STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
910 State Office Building
Portland, Oregon 97201

OPEN-FILE REPORT O-86-14

RADON-222 AS A REAL-TIME TRACER OF HYDROTHERMAL ACTIVITY ON THE GORDA RIDGE

By David Kadko,
College of Oceanography, Oregon State University,
Corvallis, Oregon 97331

Final Report for Contract No. 63-630-8505

Submitted to:

Oregon Department of Geology and Mineral Industries

and the

Gorda Ridge Technical Task Force

Released July 1986

NOTICE

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ABSTRACT

Radon-222 is a chemically inert, radioactive gas with a relatively short (3.8 day) half life. It is highly enriched in venting hydrothermal fluids, and because it is measured at sea, may be used in real-time detection of seafloor hydrothermal systems. In 1985, during two cruises to the Gorda Ridge, radon profiles were obtained by hydrocasts. High concentrations of this isotope, and of other tracers such as dissolved manganese, indicated the presence of hydrothermal activity at several locations along the ridge. Stations at the northern Gorda Ridge displayed the highest concentrations of these indicators, which suggests that this area has the greatest potential for locating active venting.

INTRODUCTION

Several water-column reconnaissance methods exist that are used to detect the occurrence of active submarine hydrothermal systems. These include chemical tracers (such as Mn, CH_4, and ^3He), physical tracers (such as temperature), and the use of deeply towed cameras (Weiss et al., 1977; Lupton et al., 1977; Lupton et al., 1980). These methods, however, either lack sensitivity (weak signal or high background) or cannot be used on a real-time basis. Radon-222 is a chemical tracer that is highly enriched in hydrothermal waters. It is a chemically inert, radioactive gas (half life = 3.8 d) that is easily measured at sea. It offers two advantages over other tracers: 1) Because it is measured at sea, it is valuable in locating hydrothermal plumes on a real-time basis. Samples are collected from 30-ℓ Niskin bottles by hydrocasts, and this water can be analyzed for the ^{222}Rn within hours after collection. 2) Because it is radioactive with a relatively short half life, its presence in the water column must indicate a nearby source. Thus the detection of plumes of radon-222 above a mid-ocean spreading center would imply a local occurrence of hydrothermal venting (Kadko and Lupton, 1984).

In 1985, radon-222 analyses were performed on hydrocast samples taken during two expeditions to the Gorda Ridge. The first occurred in May and covered 18 days on the NOAA research vessel *Surveyor* and the second was a 7 day cruise in August on the Oregon State University research vessel *Wecoma*. The *Surveyor* expedition surveyed nearly the entire length of the Gorda Ridge, including a station on the Blanco Fracture Zone, for the purpose of obtaining the general distribution of hydrothermal activity in the area (Fig. 1). The *Wecoma* cruise centered on the northern Gorda Ridge where an attempt was made to pinpoint the sources of hydrothermal signals detected in that region during the earlier *Surveyor* expedition.

In addition to the radon-222 analyses, investigations of other hydrothermal indicators were performed by NOAA and OSU personnel during this project. Included in this work were measurements of temperature, relative particle concentration, and trace metal concentrations. The occurrence of anomalous values for more than one of these parameters was a strong indication of hydrothermal venting. The concurrent presence of radon further suggested nearby venting. In this report, the results of the radon surveys performed on the Gorda Ridge in 1985 are presented.

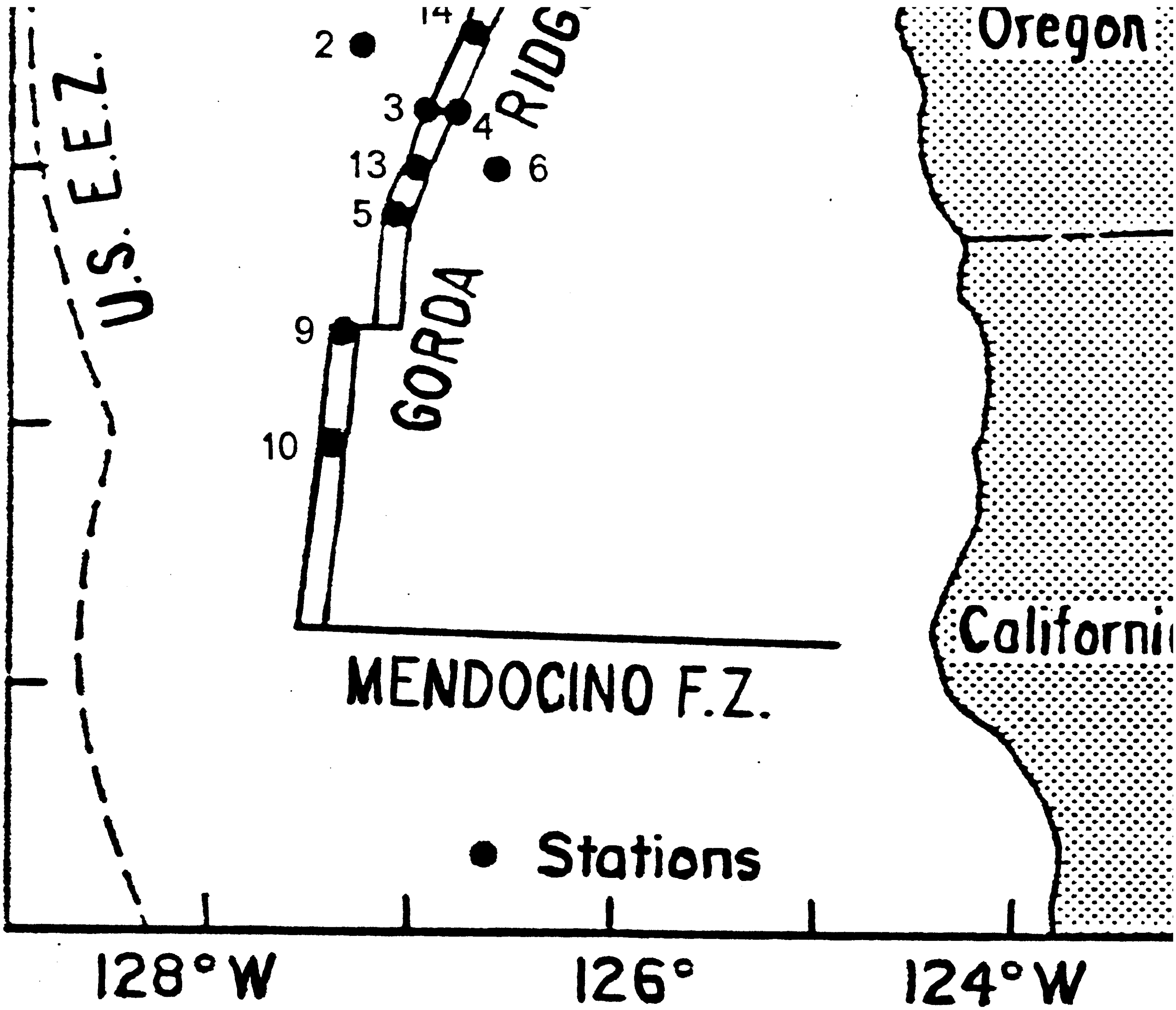


Fig 1. Location of stations occupied during the 1985 expeditic to the Gorda Ridge by the research vessels Surveyor anc Wecoma.

METHOD

Water for the radon analysis was collected in 30-ℓ Niskin bottles by hydrocast or rosette sampling. Twenty liters of the sample were transferred into an evacuated glass bottle. The radon was stripped from the sample by continuous bubbling of He and then trapped on an activated charcoal column at dry ice temperature. The column was then heated to approximately 375°C during which time the radon was pulled into an evacuated ZnS scintillation cell. The cell was placed against a photomultiplier tube detector and counts were allowed to accumulate for approximately 8 hours. The data were converted to disintegrations per minute per 100 liters of seawater (dpm/100 ℓ). (For details of the procedure see Mathieu reference).

In the following discussion the data is presented as excess radon (tables 1 and 2). This is the radon present in seawater over the background level supported by dissolved radium-226, which is the parent nuclide of radon. For this region, this background is 27-30 dpm 100 ℓ. This is determined by either direct measurement of the radium, or by measuring the radon well above any bottom source (i.e. only the background will be sampled). Aside from hydrothermal venting, some excess radon can diffuse out of the sediment into the bottom water. This bottom excess is usually distinguishable from mid-depth plumes of radon caused by hydrothermal emission, as radon atoms from the sediments rapidly decay as they are transported away from the bottom.

TABLE 1

Radon-222 Results - Surveyor May 1985

Station	Cast	Depth (m)	Excess ^{222}Rn (dpm/100 ℓ)	Comments
GR-1	1	3533	33.0	
		3423	10.1	
		3342	14.8	
		3251	3.7	
		3139	-7	Below background?
		3047	>7	Some sample lost
		2845	-0.7	
		2631	0.4	
				BGD ~ 27 dmp/100 ℓ
GR-3	4	3191	64.9	
		3133	6	
		2980	8.2	
		2879	4.1	
		2778	17.1	
		2679	-0.9	
		2529	16.8	
		2301	-1.2	
GR-5	7	3313	31.3	
		3252	sample lost	
		3098	6.1	
		2945	sample lost	
		2791	sample lost	
		2627	7.1	
		2485	2.3	
		2228	0	
				BGD ~ 27 dpm/100 ℓ
GR-5	11	3656	40.7	
		3569	27.3	
		3469	30.7	
		3362	4.6	
		3255	5.1	
		3111	10.4	
		3012	10.9	
		2880	1.2	
				BGD ~ 27 dpm/100 ℓ

Table 1 (continued)

Station	Cast	Depth (m)	Excess ^{222}Rn (dpm/100 ℓ)	Comments
GR-10	8	3312	110.7	
		3085	11.1	
		2935	13.7	
		2835	5.2	
		2669	-0.1	
		2521	4.4	
		2372	10.9	
		2224	2.5	
				BGD ~ 27 dpm/100 ℓ
GR-9	9	3428	54.6	
		3271	29.5	
		3116	27.7	
		2961	8.4	
		2806	8.9	
		2651	4.9	
		2496	-5	Below background
		2341	3.1	
				BDG ~27 dpm/100 ℓ
GR-14	13	2997	77.3	BGD = 29.7 ± 2.6*
		2868	3.5	BGD = 28.9 ± 1.0*
		2837	8.1	BGD = 30.8 ± 1.1*
		2787	13.2	BGD ~ 30 **
		2720	4.0	BGD ~ 30 **
		2568	0	BGD = 33.9 ± 1.6*

* measured Ra-226
** assumed values

TABLE 2
Radon-222 Results - Wecoma - August 1985

Station	Depth (m)	Excess ^{222}Rn (dpm/100 ℓ)*	Mn (nM)**
GR-14			
Hydro #1	2625	25.1	1.3
	2550	13.3	1.2
	2475	1.2	2.2
	2400	2.7	2.4
	2325	5.6	3.0
	2250	2.3	8.9
	2175	-0.1	8.8
	2100	0.8	6.9
Hydro #2	2565	-	5.3
	2485	-	5.1
	2425	4.6	3.7
	2365	-	2.8
	2305	-	3.0
	2245	-	2.1
	2185	-	2.6
	2125	-	1.7
Hydro #5	2610	7.6	5.5
	2510	7.4	3.6
	2460	5.9	2.9
	2410	4.1	3.3
	2360	<0	1.6
	2310	1.4	2.7
	2260	~0	2.9
	2160	~0	2.1
GR-15			
Hydro #3	3200	-	
	3150	-1.5	
	3100	10.5	
	3050	4.3	
	3000	-1.1	
	2925	8.1	
	2850	-0.7	
	2750	-	

Table 2 (continued)

Station	Depth (m)	Excess ^{222}Rn (dpm/100 ℓ)*	Mn (nM)**
GR-15 (continued)			
Hydro #4	2965	15.2	10.7
	2915	15.5	11.5
	2865	11.2	13.1
	2815	24.0	10.8
	2765	5.4	11.5
	2715	4.5	11.2
	2665	0.1	11.2
	2615	-5	12.3

* BGD ~ 28 dpm/100 ℓ
** Data from R. Collier (OSU)

RESULTS

Surveyor expedition

Station GR-1 was located in the Cascadia Basin (fig. 1) in the Blanco Fracture Zone. Fig. 2 shows the excess radon profile obtained at that site. The near bottom excess (below 3200 m depth) is from the sediment source, and it decreases with height above bottom in a fashion typical for deep sea areas. At 3050 m, however, a mid-depth plume was detected. This corresponded with both a small dissolved Mn anomaly (R. Collier, OSU) and slightly higher particulate Fe/Al and Mn/Al ratios (G. Massoth, NOAA). A hydrothermal influence within this layer is suggested, but the weak signal suggests either a distant or low intensity source.

Station GR-3, in the axial valley of the Gorda Ridge, displayed a strong hydrothermal signal. In figure 3 bottom excess radon is seen below 3100 m which is readily distinguished from two mid-water plumes at 2780 m and about 2400 m. The lower peak corresponded to elevated Mn concentrations, while the peak at 2400 m corresponded to both a broad maximum in Mn and in particle content as detected by the nephelometer system (E. Baker, NOAA). These observations certainly suggested a more intense, nearby source of hydrothermal venting.

Station GR-5 consisted of two casts. The first (#7) was situated towards the eastern wall of the axial valley at a bottom depth of about 3450 m. The second (#11) was in the central axial valley at a depth of about 3670 m. Both casts had indicators suggestive of hydrothermal venting, but the signals were not strong (fig. 4). Cast #7 showed small elevations of radon and manganese throughout the water column. Cast #11 showed a distinct radon plume at about 3000 m depth, which corresponded to a Mn and particle <u>minimum</u>. This is an unusual feature with no obvious explanation at this time.

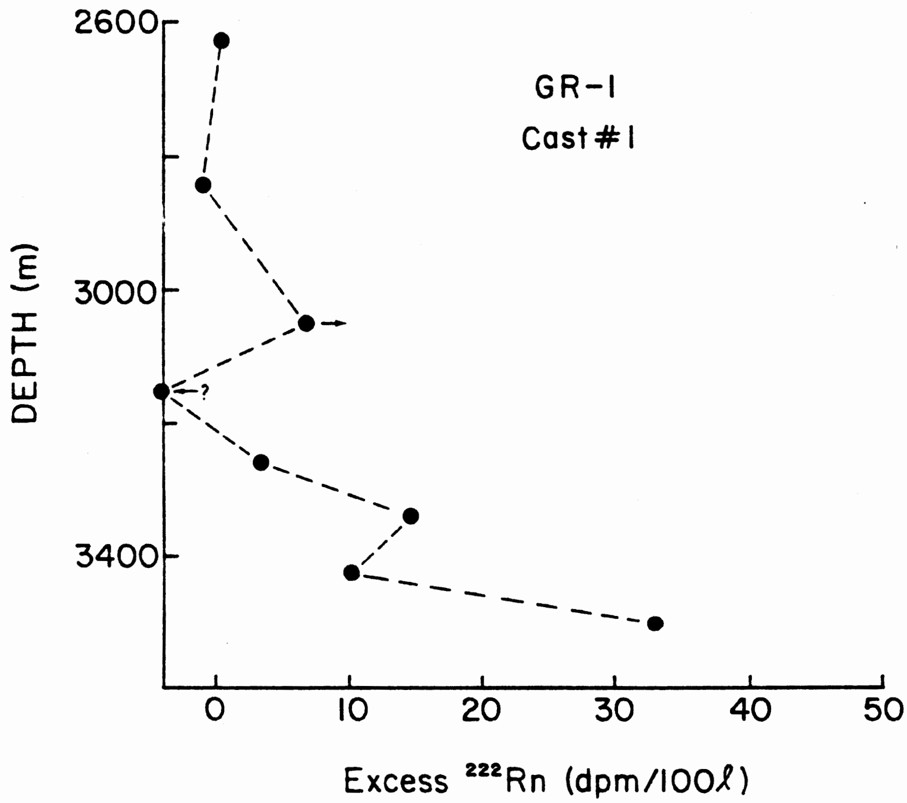


Fig 2. Excess radon-222 from Surveyor station GR-1

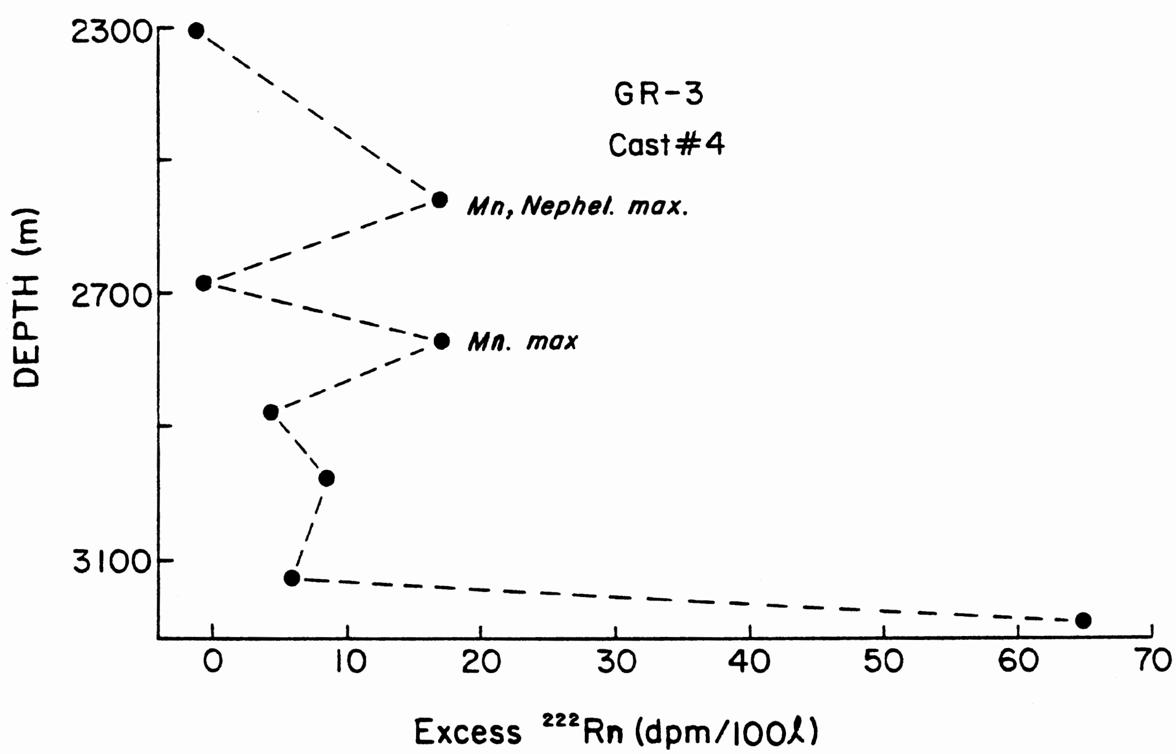


Fig 3. Excess radon-222 from Surveyor station GR-3

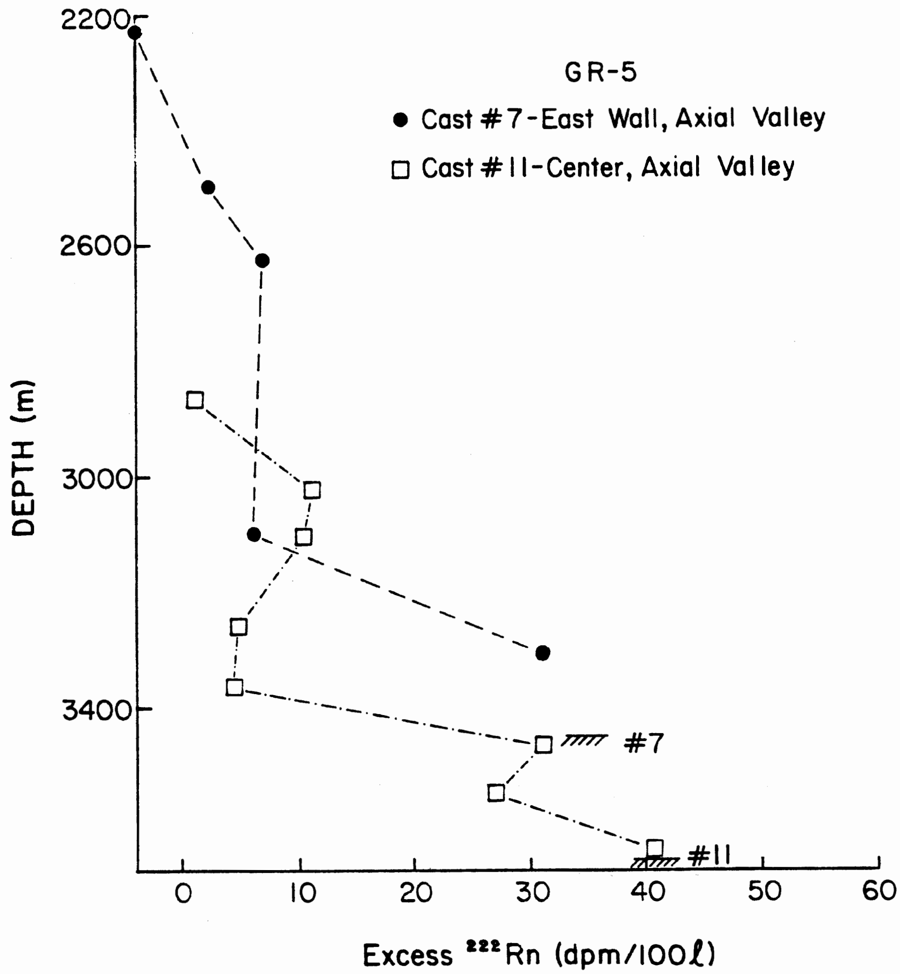


Fig.4 Excess radon-222 profiles from Surveyor station GR-5

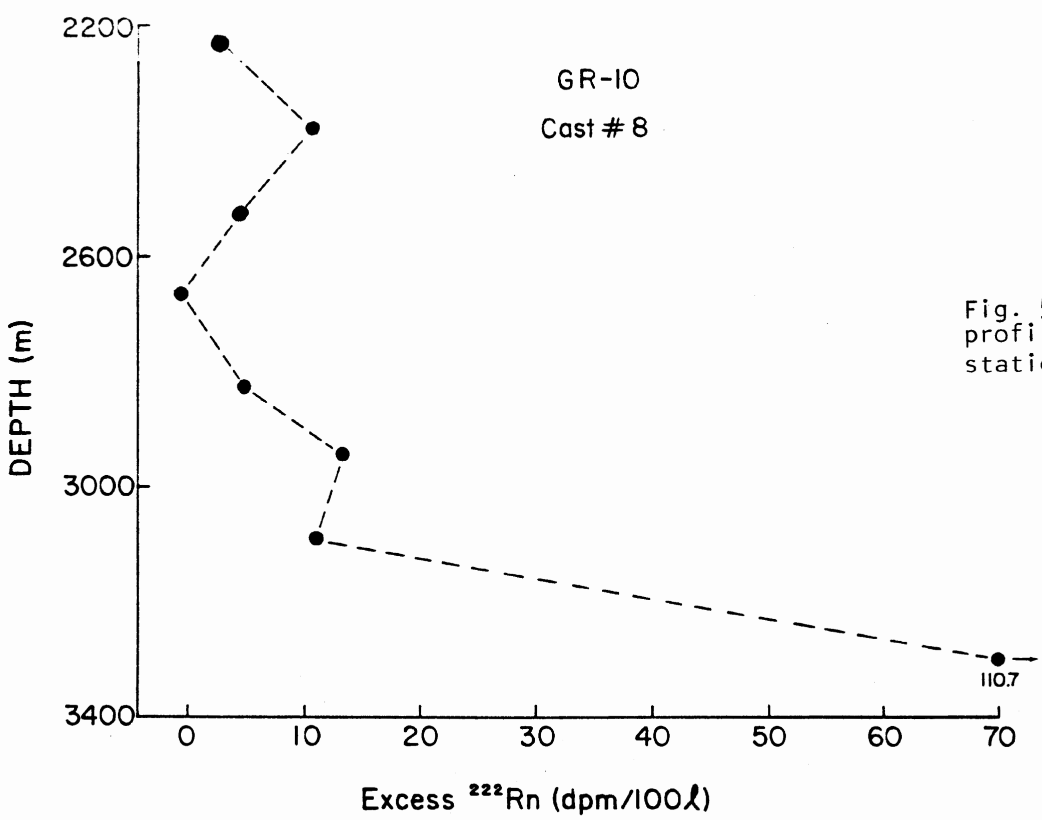


Fig. 5 Excess radon-222 profile from Surveyor station GR-10

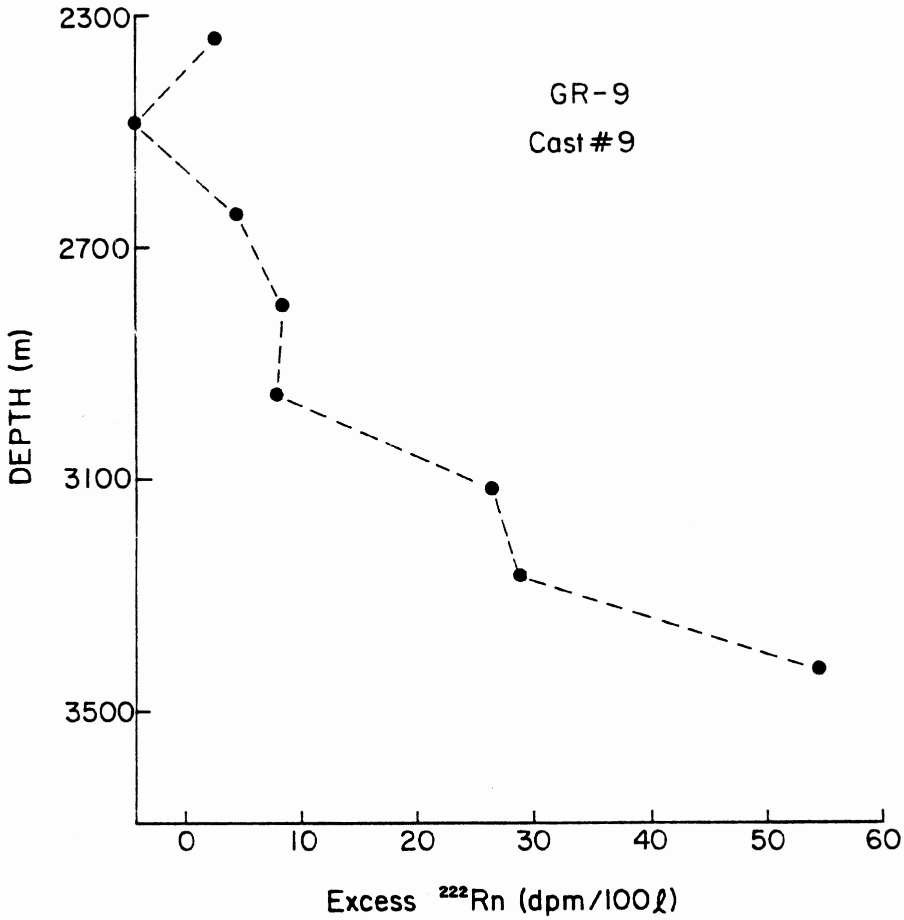


Fig 6. Excess radon-222 profile from Surveyor station GR-9

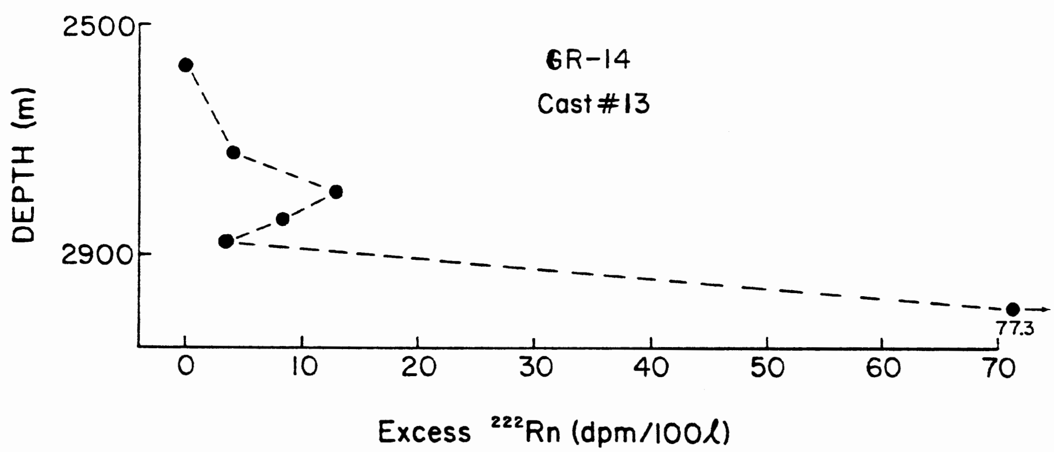


Fig. 7 Excess radon-222 profile from Surveyor station GR-14

Station GR-10 was situated in the northern Escanaba trough of the Gorda Ridge, and represents the southernmost station of the survey. As at station GR-1, a bottom excess of radon from the sediments is distinguished from a weak signal higher in the water column (fig. 5). This mid-water excess of radon at 2400 m does correspond to a weak dissolved Mn anomaly. This suggests either a distal source of venting or less intense local venting. It should be noted that massive sulfides were later dredged in the southern Escanaba trough, approximately 50 km from our site.

Station GR-1, a bottom excess of radon from the sediments is distinguished from a weak signal higher in the water column (fig. 5). This mid-water excess of radon at 2400 m does correspond to a weak dissolved Mn anomaly. This suggests either a distal source of venting or less intense local venting. It should be noted that massive sulfides were later dredged in the southern Escanaba trough, approximately 50 km from our site.

Station GR-9 (fig. 1) was another axial valley station but one which did not display any indication of nearby hydrothermal venting. Oceanographically, the site was of interest because of a strongly mixed benthic layer which displaced bottom radon, Mn, and particles over 500 meters above the seafloor. A constant temperature was also observed in the bottom 400 m (E. Baker, NOAA). The presence of hydrothermal activity at this site cannot be ruled out completely, because the intense bottom mixing may have dispersed any measurable signals. The radon profile is shown in fig. 6.

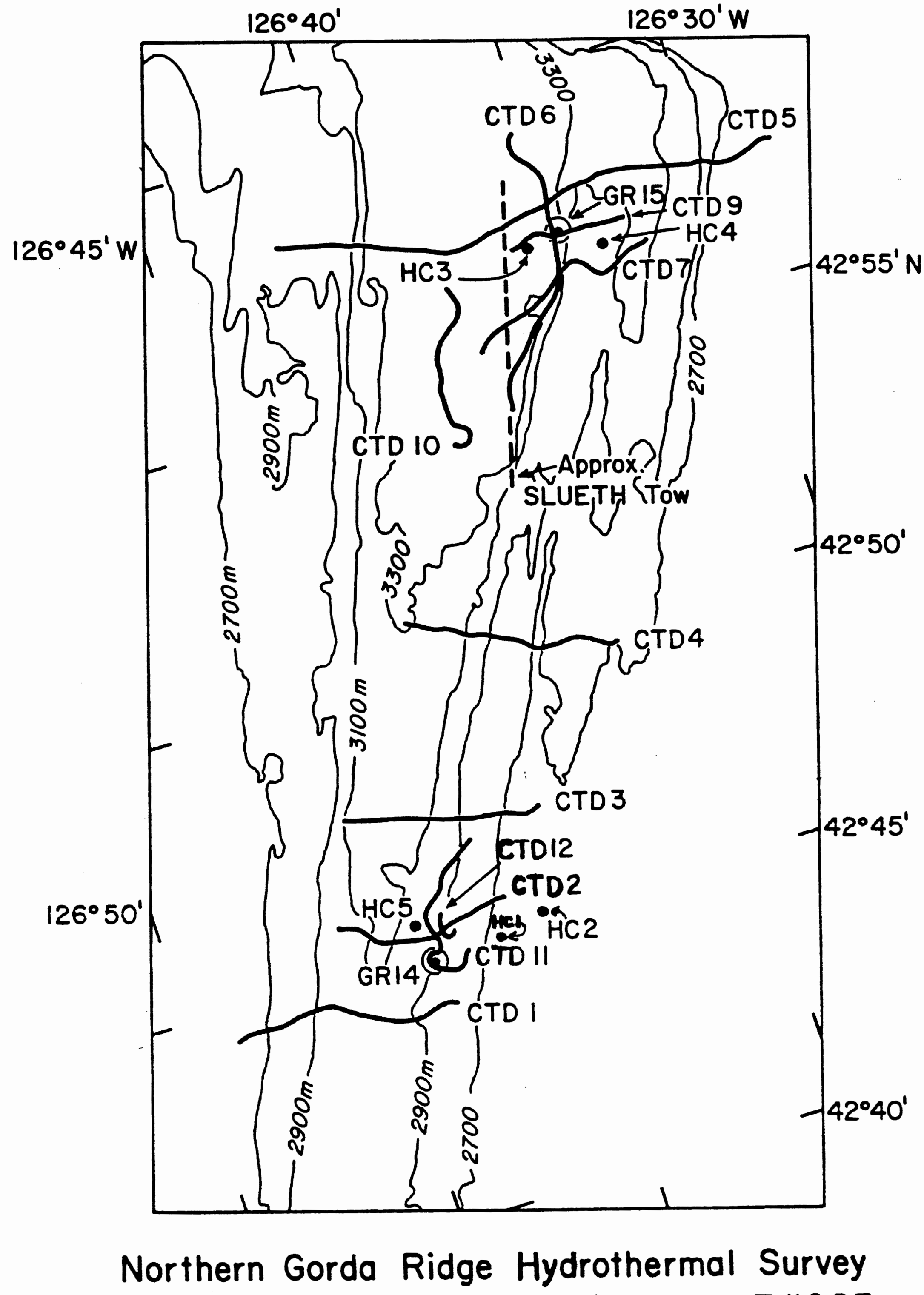
Station GR-14, located on the northern Gorda Ridge (fig. 1), showed sharp hydrothermal signals in Rn-222 (fig. 7), Mn (R. Collier, OSU) and particulate concentration (E. Baker, NOAA) at a clearly defined depth of 2800 m. This site was chosen for reoccupation in the following Wecoma cruise.

Wecoma Expedition

The purpose of this cruise was to reoccupy the northern Gorda Ridge stations (GR-14 and 15) and pinpoint sources of the strong hydrothermal signals which were observed there during the Surveyor cruise. The CTD tows and hydrocast locations are shown in fig. 8.

Station GR-14 was surveyed extensively with CTD, and transmissometer tows as well as with three hydrocasts. Temperature and particulate anomalies were detected but the signals showed appreciable spatial variability; i.e., there was no strong, extensive plume of hydrothermal material observed over the entire surveyed area. Rather, there appeared to be a generally pervasive low level signal with an occasionally more intense anomaly. Results of the hydrocasts are shown in table 2 and fig. 9. These casts were somewhat shallower than the strong hydrothermal signal detected at 2800 m in the Surveyor GR-14 cast (fig. 7). A somewhat weaker signal in radon and manganese is seen here at about 2400 m depth which did coincide with a particle maximum. During the Surveyor cruise, particulate plumes were also detected at this depth but no radon and manganese were sampled at that time. The combined GR-14 data from the two cruises suggest several sources of venting in the area, probably from different depths up along the axial valley walls.

Station GR-15 was also reoccupied during the Wecoma cruise. During the Surveyor expedition, a very large Mn and particle signal was detected at a depth of 2800-2900 meters at this site. Hydrocast #4 which was somewhat to the east of the GR-15 axial valley site (fig. 8), displayed a very large plume of radon-222 at this depth, suggesting a venting source up along the valley wall rather than from the valley floor which is located at depths greater than 3300 m. Hydrocast #3 which was west of GR-15 displayed a less intense radon signal (fig. 9). The site of hydrocast #4 has the greatest potential for locating active venting of all the areas surveyed in this study.



Northern Gorda Ridge Hydrothermal Survey
R/V WECOMA (W8508AA) 8/1-7/1985

Figure 8

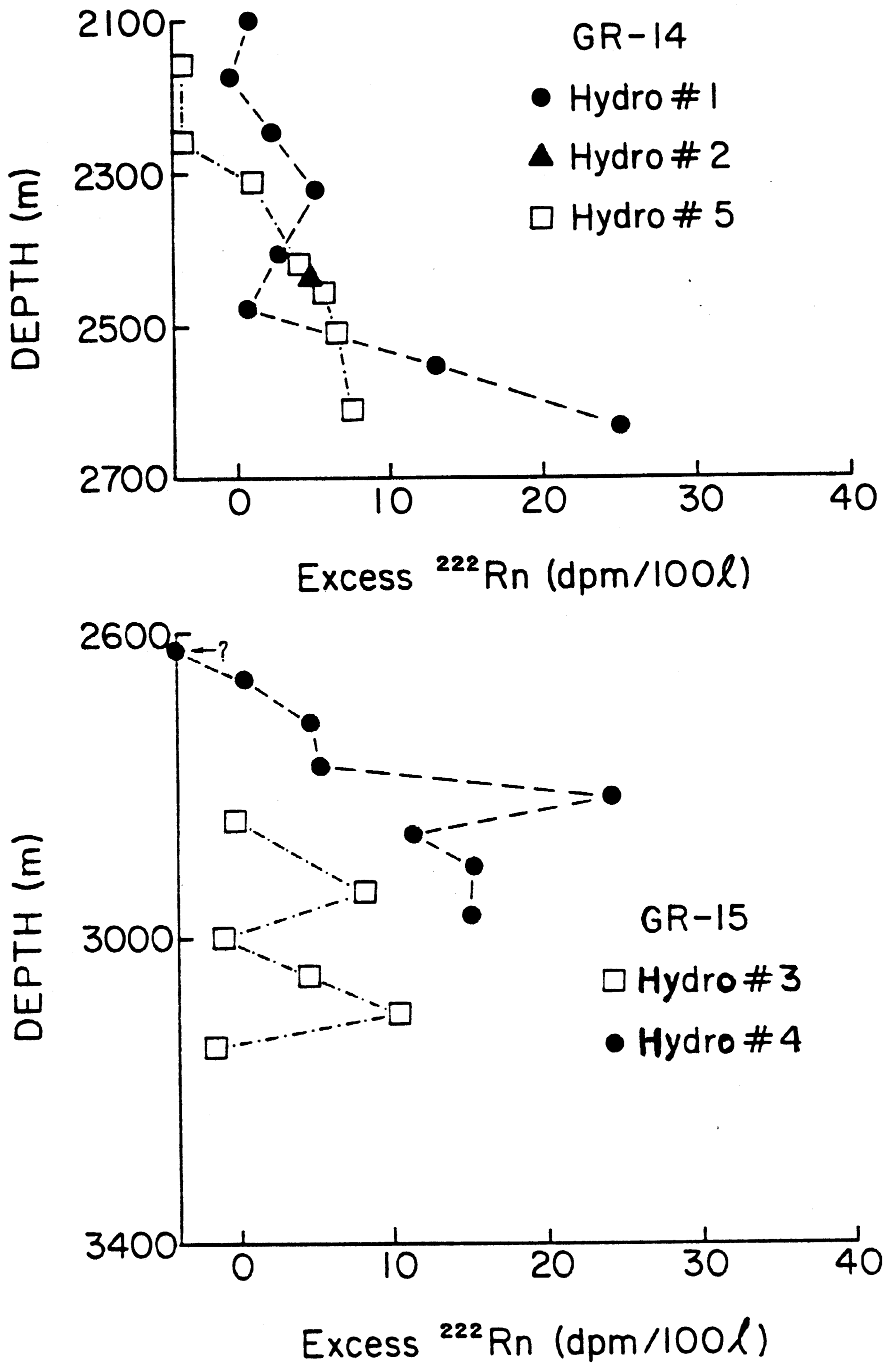


Fig. 9 Excess radon-222 profiles from Wecoma stations GR-14 and GR-15.

CONCLUSIONS

Radon-222 surveys were performed during two expeditions in 1985 which attempted to locate active hydrothermal venting along the Gorda Ridge. These analyses were made in conjunction with other investigators who measured additional parameters which are useful indicators of hydrothermal activity, such as Mn, temperature and particle concentration. Particularly high concentrations of radon and anomalous signals in these other indicators were detected over two stations in the Northern Gorda Ridge. Though the exact location of the source of these signals was not found, the depths of the apparent hydrothermal "plumes" suggest a source higher along the valley walls, rather than on the much deeper axial valley floor. Station GR-15, located at the intersection with the Blanco Fracture Zone, displayed not only the highest radon concentrations of all stations studied, but revealed high Mn and particulate concentrations as well. It perhaps has the greatest potential for locating active hydrothermal venting and hopefully will be reoccupied in future work on the Gorda Ridge.

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