nine deployments and 68 recoveries of OBH/S were accomplished (one OBH was lost during recovery); over 1300 km of MCS data were acquired in four deployments of the multichannel streamer; and four sonobuoys were launched. Preliminary velocity models were produced shipboard for two of the offshore lines. Migrated brute stacks of all MCS lines were produced in near-real-time shipboard, and further shipboard MCS processing, including velocity picldng and multiple suppression, provided improved crustal images. The data collected during this experiment will provide key information on the degree of structural and magmatic symmetry on conjugate VRM segments and on the influence of the Iceland hotspot on margm magmatism during and immediately after continental breakup. This information will provide an important framework for interpreting geological and drilling results on the margin and for constraining then-nomechanical models of VRM evolution. This study is a joint venture between US and Danish co-investigators, including data acquisition, processing, interpretation, and project financing.

Scientific Objectives

The SIGMA (Seismic Investigation of the Greenland Margin) project is designed to make accurate measurements of crustal thickness, velocity structure, and seismic reflectivity along the hotspot-influenced volcanic rifted margin (VRM) off Southeast Greenland.

VRM`s are characterized by a prism of igneous rocks, several times thicker than normal oceanic crust, that occupies the continent-ocean transition zone in an 80- to 150-km-wide belt and extends in some regions more than 1500 km along strike. This thick igneous crust has two characteristics in seismic data: a seaward-dipping reflector sequence interpreted as subaerially erupted basalt flows and intercalated volcaniclastics, and a high-velocity lower crust with P-wave velocities (7.2-7.6 km/s) suggestive of mafic/ultrainafic intrusive rocks. Several models for the thermal and mechanical processes involved in the formation of VRM have been proposed, including decompression melting during passive upwelling near a mantle plume; actively upwelling plume heads impinging on the base of the lithosphere; enhanced upper mantle convection driven by steep, cold lithospheric edges adjacent to the rift; and hot upper mantle due to non-plume "hot cells" or insulation by supercontinents.

SIGMA consists of four transacts that systematically sample the structure of the SE Greenland margin and the continent-ocean transition at increasing distance from the Iceland hotspot track. The resulting data will provide answers to several questions regarding the SE Greenland VRM, including:

- What is the structure of the transition from continental to thick igneous crust, and thence to normal oceanic crust? Is the transition abrupt or gradual? To what extent does faulting play a role? Does the abruptness of the continent-ocean transition change with distance from the Iceland plume?

- What was the total volume of magmatism during continental breakup on the SE Greenland margin and its conjugates, and how does it vary in space and time? How does this magmatism relate to distance from the Iceland plume and to its temporal magmatic budget? What is the proportion of plutonic to volcanic rocks, and how does this vary with distance from the hotspot track and with total crustal thickness?
- Does high-velocity lower crust exist beneath the margin, and if so, is there any evidence that its composition, thickness, and distribution change along strike? How might such changes relate to variations in melting conditions (temperature and degree of melting) with distance from the plume?
- Is the structure of the SE Greenland margin symmetric with its conjugate margins on the Hatton/Rockall Bank and Iceland-Faeroes Ridge? What combinations of pure shear and simple shear processes might explain the conjugate structures?

Operational Objectives

The SIGMA cruise comprised a seismic survey of the Southeast Greenland rifted margin along four transects, one along the Greenland-Iceland Ridge and three at successively greater distances from the presumed track of the Iceland hotspot. Wide-angle seismic data were recorded by 37 onshore Reftek portable seismogaphs deployed along three profiles, by 11 Woods Hole Oceanographic Institution OBH and 8 U.S. Geological Survey OBS offshore, and vertical-incidence data were recorded by the Ewing`s 4-km-long towed hydrophone streamer. Shots were fired using the Ewing`s 130-liter (8495 cu. in.) airgun array and by chemical explosions detonated by the onshore team on Transect 11.

The primary operational goals were to:

- Deploy and recover 19 OBH/S on four profiles across the Southeast Greenland rifted margin.
- Fire the 20-gun array into the OBH/S and MCS streamer on all four transacts, and into onshore arrays on Transects II and III in Greenland and Transect I in Iceland.
- Record on onshore Refteks and, if possible, OBH and OBS, chemical explosions detonated by the onshore team in Kangerdlugssuagsiak Fjord and off the coast on Transect III.
- Record sonobuoy data on the eastern part of the Greenland-Iceland Ridge profile.
- Maintain good communications with the DLC/WHOI onshore team in Greenland, with the Cambridge onshore team in Iceland, and with onshore PI`s at critical decision points.
- Produce SEGY archive files for the OBS/H data and sonobuoy data.
- Produce pseudo-real-time stacks of all MCS data and plots of shot gathers to

monitor data quality.

- Produce CDP-sorted data tapes for all MCS data.
- Copy all MCS prestack data to DAT tapes.
- Produce preliminary stacks of the MCS data along all four profiles.

Cruise Plan

Task	Duration	Elapsed Hours	Elasped Days	Date	Notes	Time
Steam St. John`s - Angmagssalik	126	126	5.25	30	Steam:	0.00
Wireline release tests	6	132	5.50	30	-	6.00
Transfer oil, Angmagssalik	6	138	5.75	30	-	12.00
Steam to Line II	8	146	6.08	30	6.08	20.00
Deploy 19 OBH/S, Line II	30	176	7.33	1	-	2.00
Deploy MCS streamer and	39	215	8.96	2	-	17.00
Shoot Line II	48	263	10.96	4	-	17.00
Reshoot MCS, shelf	14	277	11.52	5	-	7.00
Recover streamer and steam to EOL	12	289	12.02	5	-	19.00
Reshoot for OBH	377	326	13.56	7	-	8.00
Recover 19 OBH/S, Line II	41	367	15.27	9	Profile II:	1.00
Contingencyy	0	367	15.27	9	9.19	1.00
Steam to Line II	13	380	15.81	9	-	14.00
Deploy 15 OBH/S, Line II	30	410	17.06	10	-	20.00
Deploy streamer + guns	12	422	17.56	11	-	8.00
Shoot Line II	37	459	19.10	12	-	21.00
Recover guns + streamer	8	467	19.44	13	-	5.00
Recover 13 OBH/S, Line II	33	499	20.79	14	-	13.00
Steam to last OBH + deploy guns	1	500	20.83	14	-	14.00
Shoot to Iceland + recover guns	15	515	21.46	15	-	5.00
Steam back to OBH + recover 2 OBH	12	527	21.96	15	Profile I:	17.00
Contingency	0	527	21.96	15	6.69	17.00
Steam-to Line III	36	563	23.46	17	-	5.00

Weather + deploy 2 OBS	50	613	25.54	19	-	7.00
Deploy 17 OBH/S, Line III	25	638	26.58	20	-	8.00
Deploy streamer + guns	10	648	27.00	20	-	18.00
Shoot Line III	30	678	28.28	22	-	0.00
Recover streamer + wait for daylight	9	687	28.60	22	-	9.00
Reshoot line III	27	714	29.73	23	-	12.00
Recover 18 OBH/S, Line III	49	762	31.75	25	Profile III:	12.00
Contingency	0	762	31.75	25	9.79	12.00
Steam to line IV	27	789	32.88	26	-	15.00
Wait for weather	25	814	33.92	27	-	16.00
Deploy 16 OBH/S, Line IV	28	842	35.06	28	-	20.00
Deploy streamer + guns	7	849	35.35	29	-	2.00
Shoot line IV	53	902	37.56	1	-	8.00
Recover guns+streamer	4	906	37.73	1	-	11.00
Recover 3 OBH + wait for weather	51	956	39.83	3	-	14.00
Recover remaining 13 OBH/S	24	980	40.83	4	Profile IV:	14.00
Contingency - Unsed	40	-	-	-	9.08	-
Steam to St. Jothn`s	73	1053	43.88	7	-	15.00

Cruise Participants

RV Ewing

- W. Steven Holbrook Co-Chief Scientist WHOI
- Trine Dahl-Jensen Co-Chief Scientist DLC
- John R. Hopper Scientist DLC
- Paul Henkart Scientist sio
- James Dolan Research Associate WHOI
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- David DuBois Research Assistant WHOI
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- Karen Reiner Watchstander LDEO
- Bruce A. Francis Science Officer LDED
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- Paul 0. Olsgaard Electronic Technician LDEO
- John G. DiBemardo PSSO/Airgun Technician LDEO
- John G. Byme Airgun Technician LDEO
- Ropate Maiwiriwiri Airgun Technician LDBO
- Carlos A. Alvarez Airgun Technician LDEO

Cruise Data

Deployment #1 Transect II

SITE	OBH/S	TTID #	DEPLOYMENT DATE/TIME	LAT.	LON.	DEPTH(M)	START TIME	RECOVERY DATE/TIME	LAT.	LON.
2.1	Al	132	8/30/96 22:48	66 09.00'N	35 11.44'W	243	9/l/0400	9/08/96 20:20	66 08.86'N	35 11.59'W
2.2	A3	133	8/30/96 23:43	66 05.320'N	35 01.681'W	245	9/l/0400	9/08/96 21:28	66 05.39'N	35 01.69'W
2.9	C3	134	8/31/96 08:24	65 30.628'N	33 33.13l'W	275	9/l/0400	9/08/96 10:24	65 30.64'N	33 33.17'W
2.10	C9	131	8/31/96 09:41	65 24.977'N	33 19.300'W	329	9/l/0400	9/08/96 08:47	65 24.92'N	33 19.50'W
2.11	C4	491	8/31/96 11:25	65 18.087'N	33 02.796'W	940	9/l/0400	9/08/96 07:21	65 17.490'N	33 04.229'W
2.12	C1	239	8/31/96 12:49	65 11.213'N	32 46.363'W	1483	9/l/0400	9/08/96 03:49	65 11.118'N	32 46.620'W
2.13	A8	381	8/31/96 14:13	65 04.332'N	32 30.080'W	1769	9/l/0400	9/08/96 01:25	65 04.37'N	32 30.01'W
2.14	A4	7299	8/31/96 15:35	64 57.439'N	32 13.937'W	2025	9/l/0400	9/07/96 23:37	64 57.36'N	32 14.32'W

Deployment #2 Transect I

SITE	OBH/S	TTID #	DEPLOYMENT DATE/TIME	LAT.	LON.	DEPTH(M)	START TIME	RECOVERY DATE/TIME	LAT.	LON.
1.1	A3	133	9/09/96 15:50	67 34.320'N	32 47.154'W	375	9/11/1000	9/13/96 09:30	67 02.25'N	32 46.97'W
1.2	Al	132	9/09/96 18:32	66 59.7647'N	32 26.1255'W	374	9/11/1000	9/13/96 07:16	66 59.610'N	32 26.089'W
1.9	A8	381	9/10/96 08:03	66 34.266'N	29 25.803'W	319	9/11/0200	9/14/96 06:32	66 34.284'N	29 26.795'W
1.10	C4	491	9/10/96 10:25	66 30.367'N	29 00.344'W	334	9/11/0200	9/14/96 07:58	66 30.423'N	29 00.243'W
1.11	C9	131	9/10/96 13:14	66 26.39'N	28 35.300'W	327	9/11/0200	9/14/96 09:35	66 26.442'N	28 35.213'W
1.12	C3	134	9/10/96 15:47	66 22.324'N	28 10.255'W	351	9/11/0200	9/14/96 11:47	66 22.42'N	28 09.97'W
1.13	A4	7299	9/10/96 17:53	66 18.201'N	27 45.469'W	392	9/11/0200	9/14/96 14:27	66 18.150'N	27 45.643'W

Deployment #3 Transect III

SITE	OBH/S	TTID #	DEPLOYMENT DATE/TIME	LAT.	LON.	DEPTH(M)	START TIME	RECOVERY DATE/TIME	LAT.	LON.
3.1	Al	132	9/19/96 09:48	63 38.44'N	40 19.233'W	179	9/18/2000	9/25/96 13:22	63 38.104'N	40 19.014'W
3.2	A3	133	9/18/96 14:47	63 35.841'N	40 10.608'W	263	9/18/2000	9/25/96 11:31	63 35.335'N	40 10.420'W
3.3	C1	239	9/18/96 13:23	63 32.473'N	40 01.362'W	545	9/18/2000	9/25/96 10:19	63 31.947'N	40 01.178'W
3.10	C4	491	9/19/96 20:32	63 02.26'N	38 28.42'W	1919	9/20/1400	9/24/96 22:48	63 02.07'N	38 28.93'W
3.11	C3	380	9/19/96 21:51	63 56.40'N	38 11.30'W	2050	9/20/1400	9/24/96 20:34	62 55.51'N	38 11.39'W
3.12	C9	131	9/19/96 23:17	63 50.57'N	37 54.39'W	2173	9/20/1400	9/24/96 17:49	62 50.556'N	37 54.554'W
3.13	A4	7299	9/20/96 00:33	63 44.64'N	37 37.44'W	2130	9/20/1400	9/24/96 15:29	62 44.802'N	37 36.424'W
3.14	A8	381	9/20/96 01:50	63 38.71'N	37 20.77'W	2115	9/20/1400	9/24/96 12:58	62 3 8.122'N	37 20.723'W

Deployment #4 Transect IV

SITE	OBH/S	TTID #	DEPLOYMENT DATE/TIME	LAT.	LON.	DEPTH(M)	START TIME	RECOVERY DATE/TIME	LAT.	LON.
4.1	Al	132	9/28/96 21:18	59 52.89'N	45 21.80'W	131	9/29/0500	10/4/96 15:04	59 53.047'N	45 22.373'W
4.2	C4	491	9/28/96 19:49	59 46.77'N	44 57.80'W	135	9/29/0500	10/4/96 14:19	59 47.004'N	44 58.037'W
4.3	A3	133	9/28/96 18:32	59 42.010'N	44 38.626'W	147	9/29/0500	10/4/96 12:41	59 41.978'N	44 38.727'W
4.9	C9	131	9/28/96 09:30	59 11.789'N	42 46.091'W	1805	9/28/1300	10/4/96 03:00	59 11.411'N	42 47.584'W
4.10	C3	380	9/28/96 07:52	59 06.617'N	42 27.530'W	2129	9/28/1300	10/4/96 00:45	59 05.87'N	42 28.78'W
4.11	A8	381	9/28/96 05:10	59 00.077'N	42 04.648'W	2527	9/28/1300	10/3/96 21:56	58 59.91'N	42 05.30'W
4.12	A4	7299	9/28/96 02:49	58 53.459'N	41 41.870'W	2743	9/28/1300	10/3/96 19:28	58 53.756'N	41 40.881'W

- *Click to view image of OBH/S deployment locations for Lines I and II*
- *Click to view image of OBH/S deployment locations for Lines III and IV*
- *Click to view image of A8 data plot of Line 2*
- *Click to view image of OBS C1 data plot of Line 3*