

**CRUISE REPORT  
VENTS93 LEG II  
NOAA SHIP DISCOVERER  
JULY 8 - AUGUST 4, 1993**

**EVENT RESPONSE TO A VOLCANIC ERUPTION  
AT THE COAXIAL SEGMENT  
AND  
TIME SERIES SURVEYS  
AT THE CLEFT SEGMENT**

**A JOINT U.S./CANADIAN EXPEDITION**

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## CRUISE OVERVIEW

The second leg of the 1993 VENTS cruise series was designed to be a continuation of a program begun in 1992 to develop the Canadian Remotely Operated Vehicle ROPOS to survey and sample hydrothermal vent fields on the Juan de Fuca Ridge. The cruise involved 27 scientists, engineers and technicians from the U.S., Canada, and Germany. The cruise originally had three major objectives. The major focus of the cruise was to be an intensive program at the northern Cleft Segment involving biological and chemical time-series sampling at known vent sites previously visited by ALVIN (Fig. 1). The second goal was to conduct detailed mapping of some structures associated with the lava mounds erupted in the mid-1980s using the video, still camera and mesotech sonar system on the ROPOS. Thirdly, a revisit to the Middle Valley hydrothermal field on the northern Juan de Fuca Ridge was to conduct some video surveys of the Ocean Drilling Project borehole monitoring devices and, if possible, to acquire stored data through an RS232 interface. Some limited mapping and sampling were also planned if time allowed. A program of rock sampling using a gravity coring device was also planned for the Cleft Segment.

Much of VENTS Leg II became focussed on the response to the CoAxial event (see next section). Most of the work at the Cleft Segment was also accomplished. However, the visit to the Middle Valley site at the end of the cruise was canceled due to weather (seas were too high for ROPOS dives) and a day was transferred from VENTS Leg II to VENTS Leg III.

A wide range of scientific operations were conducted during the cruise (probably one of the most ambitious cruises yet on a NOAA vessel), including CTD tow-yos and casts, water sampling for a range of species and particles, Radon measurements of plume waters, SUAVE profiling, ROV dives with attendant biological, geological and chemical surveys and sampling, Sea Beam surveys, rock coring, and instrument deployments.

## COAXIAL EVENT RESPONSE

On June 26, the first of several swarms of T-phase events accompanied by a low frequency background signal originating between 46°15' and 46°30'N on the northern portion of the Juan de Fuca Ridge (Fig. 1) was detected by a realtime monitoring system installed by scientists at the Pacific Marine Environmental Laboratory in Newport, Oregon (Fox et al., 1993; Dziak and Fox, 1993). This realtime system records and analyzes the raw data from the U.S. Navy SOSUS hydrophone system deployed in the northeast Pacific. The first response was made by the scientific party on the Canadian research vessel TULLY, whom conducted a series of CTD casts (including water sampling) in the vicinity of the T-phase swarms from July 1st to 3rd. Several of the temperature/attenuation profiles showed significant hydrothermal plumes centered at depths ranging from 200 to 600 meters above the seafloor. On July 8, the DISCOVERER left Seattle carrying a CTD/Rosette, the PMEL SUAVE chemical scanner, a Sea Beam sonar system, and the ROPOS, a 5000 m HYSUB remotely operated vehicle (Embley and Franklin, 1993). The data collected on VENTS Leg II of DISCOVERER at the CoAxial site formed the basis and justification for additional experiments and surveys on portions of three follow up cruises on the DISCOVERER and MELVILLE in August and September and for a joint NSF/NOAA dedicated ATLANTIS II-ALVIN expedition in October.

## Description of CoAxial Segment

The swarms of T-phase events occurred along the 30 to 40 km ridge segment offsetting (in a right-stepping sense) the northern rift zone of Axial Volcano from the Cobb Segment to the north (Figs. 1 and 2). This previously unnamed segment is henceforth called CoAxial Segment in because of its geographic relationship to Axial Volcano. The shoalest portion (~2050 m) of its neovolcanic zone occurs between 46°03'N and 46°15'N along a constructional ridge bisecting the southern portion of its 9 km wide axial valley. The neovolcanic zone is not topographically well-defined along its northern portion, but probably follows a diffuse series of isolated volcanic hills, ridges and shallow depressions. The crest of the neovolcanic zone deepens by more than 250 m from south to north.

## Water Column Measurements

The DISCOVERER arrived at the CoAxial Segment on the evening of July 9th. Analysis of the TULLY data and continued analysis and locations of the T-wave data by that time indicated that: (1) all the later events were concentrated in the center of the northern CoAxial Axial Valley, and (2) the deep currents were carrying the plumes in an easterly direction. Consequently, the first major operation, which became a basis for later investigations, was a 53 km along-strike CTD "Tow-Yo" (where the CTD package is cycled vertically in a regular pattern as it is towed through the water) that was placed about 1 km east of the centerline of the Axial Valley and traversed from 46°08'-46°36'N (Fig. 3). During this tow, and several subsequent along-axis tows, across-axis tows (Fig. 3) and casts (primarily for Radon age-dating of the plumes) (Fig. 3), more than 80 discrete 10 and 30 liter Niskin samples taken in the plumes. Two kinds of plumes were mapped--a lower plume, usually 150-200 m above the seafloor, and an upper plume, up to 800 m above the seafloor (Fig. 4). At that time, the lower plumes extended for 39 km along the axis from 46°14'N to 46°34'N and were characterized by temperature anomalies as high as 0.07°C centered about 150-200 m above the seafloor (Fig. 4). In some places the temperature anomalies extended within 10 meters of the seafloor (generally the closest approach altitude of the CTD). The northern edge of the plumes approximated the northern extent of the northern T-phase swarm area. The southern boundary of plumes traversed by the DISCOVERER tow-yos was at approximately the southern boundary of the southern T-wave swarm at 46°14'N. The upper plumes, which were well-defined both by temperature and light attenuation anomalies, were present for about 17 km along axis and were approximately centered above the northern T-phase swarm. These upper plumes appeared to have a distinct layered structure, perhaps indicative of separate injections of hydrothermal fluid. Their rise height and ephemeral nature (they were no longer found over the axis two weeks later) indicate that they are "Event Plumes" (Baker et al., 1994). Their maximum rise height was about 800 m and the maximum temperature anomaly was at about 0.20°C (about the same as the anomalies reported by Baker et al. [1989] for the Megaplume over the southern Juan de Fuca). Preliminary results from the NOAA/PMEL SUAVE chemical scanner indicate dissolved manganese and iron anomalies in the upper plumes that exceed the Megaplume I and II levels (about 160 nmol/l). Radon dating of the upper plume showed that it was not being resupplied by continued venting during the week between the sampling period from July 12th to 19th. An across-axis tow made on August 25th at 46°16'N; 129°39'W (Fig. 2). This feature had a minimum diameter of 15 km. The source area for this event plume is not known, but it was

probably produced during one of the swarms. Its well-mixed nature strongly implies that it was produced during an event separate from the events that produced the event plumes observed at the northern swarm area .

### ROPOS Dives

The most intense hydrothermal signals emanated from an area centered over about 46°31'N in the center of the axial valley. Because of the coincidence between the northern T-phase swarms and the extensive plumes (Fig. 4), this area was chosen for detailed study of the seafloor with ROPOS. After deployment and calibration of a transponder net, the first dive (219) traversed the valley floor from east to west and encountered sediment-free, glassy lava on the west-facing slope of a ridge just north of a small, older volcano, Cage Volcano (Fig. 2). Basalt samples recovered by ROPOS from the recent flow are iridescent, glassy, lobate to pillowed flows with upper glass selvages up to 2.5 cm. thick. Subsequent video traverses and sampling (Dives 219, 221 and 234) revealed fresh lava along a ridge about 2.5 km long, oriented in a 020° direction, and up to 300 m wide. A 50 m-wide zone centered over the crest was venting warm water (up to 51°C) through the interstices of the pristine, unfractured pillow and lobate lava flows. Except for the bacterial filaments, the young lava flow was devoid of sessile organisms whereas adjacent old lavas hosted many non-vent animals. Initial analyses of vent fluid samples from both ROPOS and ALVIN indicate the presence of dissolved Mn and Fe, but surprisingly, the absence of H<sub>2</sub>S. The diffuse venting is present all the way along its axis and ends abruptly at its northern termination. Traverses made during ROPOS Dive 221 showed that venting also continued at least 4 km south of the lava flow (Fig. 2). The actively venting fracture cuts through an older constructional lava ridge. The purpose of the final ROPOS dive (HYS235) at about 19.4°N was to investigate an intense near-bottom plume signal about midway between the southern and northern swarm areas. At about 200 m above the seafloor, ROPOS began passing through an intense floccular cloud composed of irregularly shaped clumps of whitish material. The floc (probably bacterial in origin) was observed for hundreds of meters on either side of the axis of the axial valley, where it was forming small drifts on the seafloor. Although ROPOS did not discover the source of this floc, the dive set the stage for further investigations in this area. This site became known as the Floc Site.

### Sea Beam Resurvey of CoAxial Segment

The neovolcanic zone of the CoAxial Segment and the north rift zone of Axial Volcano was resurveyed with Sea Beam to locate possible lava flows associated with the T-phase swarms (Fox et al., 1992). The post-cruise comparison of the new survey and surveys from 1982 and 1991 (by onshore post-processing) showed that a depth change anomaly of up to 30m occurred between the 1991 and 1993 surveys, and that it corresponds closely to the extent of the flow as mapped by ROPOS. No other eruptive sites were detected along the path of the T-phase propagation. The analysis also revealed that a mound erupted between 1982 and 1991 about 1 km east of the 1993 eruption (Chadwick et al., 1993). This effort again demonstrated the power of the resurvey technique to locate and measure newly erupted lava flows on the seafloor.

## Discussion and Speculation

The pattern of T-phase events and water column anomalies are remarkably coincident. Most significantly, the most intense and long-lasting T-phase activity is coincident with the source area of a large hydrothermal expulsion. The propagation of seismicity down rift, its correlation with the hydrothermal plumes, and the striking correspondence between the eruption and the northern swarm area is reminiscent of Hawaiian and Icelandic lateral dike propagation events. In the Icelandic events (Bjornsson et al., 1979), an injection of magma into the upper crust beneath the central volcano triggers an along-axis dike propagation of up to 80 km along the rift zone. In a typical event during the Krafla episode from 1975 to 1984, a dike would rapidly propagate (within hours) over tens of km before approaching the surface and causing maximum deformation and seismicity over a more limited area. In some cases these intrusions were accompanied by eruptions and rapid changes in geothermal activity at the surface. The first swarm at the southern CoAxial site could represent the initial magma injection from below, with subsequent rapid migration of T-phase activity along the rift zone representing the lateral dike propagation. The pattern of events observed at the CoAxial Segment also closely matches the proposed scenario for the mid- 1980s events at the northern Cleft Segment (Juan de Fuca Ridge) where megaplumes were probably associated with an eruption of pillow mounds over a 17 km line (Embley and Chadwick, 1994; Chadwick et al., 1991).

The model developed from the Cleft data suggests that significant hydrothermal venting along the path of dike propagation might only persist during the freezing period of the dike and then rapidly die out over months to a year (depending on the width of the dike). The CoAxial Event will provide the critical test of this model. An alternate model is that the sudden release of stress along the segment is accompanied by magma injection from a deep source along its entire length, with eruptions taking place where the vertical dike reaches the surface. The pattern, temperature and chemistry of, and longevity of venting will be critical in determining the extent of magma intrusion into the upper crust. In addition, data from the rock samples collected from the ROPOS and ALVIN dives will be important in constraining the models.

It is clear that the CoAxial Event provides an ideal opportunity to conduct geophysical (T-phase, OBS etc.) hydrothermal (both water-column and seafloor), geologic (Sea Beam, sidescan, camera tows, etc.) and biologic time series of a crustal accretion event where time zero is known. This event certainly provides opportunity to test some of the inferences developed by the geological, geophysical and biologic observations made at the Cleft and 9°N sites (Embley and Chadwick, 1994; Haymon et al., 1993).

The detection of this event at the start of the field season was indeed fortunate, and allowed the maximum amount of resources to be brought to bear on the response effort. It is clear, however, that, even with this optimization of effort, much information was lost, particularly during the initial stages of the event when rapid changes were taking place. The now realized ability to remotely detect submarine volcanic events in near-realtime over a portion of the Mid-Ocean Ridge offers great new research opportunities to study submarine volcanism and the evolution of hydrothermal systems, but also new challenges on how to efficiently do so.

## References

Baker, E. T., A 6-year time series of hydrothermal plumes over the Cleft segment of the Juan de Fuca Ridge, *J. Geophys. Res.*, in press.

Bjornsson, A., G. Johnsen, S. Sigurdsson, G. Thorbergsson, and E. Trygvasson, Rifting of the plate boundary in north Iceland 1975-1978, *J. Geophys. Res.*, 84, 3029-3038, 1979.

Chadwick, W.W., Jr., R. W. Embley, and C. G. Fox, Evidence for volcanic eruptions on the southern Juan de Fuca Ridge between 1981 and 1987, *Nature*, 350, 416-418, 1991.

Chadwick, W.W. , Jr., R.W. Embley, and C.G. Fox, SeaBeam depth changes associated with recent lava flows, CoAxial Segment, Juan de Fuca Ridge: Evidence for multiple eruptions between 1981-1993, *Eos Trans. Amer. Geophys. Un.*, 74, 619, 1993.

Dziak, R.P., and C.G. Fox, Seismo-acoustic evidence of a dike injection along the CoAxial Segment, Juan de Fuca Ridge, *Eos Trans. AGU*, 74, 619, 1993.

Embley, R.W., and W.W. Chadwick Jr., Volcanic and hydrothermal processes associated with a recent phase of sea-floor spreading, *J. Geophys. Res.*, in press.

Embley, R.W., W.W. Chadwick, I.R. Jonasson, S. Petersen, D. Butterfield, V. Tunnicliffe, and K. Juniper, Geologic inferences from a response to the first remotely detected eruption on the mid-ocean ridge, *Eos Trans. Am. Geophys. Un.*, 74, 619, 1993.

Fox, C.G., Real-time detection of a volcanic eruption on the Juan de Fuca Ridge using the U.S. Navy Sound Surveillance System, *Eos Trans. AGU*, 74, 619, 1993.

Haymon, et al., Volcanic eruption of the mid-ocean ridge along the East Pacific Rise crest at 9°45-52'N: Direct submersible observations of seafloor phenomena associated with an eruption event in April, 1991, *Earth Plan. Sci. Letts.*, 119, 85-101, 1993.

## CLEFT SEGMENT

A total of 12 days were spent at the Cleft Segment. During this time, eight ROPOS dives were conducted (two were aborted). These dives were highly successful (see dive summaries) and accomplished nearly all the objectives outlined in the cruise prospectus. The ROPOS performed very well during this portion of the cruise. Two vent fluid samples were taken on the Monolith and Pipe Organ chimneys and these proved to contain a large percentage of vent fluid relative to the 1992 samples. This year, the normal titanium sampler was mated to a Lupton-type gas sampler, and both types were triggered successfully with the ROPOS actuator. Six sites previously discovered and sampled by ALVIN in 1988-91 were revisited and sampled for biology and chemistry. The SUAVE system proved to be an extremely valuable tool in rapidly assaying changes in the chemistry and temperature of these sites. Many of the marked sites were found without the benefit of acoustic navigation (Dives 225, 230, 231, and 233); the dives were targeted at a GPS position and the marker and/or vent site was then located by known geological features. An extensive biological/chemical survey was conducted at the Fountain Vent

on dives 229 and 232.

The observations, measurements and samples from these dives (particularly dives 230 and 231) confirm that some of the northern Cleft Segment diffuse hydrothermal vents appear to be significantly diminished from the level of activity seen/measured during the ALVIN dives and camera tows conducted during the late 1980s and early 1990s. Most significantly, the vents south of the sheet flow/smoker area appear to have essentially shut down. Together with the diminution of venting north of the sheet flow observed on earlier cruises, this suggests that the active hydrothermal system has contracted in towards the sheet flow area. Analysis of time-series of CTD measurements made in the overlying plumes is consistent with an overall diminishment of the hydrothermal flux since the late 1980s.

The rock coring program was very successful. The rock corer (essentially a gravity corer with a special cutting edge that's impregnated with wax) recovered basaltic glass on twenty-five of twenty-seven stations along the Cleft Segment. These samples are being used in a study of the geochemical evolution of the Cleft Segment by scientists from the University of Florida in Gainesville. The rock core stations were very complimentary to the other work conducted on the cruise since it used the trawl cable on the deep-sea winch and could be implemented with a minimum of time.

#### Instrument Deployments

Several instrument packages were deployed and recovered during the cruise. The acoustic extensometer array (six instruments) was successfully deployed and recovered at the Cleft Segment, a Rumbleometer was deployed at the CoAxial Segment, a Rumbleometer and a Bottom Pressure Recorder at Axial Volcano, and a Rumbleometer at the Cleft Segment. There were some unanticipated noise problems with the Extensometer receivers, so it was not redeployed.

#### Sea Beam Resurvey of Cleft Segment

A Sea Beam resurvey of the Cleft Segment (two lines along the entire segment) concentrated on the southernmost portion (four lines) where an unusual T-phase event (which had similar characteristics to the CoAxial event) occurred in 1992. This resurvey showed no significant depth changes above the detection limit (~10m).

## TECHNICAL STATUS OF ROPOS AND NAVIGATION SYSTEMS

Overall, the ROPOS lived up to expectations for 1993. Its performance as an event response exploration and sampling system (one of the primary reasons that the program was started on the VENTS side) was exemplary, and it showed improved performance in its sampling and surveying capabilities from 1992. The buoyant tether provided much improved operations; the system was able to maneuver in areas that would have been difficult if not impossible in 1992. The marriage of the SUAVE system to ROPOS was very successful and provided key data for both water chemistry and biology programs.

The system had significant down time during the first portion of the cruise. Clearly, there needs to be improvement in the spare parts inventory (i.e. more operational funds). Also, the system will surely improve in reliability as it is used more. The tether management system was much improved and had no significant problems during the 1993 cruise. There were no major failures of this part of the system in 1993. The need for modification of the DISCOVERER A-frame (higher, wider, stronger) remain, as does the requirement for a motion compensation system.

The navigation system was also much improved and greatly aided the ship in station keeping. The EED group at PMEL in cooperation with the Institute of Ocean Sciences ROPOS group and the Pacific Geoscience Center, conducted some extensive noise tests on the Canadian vessel TULLY in the Spring of 1993. These tests led to the design of acoustic baffles, and in conjunction with some repairs done on the range meter (RM661), this led to much improved acoustic navigation (see navigation plots of dives).

Differential navigation was supplied by two sources. A base station in Newport, Oregon provided an HF link (2 and 6 MHz) which was reliable except for some periods between dusk and dawn. During the latter part of the cruise we switched to the John Chance satellite HF link, which, after an initial problem with antenna placement was solved, operated very reliably.

## SOME COMMENTS ON THE SHIP

There was a very good synergy between the scientific party and the ship's officers and crew during Leg II. The station keeping during ROPOS dives was superb (see plots), the deck force was nearly flawless in the launch and recovery operations (probably the most demanding of any ever done on a NOAA vessel) and the CO's leadership and special interest in the project encouraged a high level of interest and enthusiasm among the rest of the officers and crew. The visibility that the event response engendered in the wider oceanographic community can only enhance the image of the DISCOVERER and the NOAA fleet in general.

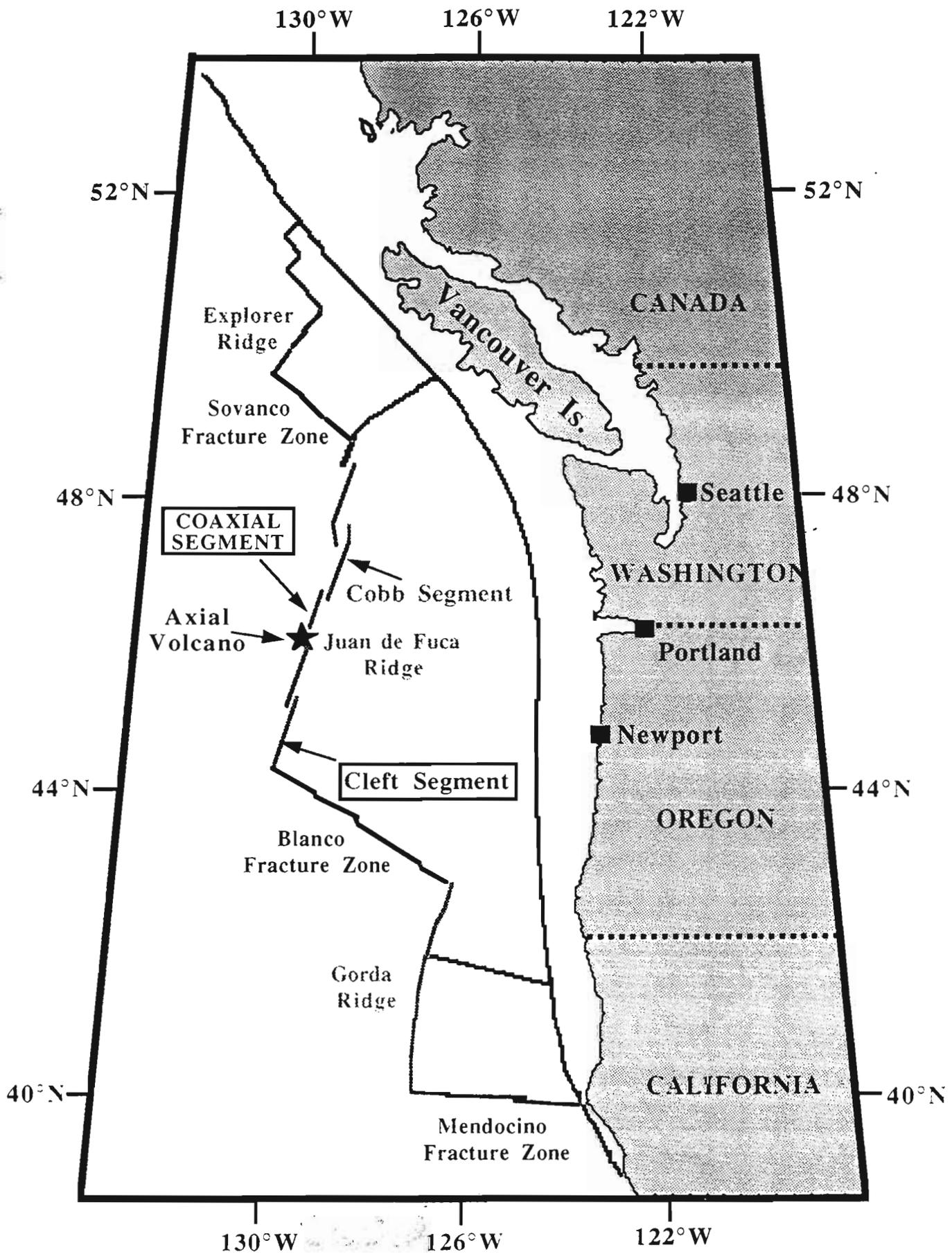


FIG. 1: LOCATION MAP SHOWING AREA OF STUDY DURING THE VENTS93 LEG II CRUISE ON THE NOAA SHIP *DISCOVERER*. THE BOXED NAMES ARE SEGMENTS OF THE JUAN DE FUCA RIDGE VISITED DURING THE CRUISE.

# COAXIAL SEGMENT

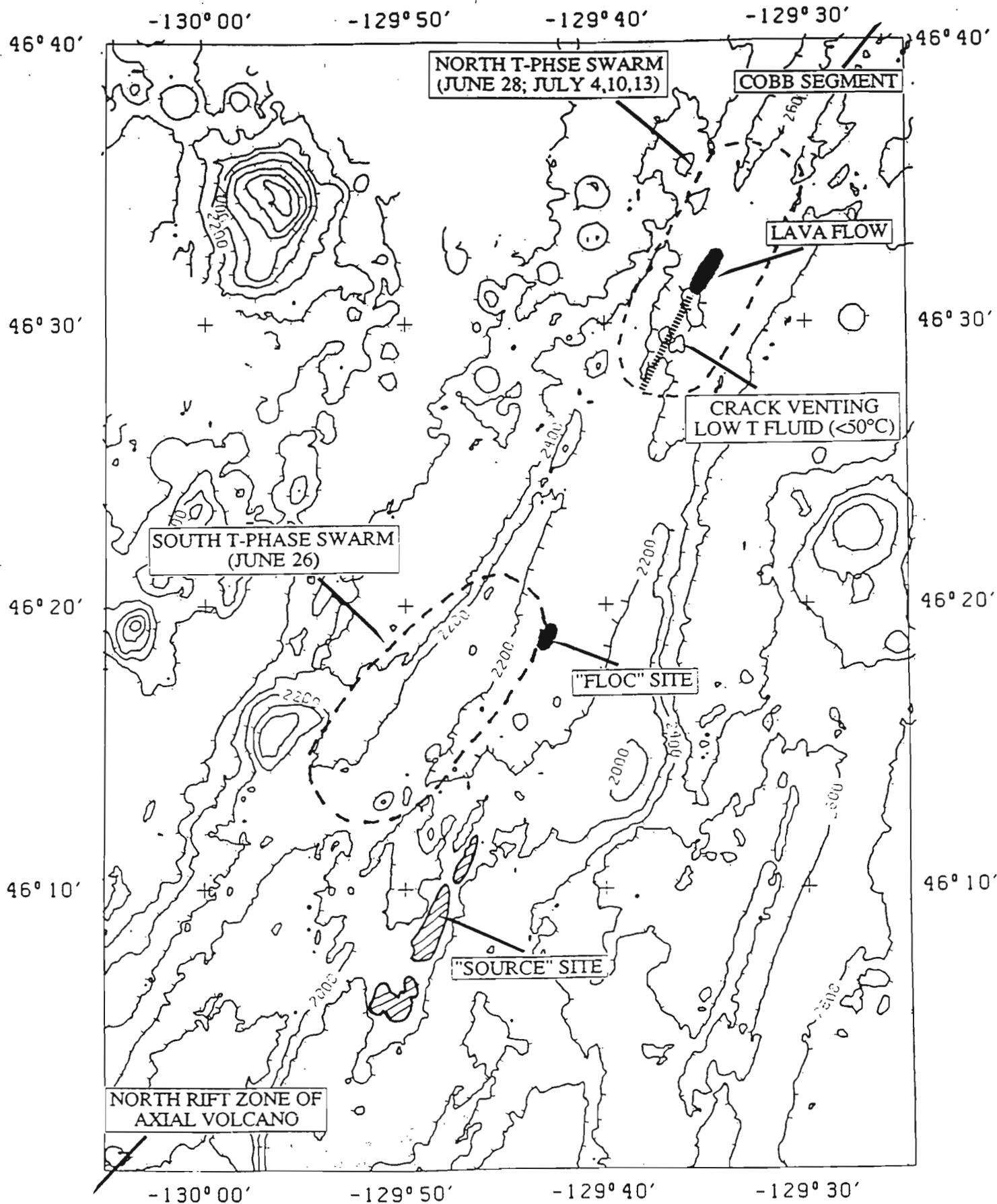


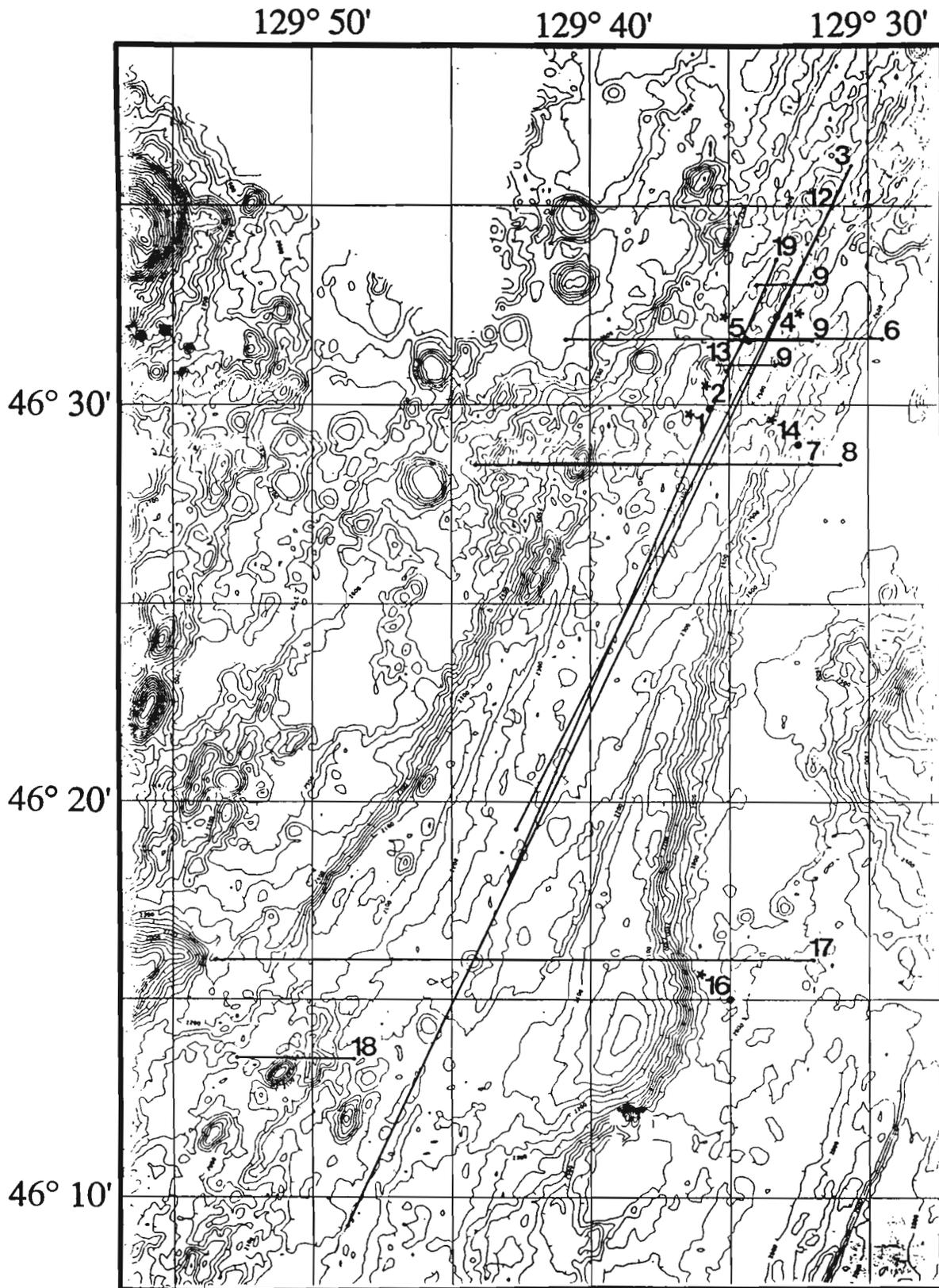
FIG. 2

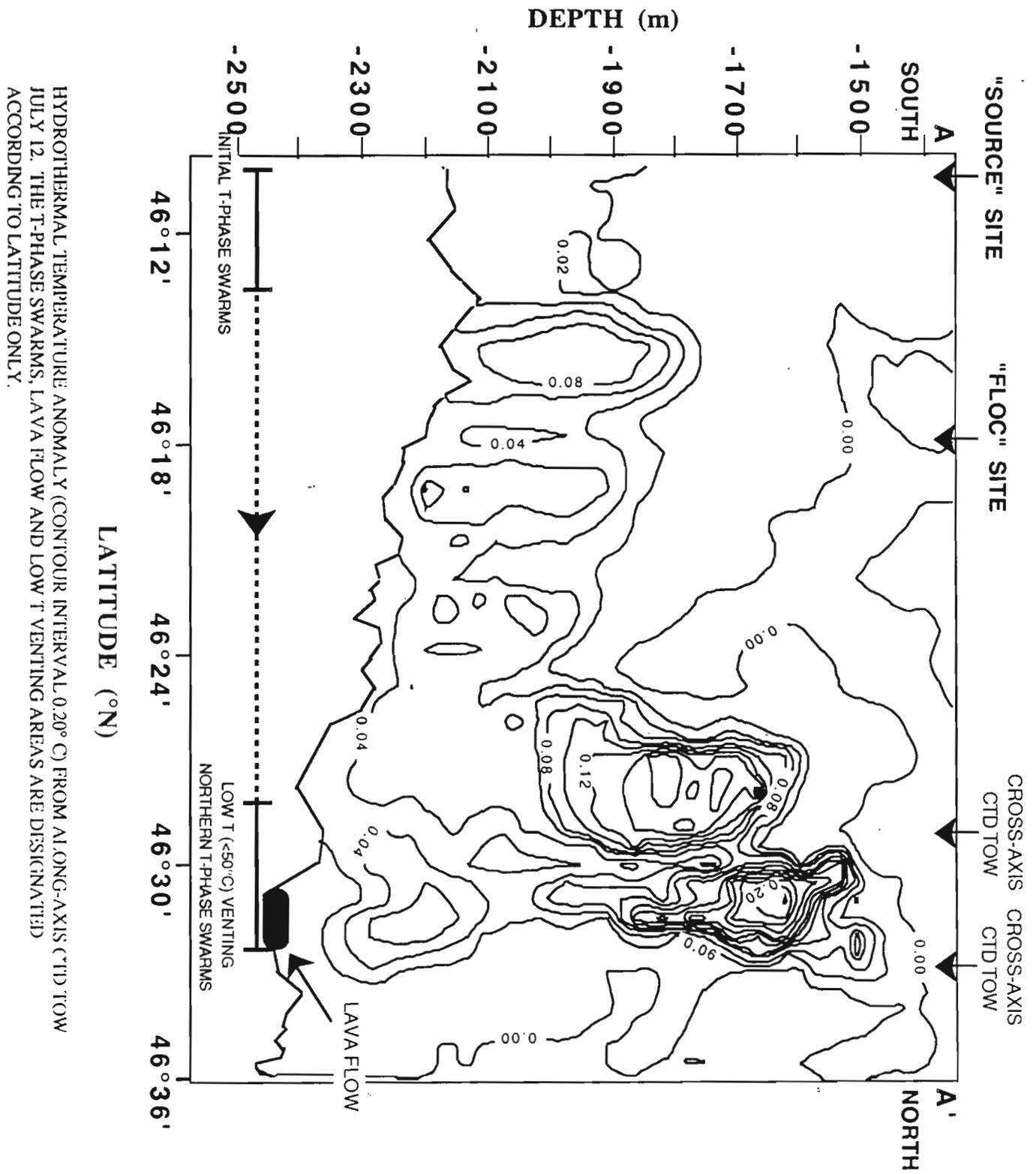
**TABLE 1: CTD TOW/CAST STATIONS**

TOW/CAST #	Lat	Lng
1*	46° 29.90'	129° 35.70'
2*	46° 29.90'	129° 35.70'
3	46° 36.00'	129° 30.60'
	46° 9.28'	129° 48.76'
4*	46° 32.21'	129° 33.28'
5*	46° 31.60'	129° 34.30'
6	46° 31.65'	129° 29.50'
	46° 31.63'	129° 40.88'
7	46° 28.50'	129° 32.00'
	46° 28.48'	129° 44.14'
8	46° 28.50'	129° 31.00'
	46° 28.55'	129° 42.56'
9a	46° 33.00'	129° 32.00'
	46° 33.00'	129° 34.00'
9b	46° 31.60'	129° 32.00'
	46° 31.60'	129° 35.00'
9c	46° 31.00'	129° 33.33'
	46° 31.00'	129° 36.00'
10	ABORTED	ABORTED
11	ABORTED	ABORTED
12	46° 34.99'	129° 31.26'
	46° 19.30'	129° 42.69'
13	46° 31.70'	129° 34.39'
	46° 30.85'	129° 35.10'
14*	46° 29.00'	129° 32.50'
15	44° 53.00'	130° 15.10'
	44° 53.72'	130° 14.78'
16*	46° 15.00'	129° 35.00'
17	46° 16.00'	129° 32.00'
	46° 16.00'	129° 53.49'
18	46° 13.50'	129° 48.50'
	46° 13.53'	129° 52.69'
19	46° 33.62'	129° 33.30'
	46° 18.00'	129° 42.95'

\*Casts

# COAXIAL SEGMENT CTD TOW/CAST STATIONS





HYDROTHERMAL TEMPERATURE ANOMALY (CONTOUR INTERVAL 0.20° C) FROM A LONG-AXIS CTD TOW JULY 12. THE T-PHASE SWARMS, LAVA FLOW AND LOW T VENTING AREAS ARE DESIGNATED ACCORDING TO LATITUDE ONLY.

FIG 4

**TABLE 2: SCIENTIFIC PARTY**

<b>NAME</b>	<b>ROLE</b>	<b>AFFILIATION</b>
Dr. Robert Embley	Chief Scientist/Geologist	NOAA/PMEL
Dr. Ian Jonasson	Geologist	Geol. Survey of Canada/Ottawa
Dr. Verena Tunnicliffe	Biologist	U. Victoria/Canada
Dr. Kim Juniper	Biologist	U. Quebec/Canada
Mr. Gary Massoth	Chemist	NOAA/PMEL
Mr. James Gendron	Chemist (Radon)	NOAA/PMEL
Ms. Jozzee Sarrazin	Biologist/Graduate Student	U. Quebec/Canada
Lt. Mike Devany	Physical Oceanographer	NOAA/PMEL
Lt. jg Chris Meinig	Engineer	NOAA/PMEL
Mr. Keith Shepherd	Chief ROPOS Pilot	Inst. Ocean Sciences/Canada
Mr. Robert Holland	ROPOS Pilot	Inst. Ocean Sciences/Canada
Mr. Robert McDonald	Engineer	Geol. Survey of Canada/Sidney, B.C.
Mr. Keith Tambouri	ROPOS Pilot	Inst. Ocean Sciences/Canada
Mr Jeff Campbell	Acoustic Nav/Electronics	NOAA/PMEL
Mr. Mike Stapp	Instrument Software Engineer	NOAA/PMEL
Dr. Dave Butterfield	Chemist	U of W/JISAO
Dr. William Chadwick	Geologist	Oregon State U./CIMRS
Mr. Matt Smith	Geologist/Graduate Student	U. Florida
Ms. Andra Bobbitt	Navigation Software Specialist	Oregon State U./CIMRS
Mr. Dan Conway	ROPOS Pilot	Inst. Ocean Sciences/Canada
Ms. Julia Getsiv	Navigation Assistant	Oregon State U./CIMRS
Dr. Sven Petersen	Geologist	Geol. Survey of Canada
Mr. Thomas Liebe	Geophysical Engineer	RF Bremen, Germany
Mr. Terry Parker	ROPOS Camera/Biologist	U. Victoria
Mr. Joel Orum	ROPOS Technician	Inst. Ocean Sciences/Canada
Mr. David A. Tennant	Physical Oceanographer	NOAA/PMEL

TABLE 3: CRUISE OPERATIONS TIME SUMMARY

JD	DATE	GMT	Event
189	7/8	4:10	depart PMC ROV dip test acoustic nav test
190	7/9	12:20 to 13:20	attempt to locate Scripps Inst. of Oceanography transponder
191	7/10	03:43 to 10:23	S93B01 Cast 001 11:31 to 02:47 Seabeam Survey I (AC 2-5)
-192	7/11	22:28 to 00:09	S93B01 Cast 002 00:44 to 12:47 Seabeam Survey II (AC 5-8)
-193	7/12	13:12 to 14:32	T93B01 Cast 003 15:20 to 19:01 Seabeam Survey III (AC 1-2)
-194	7/13	20:00 to 22:43	rumbleometer deployment VSM-2E 23:54 to 02:06 S93B02 Cast 004
		02:45 to 05:16	S93B03 Cast 005
		06:51 to 13:28	T93B02 Cast 006
		15:17 to 17:33	T93B03 Cast 007
-195	7/14	18:00 to 03:40	HYS218 04:07 to 10:29 T93B04 Cast 008
-196	7/15	12:32 to 21:00	T93B05 Cast 009
197	7/16	03:25 to 08:10	transponder deployment @ CoAxial 10:21 to 16:10 Seabeam Survey IV (AC1B, 4B, 3B, 9)
		16:57 to 21:17	T93B06 Cast 010
		22:18 to 22:52	T93B07 Cast 011
-198	7/17	23:33 to 15:17	T93B08 Cast 012 16:51 to HYS219
199	7/18	06:13 to 10:13	HYS220 18:43 to 00:20 T93B09 Cast 013
200	7/19	01:15 to 20:28	HYS221 21:03 to 23:27 S93B04 Cast 014
201	7/20	03:30 to 09:07	HYS222 10:25 to 15:00 HYS223
		16:46 to 19:55	Seabeam Survey V (AC 10)
		21:25 to 22:34	rumbleometer deployment VSM-1E
		23:20	BPR deployment
		08:00 to 15:19	transponder deployment @ Cleft
202	7/21	?	HYS224 17:46 to 01:06 HYS225
203	7/22	02:24 to 15:35	rock core sampling #1-6 20:11 to 02:45 extensometer deployment
204	7/23	16:27 to 19:26	T93B10 Cast 15
-205	7/24	20:14 to 00:25	HYS226 02:30 to 18:42 rock core sampling #7-15
-206	7/25	19:34 to 05:01	HYS227 09:15 to 18:46 rock core sampling #16-19
207	7/26	00:04 to 01:00	Seabeam Survey VI (AC 11)
		02:07 to 04:21	S93B05 Cast 16
		05:25 to 18:09	T93B11 Cast 17
		18:56 to 22:25	T93B12 Cast 18
-208	7/27	23:39 to 00:16	Seabeam Survey VII (AC 14)
		04:52 to 05:29	HYS228
-209	7/28	08:04 to 03:00	HYS229 03:46 to 06:45 rock core sampling #20-21
		07:37 to 22:21	HYS230
-210	7/29	23:09 to 02:09	extensometer recovery @ Cleft
		03:21 to 14:34	rock core sampling #22-27
-211	7/30	15:40 to 02:30	Seabeam Survey VIII (CL 3A, 2B, 6, 4A, 4B)
		03:14 to 12:31	HYS231 13:17 to 16:17 Seabeam Survey VIV (CL 4A, 3A)
-212	7/31	17:08 to 09:30	HYS232 12:13 to 19:58 HYS233
		20:14 to 23:43	transponders recovery @ Cleft
213	8/1	00:35 to 01:50	rumbleometer deployment VSM-1S @ Cleft
		02:35 to 08:06	Seabeam Survey X (CL 1A, AC 12)
		08:48 to 18:22	HYS234
		18:45 to 21:08	transponders recovery @ CoAxial
-214	8/2	22:45 to 08:32	HYS235 09:54 to 14:11 Seabeam Survey XI (AC 13, 15, 16, 16B)
-215	8/3	15:46 to 02:27	T93B13 Cast 19
		06:25 to 15:09	Seabeam Survey XII (AC 11B, 9B, 0)
217	8/5	19:00	arrive @ PMC

**TABLE 4: CRUISE OPERATIONS LOCATION SUMMARY**

<u>JD</u>	<u>Event - Samples Taken</u>	<u>Location</u>
189	Depart from PMC	Seattle, WA
	ROV Dip Test	Puget Sound, WA
	Acoustic Navigation Test	Puget Sound, WA
190	Attempt to locate Scripps Inst. of Oceanography transponder	
191	S93B01 Cast 001	site: 46°29.90' N, 129°35.70' W
	Bottle #1: 2344 m	46°29.90' N, 129°35.70' W
	Bottle #2: 2094 m	46°29.90' N, 129°35.80' W
	Bottle #3: 2000 m	46°29.92' N, 129°35.85' W
	Bottle #4: 1982 m	46°29.90' N, 129°35.80' W
	Bottle #5: 1901 m	46°29.95' N, 129°35.74' W
	Bottle #6: 1884 m	46°29.96' N, 129°35.71' W
	Bottle #7: 1876 m	46°29.93' N, 129°35.69' W
	Bottle #8: 1831 m	46°29.93' N, 129°35.71' W
	Bottle #9: 1812 m	46°29.91' N, 129°35.71' W
	Bottle #10: 1546 m	46°29.90' N, 129°35.80' W
	Seabeam Survey I	
	AC 2 (bad nav., redo later)	start: 46°28.00' N, 129°34.20' W
		end: 46°39.00' N, 129°29.20' W
	AC 3 (bad nav. for S., redo later)	start: 46°39.00' N, 129°30.30' W
		end: 46°06.00' N, 129°46.40' W
	AC 4 (partial bad nav., redo later)	start: 46°06.00' N, 129°47.50' W
		end: 46°39.00' N, 129°31.40' W
	AC 5 (partial)	start: 46°39.00' N, 129°32.50' W
		end: 46°29.90' N, 129°37.00' W
-192	S93B01 Cast 002	site: 46°29.90' N, 129°35.70' W
	Bottle #1: 2347 m	46°29.70' N, 129°35.18' W
	Bottle #2: 2301 m	46°29.72' N, 129°35.14' W
	Bottle #3: 2027 m	46°29.62' N, 129°35.19' W
	Bottle #4: 1912 m	46°29.61' N, 129°35.28' W
	Bottle #5: 1847 m	46°29.62' N, 129°35.40' W
	Bottle #6: 1804 m	46°29.64' N, 129°35.52' W
	Bottle #7: 1746 m	46°29.67' N, 129°35.56' W
	Bottle #8: 1535 m	46°29.76' N, 129°35.52' W
	Seabeam Survey II	
	AC 5 (partial)	start: 46°29.90' N, 129°37.00' W
		end: 46°06.00' N, 129°48.60' W
	AC 6	start: 46°06.00' N, 129°49.50' W
		end: 46°39.00' N, 129°33.60' W
	AC 7	start: 46°39.00' N, 129°34.70' W
		end: 46°06.00' N, 129°50.50' W
	AC 8	start: 46°06.00' N, 129°51.50' W
		end: 46°39.00' N, 129°35.70' W
-193	T93B01 Cast 003	start: 46°36.00' N, 129°30.60' W
		end: 46°09.28' N, 129°48.76' W
	Bottle #1: 2290 m	46°32.11' N, 129°33.33' W
	Bottle #2: 1659 m	46°31.56' N, 129°33.73' W

Bottle #3: 2219 m  
 Bottle #4: 1662 m  
 Bottle #5: 1628 m  
 Bottle #6: 2228 m  
 Bottle #7: 1773 m  
 Bottle #8: 2204 m  
 Bottle #9: 1819 m  
 Bottle #10: 2008 m

\*  
 46°31.42' N, 129°33.82' W  
 46°31.03' N, 129°34.03' W  
 46°29.98' N, 129°34.82' W  
 46°29.21' N, 129°35.40' W  
 46°29.08' N, 129°35.46' W  
 46°27.50' N, 129°36.60' W  
 \*

\*\*bottle positions estimated based on  
 wire out and CTD depth

Seabeam Survey III

AC 2 (redo)

start: 46°12.00' N, 129°45.20' W  
 end: 46°39.00' N, 129°29.20' W  
 start: 46°39.00' N, 129°28.10' W  
 end: 46°28.00' N, 129°33.10' W

AC 1

Rumbleometer Deployment VSM-2E

-194

S93B02 Cast 004

S93B03 Cast 005

Bottle #1: 2419 m  
 Bottle #2: 2177 m  
 Bottle #3: 1956 m  
 Bottle #4: 1867 m  
 Bottle #5: 1710 m  
 Bottle #6: 1620 m  
 Bottle #7: 1620 m  
 Bottle #8: 1486 m

46°31.97' N, 129°34.57' W  
 46°32.21' N, 129°33.28' W  
 46°31.60' N, 129°34.30' W  
 46°31.60' N, 129°34.33' W  
 46°31.68' N, 129°34.30' W  
 46°34.62' N, 129°34.30' W  
 46°31.64' N, 129°34.28' W  
 46°31.64' N, 129°34.23' W  
 46°31.59' N, 129°34.36' W  
 \*

T93B02 Cast 006

start: 46°31.63' N, 129°34.33' W  
 end: 46°31.65' N, 129°29.50' W  
 end: 46°31.63' N, 129°40.88' W  
 46°31.62' N, 129°29.80' W  
 \*

Bottle #1: 2317 m  
 Bottle #2: 1563 m  
 Bottle #3: 1528 m  
 Bottle #4: 1699 m  
 Bottle #5: 1783 m  
 Bottle #6: 1812 m  
 Bottle #7: 2201 m  
 Bottle #8: 1521 m  
 Bottle #9: 2098 m  
 Bottle #10: 1600 m

46°31.63' N, 129°30.55' W  
 46°31.64' N, 129°31.85' W  
 46°31.63' N, 129°34.15' W  
 46°31.66' N, 129°34.88' W  
 46°31.62' N, 129°35.10' W  
 46°31.67' N, 129°36.14' W  
 46°31.69' N, 129°38.05' W  
 46°31.63' N, 129°39.05' W

\*\*bottle positions estimated based on  
 wire out and CTD depth

T93B03 Cast 007 - Aborted midway

start: 46°28.50' N, 129°32.00' W  
 end: 46°28.48' N, 129°44.14' W  
 \*

Bottle #1: 1682 m

\*\*bottle positions estimated based on  
 wire out and CTD depth

-195

HYS218

ROV didn't touch bottom

T93B04 Cast 008

target: 46°30.90' N, 129°33.70' W

Bottle #1: 1651 m  
 Bottle #2: 2242 m

start: 46°28.50' N, 129°31.00' W  
 end: 46°28.55' N, 129°42.56' W  
 46°28.38' N, 129°31.10' W  
 46°28.35' N, 129°31.05' W

	Bottle #3: 1879 m	46°28.48' N, 129°34.53' W
	Bottle #4: 2259 m	46°28.53' N, 129°35.43' W
		**bottle positions estimated based on wire out and CTD depth
-196	T93B05 Cast 009	
	Tow line #1:	start: 46°33.00' N, 129°32.00' W
		end: 46°33.00' N, 129°34.00' W
	Bottle #1: 2280 m	46°33.01' N, 129°33.60' W
	Tow line #2:	start: 46°31.60' N, 129°32.00' W
		end: 46°31.60' N, 129°35.00' W
	Bottle #2: 1960 m	46°31.31' N, 129°34.60' W
	Tow line #3:	start: 46°31.00' N, 129°33.33' W
		end: 46°31.00' N, 129°36.00' W
	Bottle #3: 1846 m	46°31.35' N, 129°33.70' W
	Bottle #4: 2450 m	46°31.00' N, 129°35.92' W
		**bottle positions estimated based on wire out and CTD depth
197	Transponder Deployment	Ax-Cobb
	10.5: 2335 M	46°31.03' N, 129°33.08' W (457711.3/5151659.7)
	11.5: 2338 m	46°30.81' N, 129°34.13' W (456367.6/5151265.8)
	8.5: 2240 m	46°31.63' N, 129°34.60' W (455777.4/5152779.5)
	13.5: 2323 m	46°31.87' N, 129°33.49' W (457193.7/5153223.0)
		**positions are "absolute" based on calibration
	Seabeam Survey IV	
	AC 1B	start: 46°28.00' N, 129°33.10' W
		end: 46°20.00' N, 129°37.10' W
	AC 4B	start: 46°18.30' N, 129°41.60' W
		end: 46°16.70' N, 129°42.30' W
	AC 3B	start: 46°15.00' N, 129°42.00' W
		end: 46°06.00' N, 129°46.40' W
	AC 9 (partial)	start: 46°06.00' N, 129°52.60' W
		end: 46°35.00' N, 129°38.60' W
	T93B06 Cast 010 - Aborted	
	T93B07 Cast 011 - Aborted	
-198	T93B08 Cast 012	start: 46°34.99' N, 129°31.26' W
		end: 46°19.30' N, 129°42.69' W
	Bottle #1: 2269 m	46°31.70' N, 129°33.60' W
	Bottle #2: 2084 m	46°30.75' N, 129°34.25' W
	Bottle #3: 2144 m	46°30.60' N, 129°34.38' W
	Bottle #4: 2040 m	46°30.50' N, 129°34.75' W
	Bottle #5: 1609 m	46°28.92' N, 129°35.50' W
	Bottle #6: 2075 m	46°26.64' N, 129°36.95' W
	Bottle #7: 2166 m	46°25.45' N, 129°37.80' W
	Bottle #8: 2173 m	46°21.90' N, 129°41.75' W
	Bottle #9: 2200 m	46°20.70' N, 129°41.65' W

	Bottle #10: 1893 m	*
		**bottle positions estimated based on wire out and CTD depth
	HYS219	target: 46°30.90' N, 129°33.70' W
	ROV on bottom f/ 19:34 to 01:15	
-199	HYS220 - Aborted	target: 46°30.72' N, 129°34.80' W
	T93B09 Cast 013	start: 46°31.70' N, 129°34.39' W
		end: 46°30.85' N, 129°35.10' W
	Bottle #1: 2366 m	46°31.47' N, 129°34.81' W
	Bottle #2: 2366 m	46°31.48' N, 129°34.83' W
	Bottle #3: 2366 m	46°31.49' N, 129°34.83' W
	Bottle #4: 2339 m	46°30.81' N, 129°35.06' W
	Bottle #5: 2358 m	46°30.95' N, 129°35.10' W
	Bottle #6: 2161 m	46°30.86' N, 129°35.06' W
		**bottle positions estimated based on wire out and CTD depth
200	HYS221	target: 46°30.72' N, 129°34.80' W
	ROV on bottom f/ 04:12 to 19:00	
	Samples #1 - 6	
	S93B04 Cast 014	site: 46°29.00' N, 129°32.50' W
	Bottle #1: 2610 m	46°29.03' N, 129°32.51' W
	Bottle #2: 2174 m	46°29.07' N, 129°32.56' W
	Bottle #3: 2098 m	46°29.04' N, 129°32.56' W
	Bottle #4: 1879 m	46°29.02' N, 129°32.53' W
	Bottle #5: 1736 m	46°29.00' N, 129°32.48' W
201	HYS222	target: 46°30.50' N, 129°35.35' W
	ROV on bottom f/ 06:07 to 06:35	
	HYS223	target: 46°31.48' N, 129°34.81' W
	ROV didn't touch bottom	
	Seabeam Survey V	
	AC 10	start: 46°39.00' N, 129°37.60' W
		end: 46°06.00' N, 129°53.70' W
	Rumbleometer Deployment VSM-1E	45°55.88' N, 129°39.14' W
	BPR Deployment	45°57.21' N, 129°59.99' W
	Transponder Deployment	Cleft Segment
	10.0: 2053.1 m	44°59.93' N, 130°11.32' W
		(406309.4/4983510.8)
	11.5: 2037.3 m	44°59.38' N, 130°11.47' W
		(406099/4982489.3)
	12.5: 2042.4 m	44°59.17' N, 130°11.99' W
		(405411.3/4982108.8)
	13.0: 1961.7 m	44°59.00' N, 130°11.10' W
		(403948.1/4981821.6)
	10.5: 2059 m	44°57.59' N, 130°13.07' W
		(403945.4/497203)
		**positions are "absolute" based on calibration
202	HYS224	target: 44°59.41' N, 130°12.06' W
	ROV didn't touch bottom	

	HYS225	target: 44°59.41' N, 130°12.06' W
	ROV on bottom f/ 20:44 to 22:45	
203	Rock Core Sampling	
	#1: 2200	44°59.55' N, 130°12.73' W
	#2: 2209	44°40.60' N, 130°23.34' W
	#3: 2256	44°41.50' N, 130°20.70' W
	#4: 2267	44°43.33' N, 130°19.92' W
	#5: 2245	44°46.52' N, 130°18.55' W
	2246	44°46.50' N, 130°18.60' W
	#6: 2232 m	44°48.20' N, 130°17.75' W
	2243 m	44°48.19' N, 130°17.73' W
	Extensometer Deployment	44°59.11' N, 130°15.23' W
204	T93B10 Cast 15	start: 44°53.00' N, 130°15.10' W
		end: 44°53.72' N, 129°14.78' W
		**bottle positions estimated based on wire out and CTD depth
-205	HYS226	target: 44°59.41' N, 130°12.06' W
	ROV on bottom f/ 22:57 to 00:18	
	Rock Core Sampling	
	#7: 2235 m	44°58.22' N, 130°14.63' W
	#8: 2226 m	44°58.01' N, 130°13.99' W
	2224 m	44°58.00' N, 130°13.98' W
	#9: 2298 m	44°57.80' N, 130°13.27' W
	2295 m	44°57.79' N, 130°13.32' W
	#10: 2294 m	44°57.60' N, 130°12.71' W
	2292 m	44°57.59' N, 130°12.69' W
	#11: 2277 m	44°57.47' N, 130°11.88' W
	#12: 2313 m	44°57.26' N, 130°11.40' W
	2310 m	44°57.26' N, 130°11.40' W
	#13: 2278 m	44°57.08' N, 130°10.78' W
	2285 m	44°57.08' N, 130°10.77' W
	#14: 2352 m	44°56.90' N, 130°10.18' W
	#15: 2293 m	44°59.01' N, 130°11.21' W
	2294 m	44°59.99' N, 130°11.21' W
206	HYS227	target: 44°59.76' N, 130°11.89' W
	ROV on bottom f/ 23:07 to 02:42	
	Rock Core Sampling	
	#16: 2266 m	44°44.91' N, 130°19.17' W
	2268 m	44°44.91' N, 130°19.11' W
	#17: 2300 m	44°49.37' N, 130°17.05' W
	2302 m	44°49.38' N, 130°17.03' W
	#18: 2235 m	44°58.63' N, 130°10.03' W
	#19: 2343 m	44°58.80' N, 130°10.54' W
	2328 m	44°58.82' N, 130°10.55' W
207	Seabeam Survey VI	
	AC 11	start: 46°06.00' N, 129°54.80' W
		end: 46°17.00' N, 129°49.43' W
	S93B05 Cast 16	site: 46°15.00' N, 129°35.00' W
	T93B11 Cast 17	start: 46°16.00' N, 129°32.00' W
		end: 46°16.00' N, 129°53.49' W
	Bottle #1: 1616 m	46°15.94' N, 129°33.10' W

	Bottle #2: 1879 m	46°16.02' N, 129°36.25' W
	Bottle #3: 1786 m	46°16.04' N, 129°36.75' W
	Bottle #4: 1776 m	46°16.05' N, 129°37.51' W
	Bottle #5: 1753 m	46°16.02' N, 129°40.00' W
	Bottle #6: 2162 m	46°16.02' N, 129°46.10' W
	Bottle #7: 2086 m	46°16.00' N, 129°46.70' W
	Bottle #8: 2003 m	46°15.98' N, 129°47.75' W
	Bottle #9: 1962 m	46°15.98' N, 129°48.25' W
		**bottle positions estimated based on wire out and CTD depth
	T93B12 Cast 18	start: 46°13.50' N, 129°48.50' W
		end: 46°13.53' N, 129°52.69' W
	Bottle #1: 2069 m	46°13.50' N, 129°48.51' W
	Bottle #2: 1932 m	46°13.54' N, 129°50.80' W
		**bottle positions estimated based on wire out and CTD depth
-208	Seabeam Survey VII AC 14	start: 46°14.00' N, 129°53.80' W
		end: 46°06.00' N, 129°57.70' W
	HYS228	target: 44°59.68' N, 130°11.95' W
	ROV didn't touch bottom	
-209	HYS229	target: 44°59.68' N, 130°11.95' W
	ROV on bottom f/ 10:21 to 00:45	
	Samples #1-3	
	Markers #880-8812	
	Rock Core Sampling	
	#20: 2320 m	44°59.71' N, 130°13.60' W
	2325 m	44°59.69' N, 130°13.61' W
	#21: 2287 m	44°59.10' N, 130°11.65' W
	HYS230	target: 44°57.77' N, 130°12.91' W
	ROV on bottom f/ 10:08 to 20:55	
	Sample #1	
	Extensometer Recovery	44°59.11' N, 130°15.23' W
210	Rock Core Sampling	
	#22: 2287 m	44°51.23' N, 130°16.31' W
	#23: 2296 m	44°51.39' N, 130°16.39' W
	#24: 2301 m	44°52.50' N, 130°15.25' W
	2302 m	44°52.51' N, 130°15.26' W
	#25: 2302 m	44°54.39' N, 130°14.36' W
	#26: 2328 m	44°56.92' N, 130°10.19' W
	2327 m	44°56.90' N, 130°10.19' W
	#27: 2373 m	44°58.51' N, 130°09.30' W
	2376 m	44°58.51' N, 130°09.31' W
-211	Seabeam Survey VIII	
	CL 3A (partial)	start: 44°53.32' N, 130°15.67' W
		end: 44°20.00' N, 130°30.00' W
	CL 2B	start: 44°20.00' N, 130°31.10' W
		end: 44°37.00' N, 130°23.85' W
	CL 6	start: 44°35.00' N, 130°25.80' W
		end: 44 20.00' N, 130°32.20' W

	CL 4B/4A (partial)	start: 44 20.00' N, 130°28.90' W
	HYS231	end: 44 55.08' N, 130°13.85' W
	ROV on bottom f/ 05:12 to 10:40	target: 44 55.08' N, 130°14.05' W
	Seabeam Survey VIII	
	CL 4A (partial)	start: 44°55.08' N, 130°13.85' W
	CL 3A	end: 45°12.00' N, 130°06.50' W
		start: 45°12.00' N, 130°07.60' W
		end: 44°53.35' N, 130°15.67' W
-212	HYS232	target: 44°58.75' N, 130°12.43' W
	ROV on bottom f/ 17:32 to 05:20	
	HYS233	target: 44°58.21' N, 130°12.79' W
	ROV on bottom f/ 14:36 to 18:09	
	Transponders Recovery	Cleft Segment
	10.5	44°57.59' N, 130°13.07' W
	13.0	44°59.00' N, 130°13.10' W
	12.5	44°59.17' N, 130°11.99' W
	11.5	44°59.38' N, 130°11.47' W
	10.0	44°59.93' N, 130°11.32' W
213	Rumbleometer Deployment VSM-1S	44°58.25' N, 130°12.98' W
	Seabeam Survey X	
	CL 1A (partial)	start: 45°01.64' N, 130°09.91' W
	AC 12	end: 45°12.00' N, 130°05.40' W
		start: 46°06.00' N, 129°55.80' W
	HYS234	end: 46°27.00' N, 129°45.40' W
	ROV on bottom f/ 10:32 to 18:00	target: 46°31.48' N, 129°34.85' W
	Samples #1 - 6	
	Marker P1	
	Transponders Recovery	Ax-Cobb
	13.5	46°31.87' N, 129°33.49' W
	8.5	46°31.63' N, 129°34.60' W
	11.5	46°30.81' N, 129°34.13' W
	10.5	46°31.03' N, 129°33.08' W
-214	HYS235	target: 46°19.40' N, 129°42.00' W
	ROV on bottom f/ 01:12 to 07:16	
	Seabeam Survey XI	
	AC 16	start: 46°06.00' N, 129°59.70' W
		end: 46°14.00' N, 129°55.70' W
	AC 15	start: 46°14.00' N, 129°54.70' W
		end: 46°06.00' N, 129°58.70' W
	AC 13	start: 46°06.00' N, 129°56.70' W
		end: 46°27.00' N, 129°46.40' W
	AC 16B	start: 46°06.00' N, 129°59.70' W
		end: 46°09.00' N, 129°58.18' W
-215	T93B13 Cast 19	start: 46°33.62' N, 129°33.30' W
		end: 46°18.00' N, 129°42.95' W
	Bottle #1: 2215 m	46°30.60' N, 129°35.22' W
	Bottle #2: 2160 m	46°30.53' N, 129°35.25' W
	Bottle #3: 1834 m	46°30.30' N, 129°35.39' W
	Bottle #4: 2213 m	46°29.04' N, 129°36.27' W

Bottle #5: 1655 m  
Bottle #6: 2355 m  
Bottle #7: 2146 m  
Bottle #8: 2111 m  
Bottle #9: 2111 m

46°28.09' N, 129°36.95' W  
46°27.92' N, 129°37.00' W  
46°24.18' N, 129°39.40' W  
46°20.32' N, 129°41.60' W  
46°20.32' N, 129°41.60' W

\*\*bottle positions estimated based on  
wire out and CTD depth

Seabeam Survey XII

AC 11B

start: 46°39.00' N, 129°38.60' W

end: 46°17.00' N, 129°49.43' W

AC 9B

start: 46°39.00' N, 129°36.70' W

end: 46°35.00' N, 129°38.60' W

AC 0

start: 46°39.00' N, 129°27.00' W

end: 46°29.00' N, 129°31.50' W

217 Arrive at PMC

Seattle, WA

\*refer to incomplete data records

**TABLE 5: DGPS USE DURING CRUISE**

JD	GMT	DGPS Status		
		HF link	Chance Sat.	reg. GPS
189	10:00	x		
191	17:55			x
192	0:44	x		
	1:43			x
	1:45	x		
194	17:20		x	
	1:07	x		
195	22:34			x
196	21:06	x		
	22:15			x
	22:23	x		
197	11:20			x
	16:52	x		
199	5:19		x	
200	3:06	x		
	6:43		x	
	6:50			x
	7:00	x		
	7:21		x	
	11:26	x		
	11:55			x
201	23:20		x	
202	17:46	x		
203	4:25		x	
	11:02	x		
	11:14		x	
204	1:05	x		
	8:02		x	
206	22:45			x
207	4:56	x		
	16:20			x
	16:41	x		
208	4:20		x	
	10:43	x		
	11:00		x	
209	10:24	x		
	10:30		x	
215	2:50	x		
	3:35			x
<b>Total Days</b>		<b>19</b>	<b>19</b>	<b>10</b>

TABLE 6: ROPOS DIVE LIST OF VIDEO COVERAGE

DIVE	TAPE #	SUBJECT	GMT		JD	REMARKS	
			START	END			
HYS219	1	North CoAxial segment/new eruptive site	19:30	21:26	198		
	2		21:27	23:27			
	3		23:27	-			
	4		0:48	1:15	199	record button not pressed restart tape #3, for SVHS (8mm is complete)	
			1:15	1:40		end of dive	
HYS221	1	North CoAxial segment/new eruptive site	3:20	5:16	200		
	2		5:16	7:11			
	3		7:11	9:05			
	4		9:05	9:53			repositioning
	5		10:22	11:20			
	6		11:52	12:31			repositioning
	7		13:24	14:22			
			15:08	15:58			repositioning
	16:28	17:15					
			18:14	19:12		ROV off bottom	
HYS222	1	North CoAxial segment/new eruptive site	6:07	6:57	201	stopped @ 06:43 for transit in cage, started @ 06:49, end of dive @06:57	
HYS225	1	Monolith, Table I and Table II Vents	21:08	23:03	202	off bottom, dive aborted	
HYS226	1	Monolith, Table I and Table II Vents	22:52	0:11	204	ground fault, dive aborted	
HYS227	1	Fountain Vent	23:06	0:04	205-206	stop for repositioning	
	2		0:09	1:07			
			1:07	2:08		ROV off bottom	
HYS229	1	Fountain Vent (Markers 880-8812)	10:15	10:56		repositioning	
			11:24	12:38			
	2		12:38	14:41			
	3		14:41	16:40			
			17:11	19:01			
			19:01	20:58			
			20:58	21:18		ROV back to cage	
	22:51	23:59	started tape @ 22:51				
			23:59	0:40			
HYS230	1	South Cleft segment (Marker 46, 46-Worms)	10:08	10:16	209	repositioning	
			10:43	10:55		loose cap	
			12:01	13:39			
	2		13:39	15:18		reaching Fountain Vent	
	3		17:30	19:26			
	4		19:26				

DIVE	TAPE #	SUBJECT	GMT		JD	REMARKS
			START	END		
HYS231	1	South Cleft segment (54-Worms, Marker 22)	5:13	5:57	211	ROV on bottom - ROV back to cage
			6:12	6:23		ROV on bottom - ROV back to cage
			6:41	7:36		
	2		7:36	9:27		
	3		9:27	10:38		ROV off bottom
HYS232	1	Cavern/Fountain Vent (Marker 4, Marker M, Marker 2)	19:45	21:40	211	
			21:40	23:37		
			23:37	0:49		ROV back to cage
			1:09	1:59		
			1:59	2:17		reaching Fountain Vent
	5		3:16	5:14		
HYS233	1	Pipe Organ Vent (Marker 40)	14:37	16:33	212	
			16:33	18:10		ROV off Bottom
HYS234	1B	North CoAxial segment/new eruptive site	15:18	17:40	213	
	2B		17:40	18:00		
HYS235	1	South CoAxial segment/new eruptive site	0:55	2:45	215	
			2:45	7:07		
			7:07	7:17		



HYS234-11:38	213	2381	CoAxial flow site near Marker P1 (venting area)	Suction	46° 31.422'	129° 34.845'	NOAA/PMEL in Seattle
HYS234-15:09	213	2392	CoAxial flow site 50° C venting water	Suction	46° 31.698'	129° 34.701'	NOAA/PMEL in Seattle
HYS234-15:09	213	2392	CoAxial flow site 50° C venting water	Suction	46° 31.698'	129° 34.701'	NOAA/PMEL in Seattle

0no temp probe data during dive  
\*ship navigation

**BIOLOGICAL SAMPLES**

\*Contact Verena Tunncliffe at U. Victoria for information

**VIDEO TAPES**

Originals are located at NOAA/PMEL in Newport, OR  
Contact Point Robert Embley

**ROPOS STILL CAMERA**

Originals are located at U. Victoria, Canada  
Contact Point Verena Tunncliffe

## 1993 VENTS LEG 2

### ROPOS DIVE SUMMARIES (all times GMT)

HYS217: Puget Sound - JD189 (7/8); 0835 in water; 0850 at surface

Objective: ROV dip test

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HYS218: Aborted - wire problem

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HYS219: North CoAxial segment/new eruptive site (Marker Y10) - JD198-199 (7/17-7/18); 1653 in water; 1934-0140 on bottom; 0315 at surface

Objectives: (1) Locate, map and sample lava flow/fissure the system produced by the earthquake swarms, (2) Explore area west of old lava lake to search for plume signature, fissure and new lava.

#### Achievements:

A transponder net was placed around the suspected eruption site and, although the eruption site turned out to be at the western edge of the net, successful transponder navigation occurred for most of the dive

This dive was restricted to the northern end of what has now been named the CoAxial segment, based on its location north of Axial Seamount and south of Cobb segment. ROPOS landed in broken ropy talus. The ROPOS began its traverse in a northwest direction (heading ~260-290°) across old, heavily sedimented ropy and lobate sheet flows which showed little relief during the first 0.5 hr. Due to a telemetry problem the ROV left the bottom to return to the cage at 20:04 h and returned to the seafloor among heavily sedimented pillow lavas at 20:23 h with telemetry restored. ROPOS then traversed lobate ropy sheet flows interspersed with large decorated pillows/tubes until encountering drained out pillows and a relatively recent fracture where old lavas met younger white-veined lightly sedimented lavas. ROPOS reentered heavily sedimented patches of sheet flow interspersed with ropy lava at 20:59 h and then sedimented pillows and lobate sheet flows at 21:03 h. A wall of radially fractured pillows was encountered at 21:23 h and again less sedimented more shiny small pillows were discovered at 21:26 h. At 21:27, the ROPOS began to ascend the younger mound of lava, reaching the top of the ridge at 21:34 h. The ROV went slightly down slope before beginning to ascend again through young lava at 21:41 h. Total relief from the base of the first mound to the top of the second was approximately 75 m. Large old decorated pillows and tubes were found on the west side of the young mounds. Post-cruise analysis of the Sea Beam resurvey data showed that this lava flow was erupted between 1982 and 1991. At 22:02 h, a contact with very glassy, unsedimented lava was crossed (after 2.45 hours on the bottom). The sediment-free lava was in the form of bulbous lobate flows and small pillows/lobes, appearing shiny and significantly blacker than the older lava. A 1.7°C temperature anomaly was measured at the edge. The ROV began climbing over the fresh lava at 22:04 h and encountered some alteration staining along cracks in the pillows at 22:08 h. The western edge of the lava flow was crossed after western side of the lava lobe at 22:10 h, where new pillows were in contact with broken up old pillows/lobes. ROPOS changed course to the NE and ascended a slope of older lavas. At 22:21 h, the ROPOS encountered the primary new lava flow (probably 2 1/2 weeks old) and climbed up over a steep pillow slope (east-facing), encountering hydrothermal precipitates and floc in the water at 22:30 h. Hydrothermal activity intensified and the ROV

stopped among stained fractures in drain-outs at 22:39 h to deploy marker Y10 at 22:52 h (1.7°C). ROPOS commenced its traverse at 22:57 h and then stopped to make a series of temperature measurements, the maximum measured 13°C at 23:12 h. ROPOS left the venting area at 23:15 h and re-entered at 23:20 h. A plateau in the middle of the lava flow (total depth 2380 m) was reached at 23:23 h and hydrothermal staining (but no obvious active venting) was found at 23:27 h. The new/old lava contact was reached at 23:44 h, where it was noted that the contact is virtually symmetrical with respect to depth on each side. The width of the lava flow was about 350 m. ROPOS hovered above the lava flow at 23:51 h, noting the width of the flow from the last traverse approximately 350 m. At this point the ship relocated 200 m east with the ROV following above the seafloor. ROPOS returned to the bottom at 00:00 h on older sedimented lava, finding the eastern edge of the lava contact at 00:02 h. ROPOS drove NE (~308°), traversing very glassy small lobate flows and pillows. A small amount of hydrothermal activity and shimmering water in the new lava at 00:07 h and extensive coating of precipitate on small lobes at 00:09 h were encountered before finding good exfoliation of glass (extensive spalled surfaces) and evidence of drainouts at 00:10 h. By 00:14 h, there was very little hydrothermal precipitate or staining, and all evidence for venting was gone by 00:28 h. The ROV continued transiting the fresh lava, finding white specs on pillows and floc raining down at 00:35 h. ROPOS changed course to ~100° in order to reenter the venting area (00:42 h). The eastern edge of the flow was encountered at 00:44 h, where a tubular-shaped sponge was seen on old lava. The ROV rose in the water column, returning to the bottom and new lava at 00:46 h. The ROV remained at the contact until 00:52 h when it resumed transit at a heading of 290-300°, beginning its third and final traverse. ROPOS traversed new pillows and signs of hydrothermal staining were encountered in new lava at 00:57 h. The greatest amount of staining seen so far on the dive was found at 00:58 h, where shimmering water was evident in the lobe interstices, but no T anomaly was measured. The stained lava was left at 00:59 h. ROPOS crossed grayish broken lobes among fresh black ones, noticing that some of the lobes had shed a considerable amount of glass. The ship relocated 100 m NW at 01:05 h. ROPOS stopped over new lobated flows with bacterial floc in the water at 01:09 h and was over stained lava at 01:12 h. The ROV continued heading NW over stained lobated flows. Some minor indications of old venting were seen at 01:16 h. ROPOS changed course due west at 01:21 h crossing new lavas until reaching the contact at 01:27 h. The ROV came up in the water column at 01:28 h to get a good navigation fix before returning to the cage. One Major sample of ambient seawater taken accidentally due to an electronic malfunction was obtained at time unknown. Total distance traversed during the dive was estimated at 3000 m.

The dive ended at 01:42 h, after 6.10 hours of bottom time, due to the ROPOS's low oil level.

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HYS220: Aborted - telemetry problems

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HYS221: North CoAxial segment/new eruptive site (Markers Y15, Y2) - JD200 (7/19); 0115 in water; 0316-1900 on bottom; 2025 at surface

Objectives: (1) Map southern portion of lava flow and south along graben (2) Obtain samples of old and new lava; (3) SUAVE profiling of venting

Achievements:

ROPOS explored west and south of the transponder net, so there was no transponder navigation for this dive (only ship GPS).

ROPOS landed in tubular sedimented lava and commenced its traverse of the seafloor at a heading of  $\sim 300^\circ$ . Striated pillows were encountered at 03:25 h and the first signs of animals and white floc were found among older pillows and tubes at 03:35 h. ROPOS continued to traverse old pillows encountering, occasional drain-outs, small eruptive mounds and hydrothermal fallout for a cumulative bottom time of  $\sim 1$  hr until reaching the edge of the new lava flow at 04:11 h. The PMEL SUAVE chemical scanning system measured an increase in Fe, Mn and temperature along an incline covered with fresh lava buds, pillows and lobes. The first signs of weak venting were seen at 04:21 h and larger pieces of bacterial floc at 04:24 h, where the new lava lobes flattened out. The ROV stopped at 04:26 among weak venting, floc and stained pillows for a failed attempt at a basalt sample before deploying Marker Y15. The first basalt sample (where a  $0.54^\circ\text{C}$  anomaly was measured) of glass pieces was taken at 04:45 h and placed in bin #4. The ROV resumed its traverse at 04:55 h, heading  $\sim 270^\circ$ , left the stained lava area at 04:58 h and reached the western edge of the lava flow and a lava wall at 05:00 h. ROPOS began driving back east to the venting zone at 05:02. After ROPOS changed course to  $\sim 008^\circ$ , venting was encountered at 05:07 h. Significant bacterial floc was seen in the water column at 05:09 h before the venting region was left behind at 05:10 h. Alterations and fractures in the new lava were found at  $\sim 05:16$  h where marker Y2 was deployed (near the edge of the flow). Two altered basalt samples were taken at that location, one at 05:29 h and placed in bin #6, the other at 05:32 h and placed in bin #3. The contact was with old talus, and a sample of this taken at 05:51 h (placed in bin #7) revealed a brown coating of probably Mn on the underside. ROPOS resumed an eastward traverse and encountered extensive yellow staining and a hole puffing out bacterial floc at 06:05 h, where a  $+1.0^\circ\text{C}$  anomaly was measured.

The ROV returned to the cage to reposition on the side of Cage Volcano and touched bottom at 07:39 h among old lobate flows. A collapse pit on the edge of a  $020^\circ$  trending large fracture was found at 07:41 h and the ROV proceeded to follow the fracture. ROPOS encountered a wall in the center of the fracture at 07:43 h and discovered floc in the water at 07:47 h when the ROV descended into new lava. The ROV found the new lava contact at 07:53 h at the base of a cliff before coming up again briefly, and returned to the bottom at 08:03 h among old lobated sheet flows and significant sediment cover. ROPOS landed in shimmering water at the bottom of a shallow graben-like structure. There was heavy staining and alteration on the broken lavas. ROPOS began a NE-NW zigzag exploration pattern along a (still over old lava) and found the southern edge of the lava in the graben at 08:54 h. Crinoids were seen on old lava at the contact edge.

ROPOS then began following the graben south to look for vigorous venting. The ROV traversed older lavas consisting mainly of lobate flows until 09:08 h when some weakly venting broken up pillows were found. Here ROPOS stopped to obtain a sample of the broken rock (square-shaped) with pacman. The claw sampler proved more effective in this case and the sample was obtained at 09:14 h. The ROV resumed its traverse, heading SE ( $\sim 150$ - $280^\circ$ ) encountering altered stained old tubular lavas at 09:17 h. Vigorous venting and bacteria among the stained lava were seen at 09:20. ROPOS approached a V-shaped cleft in the central graben at 09:21 h. Some black stains, shearing in an old talus pile and glass from the eruption were discovered at 09:22 h. More sheared lavas, fractures and bacterial strings were seen up to 09:25 h when ROPOS return to cage for tether management.

The ROV returned to the bottom among old fractured altered pillow lavas at 09:28 h. The amount of floc in the water column increased at 09:29 h when a large fissure was seen. Extensive venting was found down in the fissure through white and yellow stained rocks. A  $0.3^\circ\text{C}$  temperature anomaly was measured with the T probe on the Pacman. ROPOS ascended out of the fissure at 09:36 h and began following it south. At 09:46 h the ROV returned to the cage in order to relocate 300 m south (to  $46^\circ 30.5'$ ,  $129^\circ 35.35'$ ).

The ROV returned to the bottom at 10:22 h in the graben near the east wall. A venting structural valley found at 10:26 h probably was linked to the structure found further north. The

trend was 350° (a cross structure to the 20° trending graben) and was the largest amount of and warmest venting seen so far. The T probe (from the scanner) measured a 10.0° C anomaly so the water was probably considerably warmer. ROPOS continued to survey this venting area noting black stains around the edges of the lava (Mn?). The navigation screen crashed at 10:44 h and ROPOS began to explore without navigation at 10:55 h. More venting talus and black stains were seen as the ROV traveled north and the navigation screen returned at 11:02 h. The obvious venting area was left at 11:03 h. Extensive broken volcanic glass was found on the old fractured pillows and the stained area ended at 11:09 h while ROPOS was still heading north. The ROV entered and momentarily left the venting area until it returned to the cage at 11:15 h, noticing significant floc in the water above the area. The ROV again relocated, ~200 m south of the previous site (46° 30.4', 129° 35.43').

The ROV traversed old, large striated sedimented pillows/tubes, encountering a collapse pit at 11:57 h, all the while maintaining an easterly course. ROPOS changed course west-northwest at 12:02 h. A fissure in old pillows seen at 12:08 h was found in a fairly flat area where a sea cucumber and sea star were seen. Floc increased in the water column beginning at 12:10 h and a small fissure with some staining was crossed. A maximum T measured 4.454° C at 12:12 h in an area of floc raining down. The amount of venting increased so that the ROV held station to measure T in an area of shimmering water, bacteria amidst old pillows/tubes. Maximum T reached was 11.6° C (again actual values were probably much greater). Another course change was made in order to follow the south-southwest trending venting line. The floc in the water was still very evident, as well as that covering the fractured pieces of old lava. ROPOS returned to the cage at 12:31 h in order to relocate 500 m further south-southwest (46° 30.1', 129° 35.58').

ROPOS returned to the bottom at 13:19 h among heavily sedimented old pillows and began heading north-northwest to look for the venting area. A large inactive fracture was found at 13:21 h in an old pillow field. Some decorated sedimented pillows were encountered and floc was seen in the water beginning at 13:23 h. ROPOS found and began to climb a lava pillow (some fractured) wall and the temperature increased to 4.3° C. The top of the wall was reached at 13:32 h, and active venting was encountered at 13:35 h. ROPOS turned around to descend and came across a dark piece (Mn coating?) of lava among old. The rock was sampled at 13:46 h and placed in bin #1 before heading south-southwest back to the venting area, all the while going down slope. The fault scarp among fractured pillows was again found at 13:53 h, just before entering the venting area. An unidentified object (shaped like a tube worm) protruding out of sediment in a diffuse venting area was seen and a failed sampling attempt made at 14:04 h. Some greatly decorated old pillows were traversed before entering the venting area (T max 11.5° C) at 14:09 h. A 170°-190° trending open fissure with active venting was found farther south and followed until 14:19 h. The venting in the fissure had ceased at 14:18 h. The ROV returned to the cage at 14:20 h to reposition 600 m south (46° 29.8', 129° 35.78').

ROPOS returned to the bottom among moderately sedimented pillows at 15:08 h. Some smaller smooth pillow lavas were traversed before encountering old striated sedimented pillows again. A stalked flower-like creature was seen at 15:13 h and another resembling a coral soon after. An ~2 m deep, 1 m wide fracture was seen at 15:16 h. The area remained floc free while crossing decorated large pillows/tubes and another relatively fresh fracture was found at 15:22 h just before entering the venting area at 15:23 h. Some type of animal covered with bacteria was found in the area and the claw sampled it at 15:29 h (bin #2). The ROV returned to the cage at 15:36 h to relocate (46° 29.25', 129° 36.18').

ROPOS returned to the bottom at 16:33 h and began heading ~290-310° over decorated pillows and tubes. A small fissure, ~2 m and west facing, with a ledge within was found at 16:36 h. The eastern facing wall of the fissure was composed of talus. The ROV continued heading N-NW encountering a fairly steep incline of lobes and tubes, a small fresh looking fracture and frequent crinoids. A small depression among heavily sedimented lobate flows and some floc in the water preceded the venting area, reached at 16:42 h. While the ROV changed course quickly from

north to south, the weakly venting area was briefly encountered three times noting no well-developed fractures, but a line of permeability in the pillows/lobes (trending ~238°). The venting became vigorous at 17:03 h with bacteria seen all over the pillows and measured anomaly 2.0° C. A very interesting object comprised of a series of crinoids trimming a white shell-shaped object (fractured pillow or sponge?) was discovered at 17:13 h. ROPOS returned to the cage at 17:16 h to reposition south.

ROPOS returned to the bottom on old lobate sedimented pillows at 18:27 h. A little bit of floc and an occasional large striated and fractured pillow were seen as the ROV headed ~320°. A fissure <1 m and an ~1 m fresh looking fracture were found one after the other at ~18:32 h. The first signs of venting were seen at 18:35 h and shimmering water in pillow interstices was seen minutes later. A large fracture with active venting occurring within was traversed at 18:37 h. The wall of the fracture had extensive venting and ROPOS began to follow the fracture north. The 320° fracture was followed south and then the ROV headed west to gage the width of the venting area at 18:44 h. The venting had decreased by 18:46 h so the ROV turned north for ~25 m and then east to recross the venting area again (the whole time remaining at least in the weak venting area). The venting area was left at 18:49 h and the ROV began to drive 50 m south. Some old decorated pillows were seen at 18:53 h and a large fracture in old pillows was found at 18:54 h (the first one seen). A second large fracture was encountered at 18:55 h and a third smaller one at 18:56 h. Some stalked organisms covered with bacteria strings were seen at 18:58 h, just before the end of the dive.

The dive ended at 18:59 h after mapping for 15.73 hours.

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HYS222: North CoAxial segment/new eruptive site - JD201 (7/20); 0330 in water; 0607-0650 on bottom; 0900 at surface

Objectives: (1) Explore area where 350° trending fractures were found at southern end of Cage Volcano (2) Further map area using Mesotech sonar (frame grabbing) and ROPOS videos

Achievements:

Transponder navigation was maintained during the brief time on the seafloor.

ROPOS landed in old lobate flows and began to proceed NW (heading ~271°) in order to locate the venting zone. Some floc was seen in the water beginning at 06:09 h and a wall of a valley found at 06:10 h showed some signs of venting. The ROV sampled a piece of older lobate flow at 06:15 h. At 06:21 h it was determined the ROV was too far north of the main venting zone so ROPOS changed course to head south. Floc was again seen in the water over sedimented lobate flows at 06:27 h, but the depth was too shallow for the venting area found in the previous dive. At 06:30 h the ROV headed back to the cage. The temperature measurements increased rapidly as ROPOS ascended suggesting the ROV was in a plume. The ROV entered the cage at 06:35 h and pointed west and east in order to get images on the Mesotech sonar. The ROV returned to the bottom at 06:49 h among old pillows and tubes.

ROPOS had to return to the surface at 06:55 h after 0.72 hours of mapping due to a cracked connector which allowed water to enter the can and cause telemetry failure.

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HYS223: Aborted - telemetry failure

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HYS224: ROV test near Axial Seamount - JD202 (7/21)

Objective: Test for leaks in telemetry can

Achievements: Leaking into the telemetry can was detected at 300 m and the problem was rectified.

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HYS225: Cleft Segment: Monolith, Table I and Table II Vents - JD202 (7/21); 1746 in water; 2044-2251 on bottom; 0106 at surface

Objectives: (1) Explore Monolith, Table I and Table II Vents in order to compare them to previous years dives (2) Obtain slurp and chimney samples at Table I Vent

Achievements:

ROPOS lacked transponder navigation so Monolith Vent was found using the Mesotech sonar and the geology of the area.

ROPOS landed on the bottom at 20:44 h too far west of the target so returned to the cage to reposition, returning to the bottom at 21:13 h among broken lobate flows. The ROV traversed broken lobes and a wall of semi-massive flows before arriving at Monolith Vent at 21:25 h. After a video transect for 0.3 hour the ROV drove 10-12 m north and took a suction sample among worms and 5-6°C water at 22:10 h. ROPOS arrived at Table I and II Vents at 22:14 h. Two slurp samples were taken, one each at the top and bottom of Table I Vent, and one chimney sample (HYS225-2231).

After having the ROV down for 2.12 hours the seas had built up too much and the ROV returned to the cage at 22:51 h.

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HYS226: Cleft Segment: Monolith (Marker 10) and Table I/II Vents - JD204 (7/23); 2020 in water; 2259-0018 on bottom; 0110 at surface

Objectives: (1) To explore Monolith Vent (2) Take a gas tight water sample

Achievements:

The ROV had a problem with the still camera while descending to the seafloor at 20:37 h. The camera was restored at 21:31 h (ROV depth 1000 m) and the ROV touched bottom at 22:59 h. ROPOS began its traverse heading 280° over lobate pillows. With excellent navigation, Marker 10 was found at 23:00 h and the base of Monolith at 23:08 h, after traversing for only 0.1 hour. Once there, a video approach and transect of the vent began at 23:14 h. The top of the vent was reached at 23:17 h, and the middle to top area was surveyed from 23:17 h to 23:21 h. ROPOS returned to the base briefly at 23:22 h before returning to the top to begin sampling water. Worms were noted at 23:19 h (H208°) and 23:21 h (H341°). The Gas-Tight and Major paired sample at Monolith was taken from 23:29 h - 23:35 h in the NW quadrant (~1.5 m down from the top), with maximum temperature measured with the probe 50°C.

The ROV headed 10-15 m north crossing lobate flows and arrived at Table I vent at 23:59 h and Table II vent at 00:01 h.

At 00:11 h, after 1.34 hours of bottom time, there was a ground fault in the tether and the ROV/Cage returned to the surface without power.

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HYS227: Cleft Segment: Fountain Vent - JD205-206 (7/24-7/25); 1935 in water; 2307-0210 on bottom; 0453 at surface

Objective: To map and sample (biology) Fountain Vent

Achievements:

Navigation was working well, however, a distance error between the target locations of Fountain and Monolith Vents (discovered later) contributed to much difficulty and a failed attempt at finding the vent during the dive.

ROPOS landed on the bottom at 23:07 h in jumbled sheet flows and found a fissure in the sheet flows at 23:08 h. ROPOS arrived at the base of a wall at 23:09 h and climbed up it before revisiting the cage at 23:27 h. The ROV returned to the seafloor at 23:32 h and headed west over jumbled and flat sheet flows towards the wall previously seen. Jumbled sheet flows changed to flat sheets and then broken sheets briefly from 00:11 h to 00:14 h when a large fracture was found. The sheet flows traversed were ropy to broken before finding a fissure at 00:21 h. ROPOS changed course to 025° finding talus and the first sign of warm water at 00:25 h. ROPOS returned to the fissure at 00:30 h (minor T anomaly). ROPOS held position from 00:31 h to 00:36 h before heading east for 60 m, traversing lobate flows and flat sheet flows. ROPOS changed course at 00:43 h to 260° to approach the fissure and wall. Once at the fissure (00:48 h) ROPOS assumed a 020° heading to follow it. ROPOS returned to the cage at 00:53 h and again to the bottom at 01:09 h on lobate flows. A push up structure in sheets was found at 01:11 h, just prior to finding a N-S crack. Further traverse revealed another push up structure at 01:16 h and more broken sheet/lobate flows. The wall was found at 01:19 h with alteration on the lava and an octopus was seen at 01:21 h on a fissure. ROPOS continued to traverse broken lobate flows and changed course north at 01:27 h. The ROV returned to the cage at 01:29 h to test the failing strobe on the camera and returned to the bottom at 01:47 h on broken lobate flows. ROPOS headed at 307° (01:52 h) in search of old chimneys, which were not found and headed 020° briefly at 01:54 h to the fissure and then 320° to head up a ledge. The ROV went up in the water column at 02:01 h to try to get a fix before telemetry failure at 02:10 h resulted in the end of the dive.

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HYS228: Aborted - tether problem

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HYS229: Cleft Segment: Fountain Vent (Marker 42, Markers 880-8812) - JD 208-209 (7/27-7/28); 0804 in water; 1021-0045 on bottom; 0220 at surface

Objectives: (1) To find Fountain Vent and thus confirm its true position (2) Attempt to deploy 13 markers and a chain (3) Gather geological and biological samples, (4) Video and SUAVE (H<sub>2</sub>S) surveys

Achievements:

Successful transponder navigation (with the Datasonics relay on the ROV) and a correction of the Fountain Vent target enabled ROPOS to find the vent within 10 minutes of its second bottom landing.

ROPOS landed on broken sheet flows at 10:21 h and saw warm water (2.0° C) in an area

south of Fountain vent. ROPOS left the seafloor at 10:32 h and returned to the cage to avoid being pulled by the ship and The ROV touched bottom among broken sheet flows at 11:18 h (approximately 50 m from Fountain target). ROPOS headed NW encountering push-up structures at 11:30 and a slow rise over jumbled sheet at 11:31 h. Marker 42 and Fountain Vent were sighted at 11:35 h and ROPOS began to unload the markers at 11:40 h. The ROV draped a chain over Fountain Vent's chimneys at 12:45 h and then returned to the cage for a few minutes. ROPOS returned to Fountain Vent at 13:02 h and deployed markers 883,884 and 885 from 13:27 h - 15:30 h, conducting SUAVE scanning measurements and video transects at each marker site. A Video transect of the vent was conducted from 15:43 h - 15:58 h. ROPOS again returned to the cage, returning to the bottom at 16:09 h. The ROV surveyed the second stack from 16:25 h - 16:31 followed by a short visit to the cage. ROPOS returned to the bottom at 17:21 h immediately finding Fountain Vent where two sulfide samples were obtained, one at 17:50 h and another at 18:34 h. Markers 886-8812 and 880-882 were deployed from 18:17 h to 20:19 h and a tubeworms sample was taken at 20:38 h. before visiting the cage. ROPOS returned to the bottom at 22:22 h among heavily fissured broken sheets and some fissures and staining. ROPOS relocated the the Land of Giants seeing a large chimney >12 m high at 22:27 h and Deadfall Chimney (fallen chimney) with a silicified core at 22:35 h. A sample of oxide-cemented basalt talus was obtained at 22:40 h before the ROV returned to the cage at 22:50 h. ROPOS landed on the bottom at 22:56 h on lobate flows which changed to broken sheets and push up lava at 23:02 h. The ROV turned south at 23:04 h (heading ~200°) briefly before returning to the cage. ROPOS returned to the chimney field at 23:10, the cage at 23:12 h and then the bottom again on rubbly sheet flows. Broken sulfides and were seen everywhere at 23:27 h and heavy hydrothermal sediment at 23:29 h. The ROV attempted to sample the sulfide from 23:29 h to 23:45 h before moving to a new location to sample. A talus slope with old chimneys was seen at 23:47 h and ROPOS began to climb the slope mainly composed of cemented basalt rubble (very friable). A small piece of lava was sampled at 00:13 h before ROPOS turned south. A huge cross-section of a couple of chimneys were seen at 00:19 h with a very hard silicious core. A sample was attempted there yet failed.

ROPOS left the bottom at 00:45 h, finishing 14.4 hours of bottom time.

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HYS230: Cleft Segment (Marker 46, 46-Worms) - JD 209 (7/28); 0737 in water; 1008-2055 on bottom; 2217 at surface

Objectives: (1) Explore southern area south of Pipe Organ Vent to locate Marker 46 and nearby worm field (2) After repositioning the ship, attempt to relocate and continue biological/geochemical survey of Fountain Vent

Achievements:

ROPOS lacked transponder navigation for the dive up until we relocated to Fountain Vent in the northern transponder net.

The ROPOS reached the bottom at 10:08 h, landing in large striated and decorated old pillows and tubes. ROPOS returned to the cage twice, at 10:10 h to reposition and 1052 h due to being pulled by the ship. The ROV returned to the bottom at 12:01 h after passing through a buoyant plume detected in the water column over an area of old pillows. The ROV headed west looking for the old/new lava contact, traversing old pillows and passing an en-echelon fissure trending 020° (12:06 h). The ROV arrived at the contact at 12:08 h and began to follow it south along a collapse region, looking for Marker 46. Some yellow sediment and a spider crab were seen at 12:10 h. A crab on a pillar exhibiting good ring structures was seen at 12:16 h and Alvin dive weights (probably Dive 2444), with another crab hiding behind them, were discovered at

12:19 h along the edge of the collapse region. A Mn spike on the SUAVE was measured at 12:24 h near the edge of the collapse pit region. ROPOS held position waiting for the ship to catch up with the ROV from 12:26 h to 12:34 h, before heading south and then east at 12:40 in search of the lava contact, found at 12:43 h. ROPOS headed west again finding some pillars (one with two crabs on top, others with worms) in the extensive collapse region beginning at 12:53 h. Another course change then to ~245° brought ROPOS back to the collapse pit area where two unrecognizable egg-shaped objects were found at 13:02 h. Since the identity of the weights were unclear, one was sampled, and only after examination on the DISCOVERER later were they determined to be the weights from Marker 46. The ROV resumed its traverse at 13:19 h, heading first south and then north coming across small worm patches and crabs. A field covered with dead tubeworm patches and bright orange iron-oxide deposits was encountered at 13:37 h. Temperature measurements in shimmering water found in the area reached a maximum of 18° C; H<sub>2</sub>S, Mn and Fe spikes were measured as well. Two tubeworms samples were taken before getting underway at 14:32 h to the old/new lava contact, heading 260° over new lobate flows. Some venting remains were seen at 14:33 h and the eastern edge of the collapse region reached at 14:35 h. ROPOS began heading east at 14:39 h looking for more venting evidence, found almost immediately. The contact was reached at 14:41 h and followed south to a huge dead worms field discovered at 14:44 h, where a series of tubeworm samples and eighteen SUAVE measurements were taken. Traverses through this "tubeworm graveyard" were conducted from 15:05 h - 15:10 h to get the N-S dimensions of the field before the ROV revisited the cage at 15:14 h and relocated north to Fountain Vent. Once again the target was off, this time 2 m NW of the actual site (a discrepancy most likely due to using the ER responder, rather than the Datasonics relay transponder).

Due to worsening weather conditions the dive terminated at 20:55 h, after 10.78 hours on the bottom.

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HYS231: Cleft Segment (44° 54' - Worms site/Marker 22) - JD 211 (7/30); 0322 in water; 0512-1040 on bottom; 1228 at surface

Objectives: (1) Locate the 44° 54' - Worms site (Marker 22) (2) Gather samples of worms and rocks

Achievements:

Without transponder navigation, ROPOS's position was monitored based on watch circle targets and tether out.

ROPOS landed on the bottom at 05:12 h among sedimented ropy sheet flows (somewhere near Marker 22) and began heading east (~95°). A fissure was found soon after the ropy sheet flows changed to pillows at 05:21 h. The ROV continued to traverse sedimented pillows and lobes until 05:42 h when a wall of truncated pillow lavas overlain by broken up sheet flows was encountered. The other side of the wall was an area of drain-outs and old sheet flows and another cleft was found at 05:50 h. ROPOS returned to the cage at 05:55 h to relocate ~280 m southwest. ROPOS returned to the bottom at 06:12 h landing in large tubes and flat lobes, with some floc in the water. A transition from pillows and lobes to sheet flows occurred at 06:18 h. ROPOS descended into a local depression at 06:19 h and reached a wall comprised of broken pillows at 06:19 h. The wall's construction changed from broken pillows to more blocky lava to large lobated pillows at the top, which was reached at 06:21 h. The ship's watch circle was moved 100 m west and ROPOS returned to the bottom at 06:41 h among rubbly broken ropy flows. The floor of the collapse area was reached at 06:42 h where the temperature increased slightly. The ropy flows changed to heavily sedimented larger pillow/lobes at 06:43 h. The ROV went up in the water

column at 06:47 h and returned to the bottom a minute later among sedimented, broken ropy lava. A small crack was found just before the wall at 06:52 h. ROPOS found two parallel 020° trending fractures and a small graben, previously surveyed with Alvin, and proceeded to follow them north. Some white staining was seen on the fractures and the west fracture was more pronounced. Weak venting and ropy flows were entered at 07:00 h while continuing to follow the fractures. At 07:05 h ROPOS stopped to sample a piece of white rock from the fracture, but the rock texture was too friable to grab with the claw. Many sea stars were seen beginning at 07:15 h and the first sign of worms at 07:16 h. The cracks in the ropy flow became much more pronounced at 07:23 h and again ROPOS stopped to sample a piece of altered rock, obtained at 07:33 h. Hydrothermal stains much more yellow in color and lava columns with crabs on top were seen at 07:36 h. ROPOS attempted to measure a temperature anomaly in a dead tubeworms clump at 07:39 h. The dead tubeworms trail was followed north to the end of it at 07:48 h, where more lava columns and sedimented ropy flows were viewed. Again the fracture, lacking any staining, was followed beginning at 07:52 h. A franked government envelope was found at 07:53 h and a pushed up, split open ridge at 07:55 h. The water became floccy at 08:00 h and some fallout in an area of relatively thin sediment was seen soon after. The cracks showed some white alterations at 08:03 h where the two cracks merged into one. The single crack was followed and a slight temperature anomaly was measured while traversing flat sheet flows overlain by ropy flows. Some yellow precipitates and floc were seen at 08:10 h and the tubeworm field came into view ahead at 08:17 h. The area was covered with an expansive field of bleached, mostly dead, tubeworms. A closeup at 08:21 h revealed some shriveled worms in a few of the tubes. The scanner was put into position at 08:33 h, measuring a 0.10° C anomaly and slight H<sub>2</sub>S. The scanner was moved at 08:38 h and measured the same temperature anomaly. There were a few male and female crabs seen perched on the dead worms, probably searching for the last survivors. A Mn spike measured on the scanner was first seen at 08:51 h. Worm samples filling three bins were gathered there from 08:55 h - 09:19 h. From the samples recovered on the DISCOVERER, 39 worms were dead and 7 alive. In contrast, this and nearby sites contained robust tubeworm communities in 1987-1990 when surveyed with towed cameras and visited with ALVIN. ROPOS resumed its traverse of the field at 09:26 h and found Marker 22 at the southern end of the worm patch at 09:30 h. Traverses conducted from 09:34 h to 09:38 h gave some approximate measurements of 5 m by 10 m in width (E-W) and length (N-S) respectively. A ridge remnant (long wall of lava) was founded trending N-S at 09:38 h and ROPOS returned to the fracture at 09:41 h, finding some yellow precipitates. The fracture split into three to four fractures at 09:44 h, running through very flat ropy sedimented area. The area became a little rougher at 09:45 h. The fractures were only two at 09:47 h, with the one to the east more pronounced. Five-armed brittle stars in sediment and a few unidentifiable white pieces (clam remains?) were seen around 09:51 h. The claw nudged the white pieces which appeared to be solid. Yellow staining was seen more in the smaller western fracture so ROPOS zoomed in to measure the temperature. The first noticeably shimmering warm water with a 1.5° C temperature were found there. There were also slight Mn/Fe anomalies seen at 10:11 h in the push up area. The vent precipitates got thicker at 10:13 h and white alterations along fractures were seen again at 10:15 h, also found later on fractured pillows at 10:17 h. ROPOS attempted to sample a too large piece of the altered rock, dropped it in order to fracture it, and then sampled a smaller piece at 10:33 h. The ROV encountered the collapse area at 10:37 h and returned to the cage at 10:38 h due to an increase in swell size.

This concluded 5.57 hours of bottom time.

HYS232: Cleft Segment: Cavern/Fountain Vent (Marker 4 (Blue Grotto)/Marker M/Marker 2) - JD211-212 (7/30-7/31); 1731 in water; 1941-0520 on bottom; 0734 at surface

Objectives: (1) Revisit Cavern Site and markers deployed in previous years (2) Revisit Fountain Vent for additional sampling

Achievements:

Transponder navigation (with some fix discrepancies depending on which transponders were ranging) enabled the ROV to navigate fairly well.

ROPOS landed on the bottom at 19:41 h among ropy flows. The ROV encountered dead worms on the edge of a cleft at 20:03 h and a patch of live pink-tipped worms in shimmering water at 20:09 h, where the ROV stopped, measuring a 24°C temperature anomaly on the scanner at this site. Worm samples were obtained from 20:41 h - 20:50 h, filling two bays, and a basalt glass sample at 20:28 h while conducting three scanner measurements of the water column to ~30 m above the seafloor. The ROV headed west from 21:30 h - 21:32 h where the 020° trending fracture and Marker 4 (Blue Grotto) were found (located south of tubeworm beds). Scanner measurements conducted from 21:39 h - 21:48 h detected a maximum temperature anomaly of 4.1°C. Worms were sampled from 21:49 h to 22:04 h in the same location. ROPOS transited for approximately 0.8 hours before giving up on finding Marker M at 22:57 h and getting underway to explore The Cavern area, found at 23:20 h. The ROPOS traversed new lava drain-outs, ropy push-up areas and a remnant high of old and new lavas on the western edge of the collapsed area. The primary fissure was located at 23:37 h and ROPOS followed it, seeing young drain-out lavas to the west. An area of bacterial threads on rocks (eastern side of fissure) found at 00:18 h had a 4.5° C temperature anomaly. Extensive bacterial floc in drain-out/pillars were encountered at 00:37 h, where ROPOS waited until 00:45 h, when she returned to the cage. ROPOS returned to the bottom in the Cavern area and encountered more drain-outs, pillars and bacterial floc. The venting area was left at 01:27 h and some dead worms were found at 02:10 h. At 02:16 h, approximately 5.5 hours after initially touching bottom, ROPOS came up to relocate to Fountain Vent, a transit taking 1 hour. Marker 2 was never located. The ROV headed north along well-sedimented ropy sheet flows for 0.5 hours until sighting the chimneys of Fountain Vent at 03:44 h. Seven SUAVE scans/video transects were conducted at Fountain.

A tether system problem disabled the ROV from returning to the cage and the dive was terminated at 05:20 h, concluding 9.65 hours on the bottom.

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HYS233: Cleft Segment: Pipe Organ Vent (Marker 40) - JD212 (7/31); 1215 in water; 1436-1809 on bottom; 1957 at surface

Objectives: (1) To find Marker 40 and Pipe Organ Vent (2) To obtain one water sample, some slurp samples of water and biology, and (3) conduct a video survey of the vent

Achievements:

ROPOS navigated with transponder navigation, getting 2 transponder fixes occasionally in the beginning, but once at Pipe Organ had more consistent fixes.

ROPOS touched down into younger looking lobate flows at 14:36 h and began heading east over new lobate flows at 14:39 h. A collapse hole in lobate flows was found at 14:41 h and an older/newer lavas contact was reached at 14:42 h. A significant amount of yellow floc in the water was encountered at 14:43 h while looking for Marker 40. The contact was encountered again and then followed beginning at 14:44 h, heading northwest over old pillows/new lobes and drain-outs.

Shortly after changing the ROV's course south (15:24 h) ROPOS found Marker 40 (15:27 h), with Pipe Organ Vent viewed just to the west of the marker. A Gas-Tight and Major paired sample fired at the opening of one of the chimneys (~4 m off bottom) was of vent fluids measuring a temperature maximum of 262°C. Three slurp samples of chimney smoke, chimney coating and tubeworms were taken between 17:14 h and 17:39 h. One rock sample of sulfide pieces was taken at 17:41 h at the same location. The chimneys were surveyed and measured for height during video transects. The first transect began at 17:43 h and ended at 17:48 h measuring a chimney height of 9.5 m. The second transect was from 17:53 to 18:00 h and measured the second chimney 11 m tall. ROPOS returned to the cage at 18:09 h

The dive ended at 18:09 h, after 3.55 hours on the bottom.

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HYS234: CoAxial segment/new eruptive site (Marker P1) - JD213 (8/1); 0853 in water; 1032-1800 on bottom; 1932 at surface

Objectives: (1) Map the northern part of the new lava flow (2) Obtain slurp samples of warm water, bacteria and glass (3) Obtain a water sample

Achievements:

ROPOS navigated with transponders for the entire dive getting fixes based on three to four transponder ranges frequently during the dive.

The ROV touched bottom in shimmering water and took two Major samples of measured 9-11°C fluids venting out of new basalt (max 19°C) at 10:56 h. Marker P1 was deployed at this spot at 11:10 h, followed by the collection of three suction samples of bacterial floc puffing out of holes in the basalt, completed at 11:49 h. One suction sample for water was taken at 11:41 h at the same site. ROPOS began its traverse at a 020° heading at 12:11 h for 0.4 hours along the vent line, but initially found little water coming out and no temperature anomaly among the yellow stained rocks with bacteria. At 12:30 h a fissure in the new flow was crossed. ROPOS explored the area along the fissure and looked for more fractures, during which time two suction samples were taken (HYS234-1120 of basalt chips and particulate matter and HYS234-1516 of basalt glass), until 13:07 h when the ROV relocated NE 200 m, returning to the bottom at 13:44 h. ROPOS drove NW up a very steep pillow slope and then resumed a 020° heading in order to follow the venting. Between 14:56 h and 15:16 h, where measured temperatures increased up to 51.37°C, two more suction samples of water were taken, the second sample containing pieces of glass. After 0.75 hours of further transit northwards, with a brief E-W traverse the ROV took another suction sample of water containing bacterial floc at 16:01 h. At 16:18, the ROPOS returned to the cage and was moved about 350 m north in order to find the northern limit of the lava flow. An older, fissured pillow terrain was sighted at 16:36. The old/new lava contact was reached at 17:15 h after ROPOS worked its way southward through the fissured terrain. Temperatures up to 13°C were recorded in vents on the new lava. At one place, the northern terminus of the lava lay within a narrow graben about 5 m deep.

The dive ended at 18:00 h, concluding 7.47 hours of bottom time.

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HYS235: CoAxial segment/near 46° 16'-19' - JD213-214 (8/1-8/2); 2246 in water; 0112-0716 on bottom; 0826 at surface

Objectives: (1) Make a SE-NW transect across the central part of the CoAxial Segment where high CTD temperature anomalies had been found earlier (2) Obtain some rock samples of older lava (3)

Investigate an area of apparent depth change in Seabeam resurvey farther south

Achievements:

ROPOS encountered a floc "snowstorm" 200 m above the bottom at 00:55 h while descending to the seafloor, and touched bottom at 01:12 h among old lavas with fissures and scarps. The ROV began its traverse by heading west, observing large floc pieces on the seafloor nearly continuously. The source of this venting, however, was never found.

ROPOS continued heading west-northwest for approximately 5 hours, observing significant glass on old lavas at 01:32 h. One old pillow basalt sample of talus was taken at 01:45 h. ROPOS crossed many fissures and scarps, one of which located along the axial ridge looked recent. At 06:32 h the ROV changed to a 180°-200° course for the rest of the dive, taking one more old pillow basalt sample at 07:00 h from a pile of broken pillows.

After relocating several miles further south ROPOS traversed an area of apparent Seabeam change, but no new lavas were found.

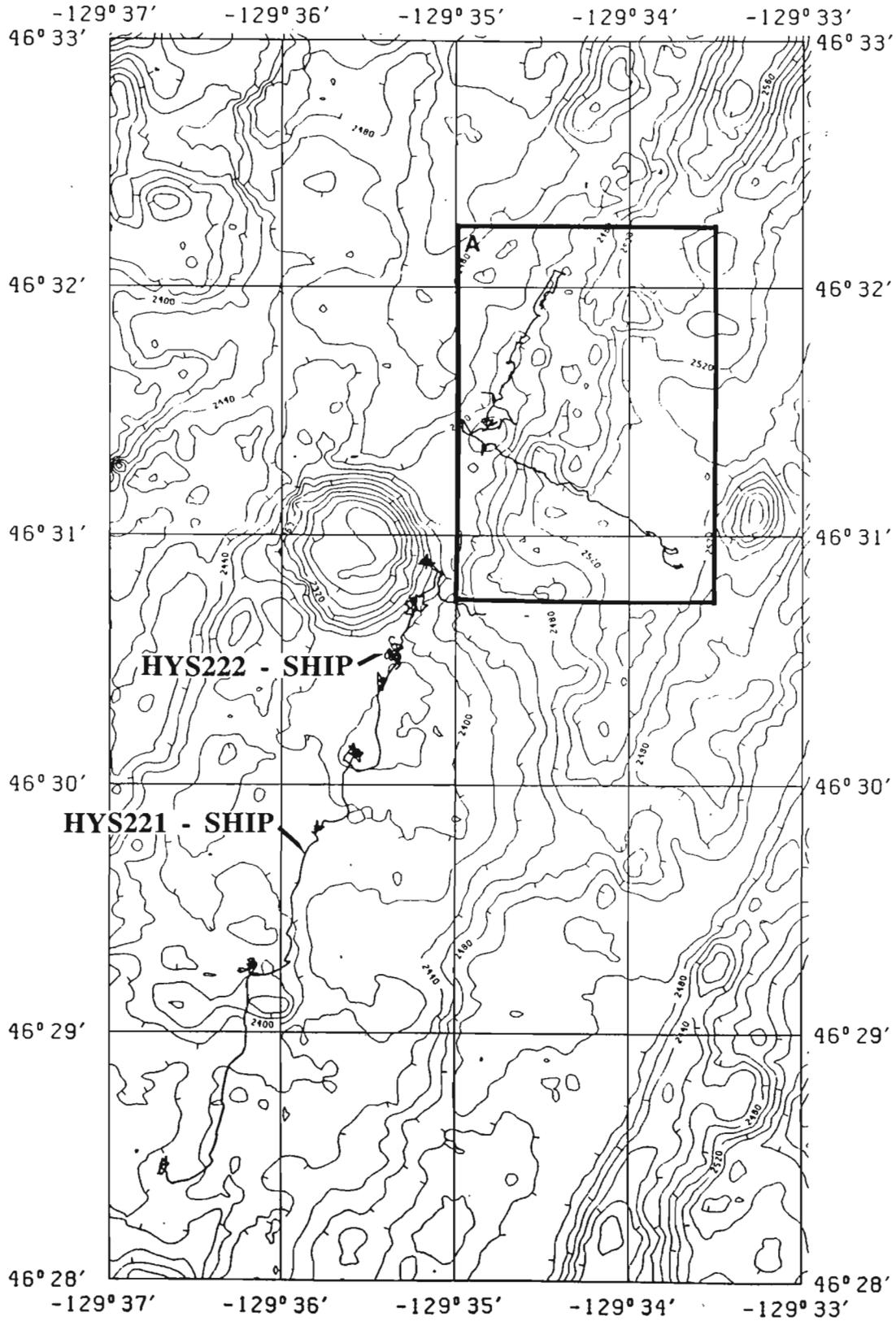
The dive ended at 07:16 h, after 6.07 hours of bottom time, due to rapidly building seas.

# MAPS WITH ROPOS/SHIP NAVIGATION

## KEY TO SYMBOLS

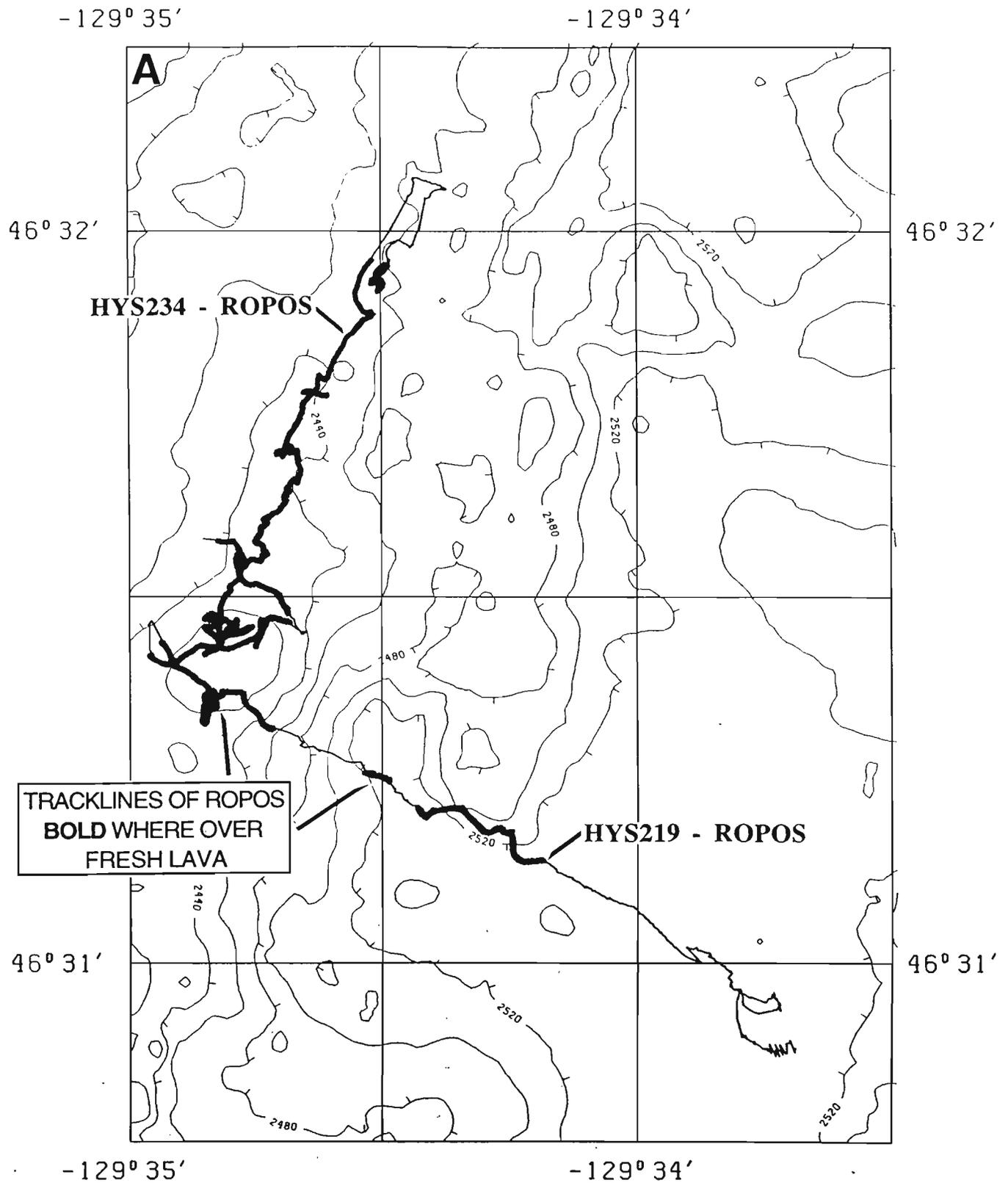
a	animal sample
b	basalt sample
c	chimney sample
s	sulfide sample
sl	slurp sample
tw	tubeworm sample
w	water sample
Y#/P#	marker deployed
880-12	markers 880-8812 deployed
chain	chain deployed

# COAXIAL SEGMENT



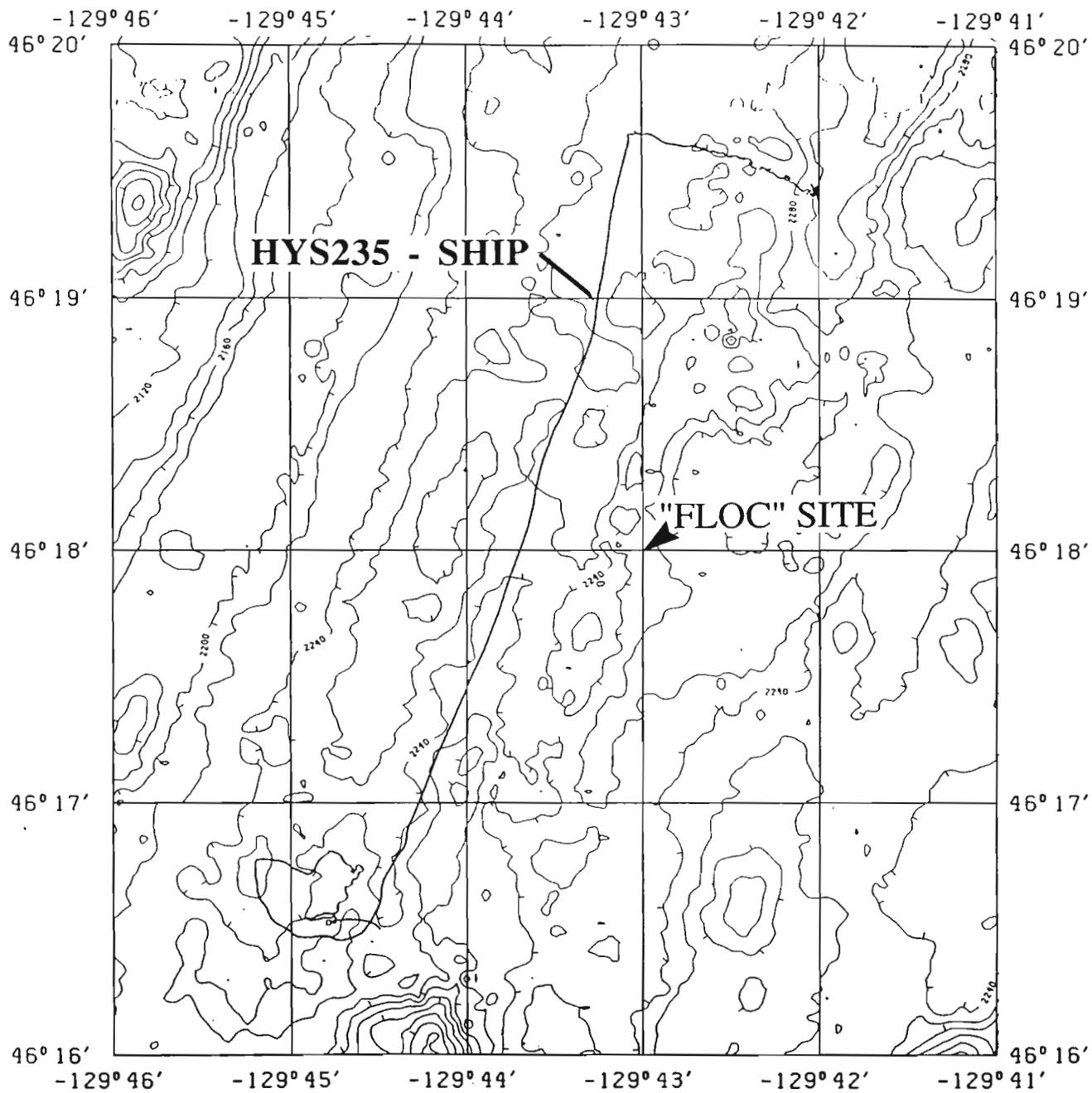
Detailed dive tracks (in UTM) follow on pages 47-49 & 60.

# COAXIAL SEGMENT: FLOW SITE



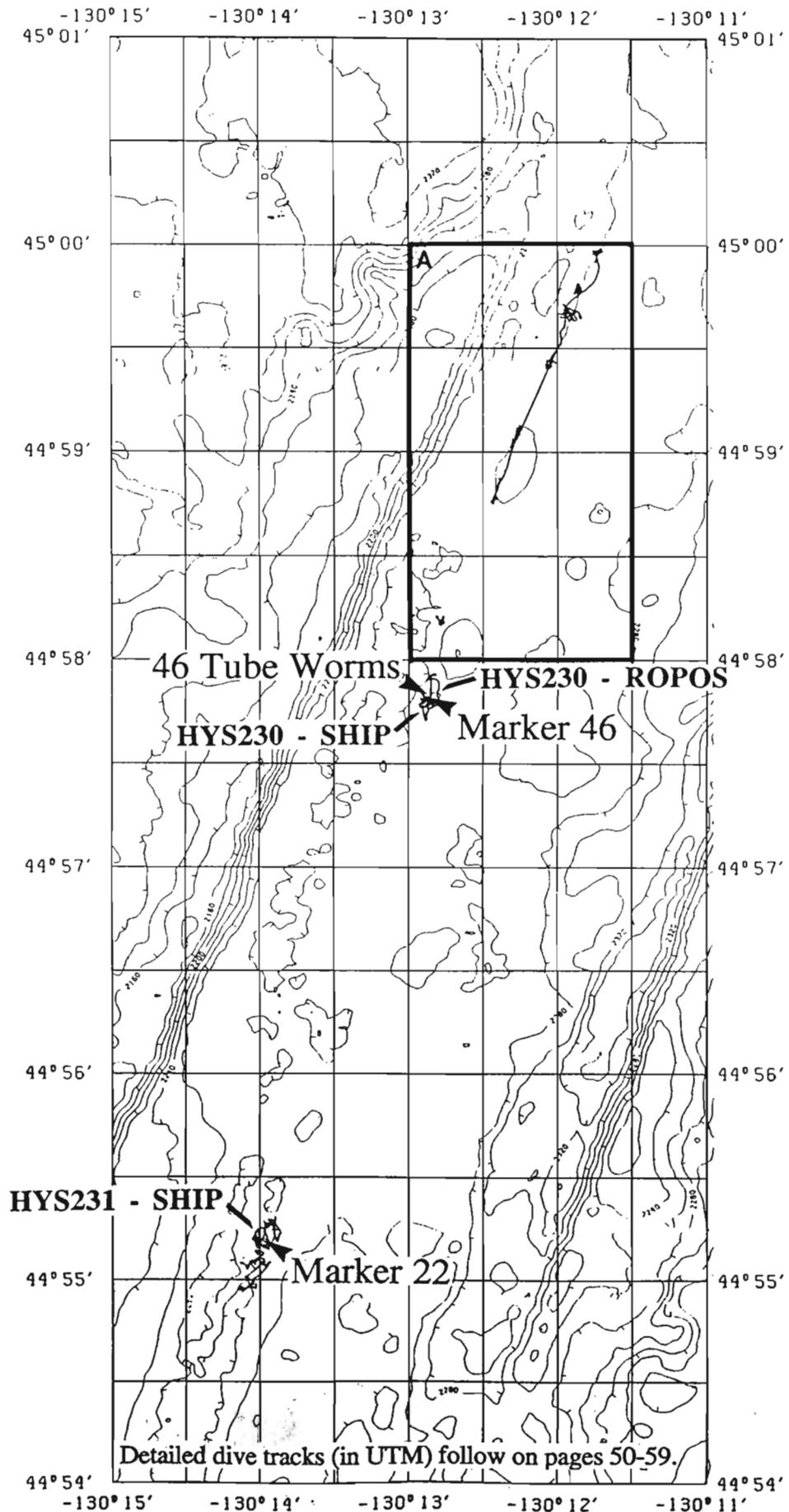
Detailed dive tracks (in UTM) follow on pages 47 & 60.

# COAXIAL SEGMENT: FLOC SITE

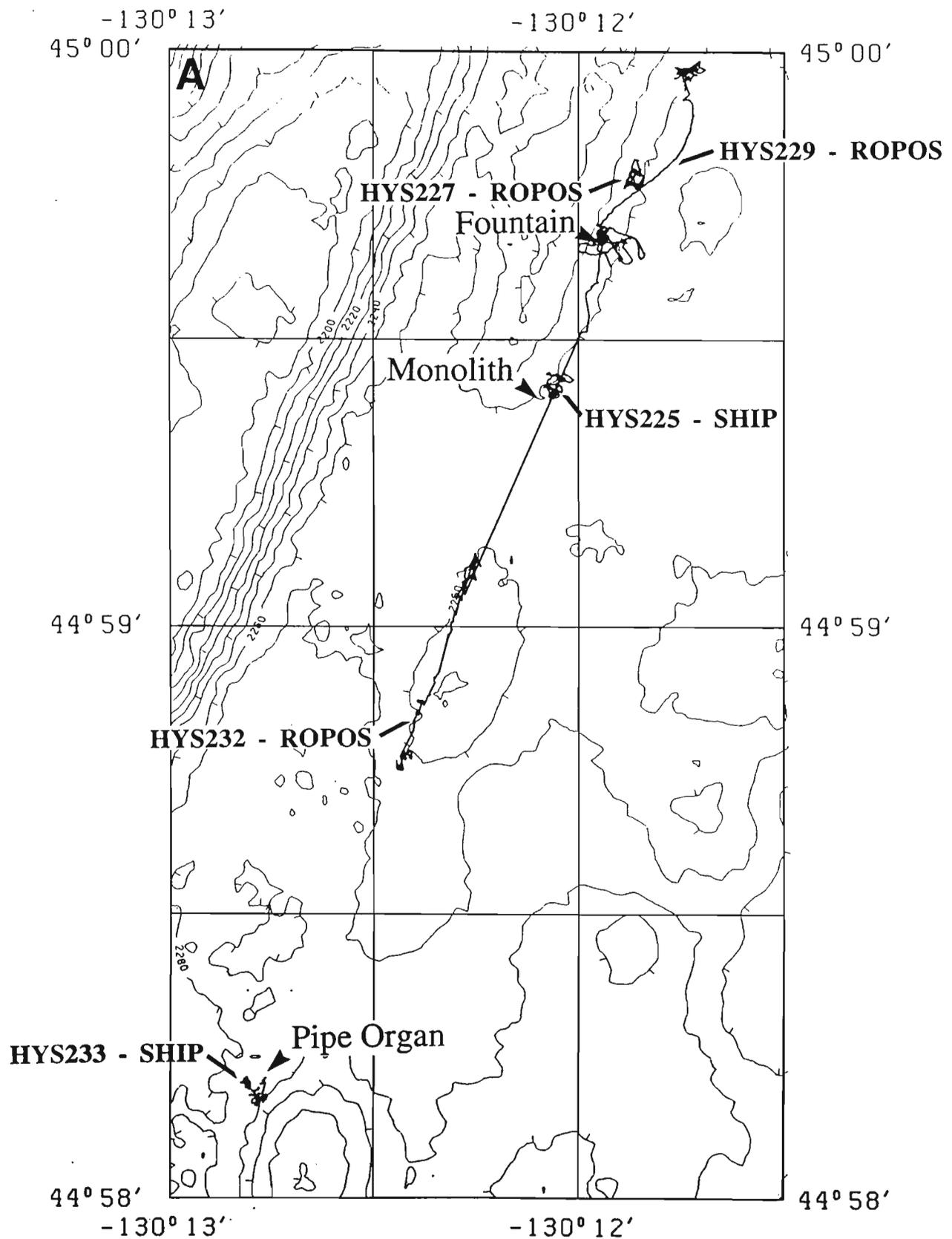


Detailed dive track (in UTM) follows on page 61.

# CLEFT SEGMENT



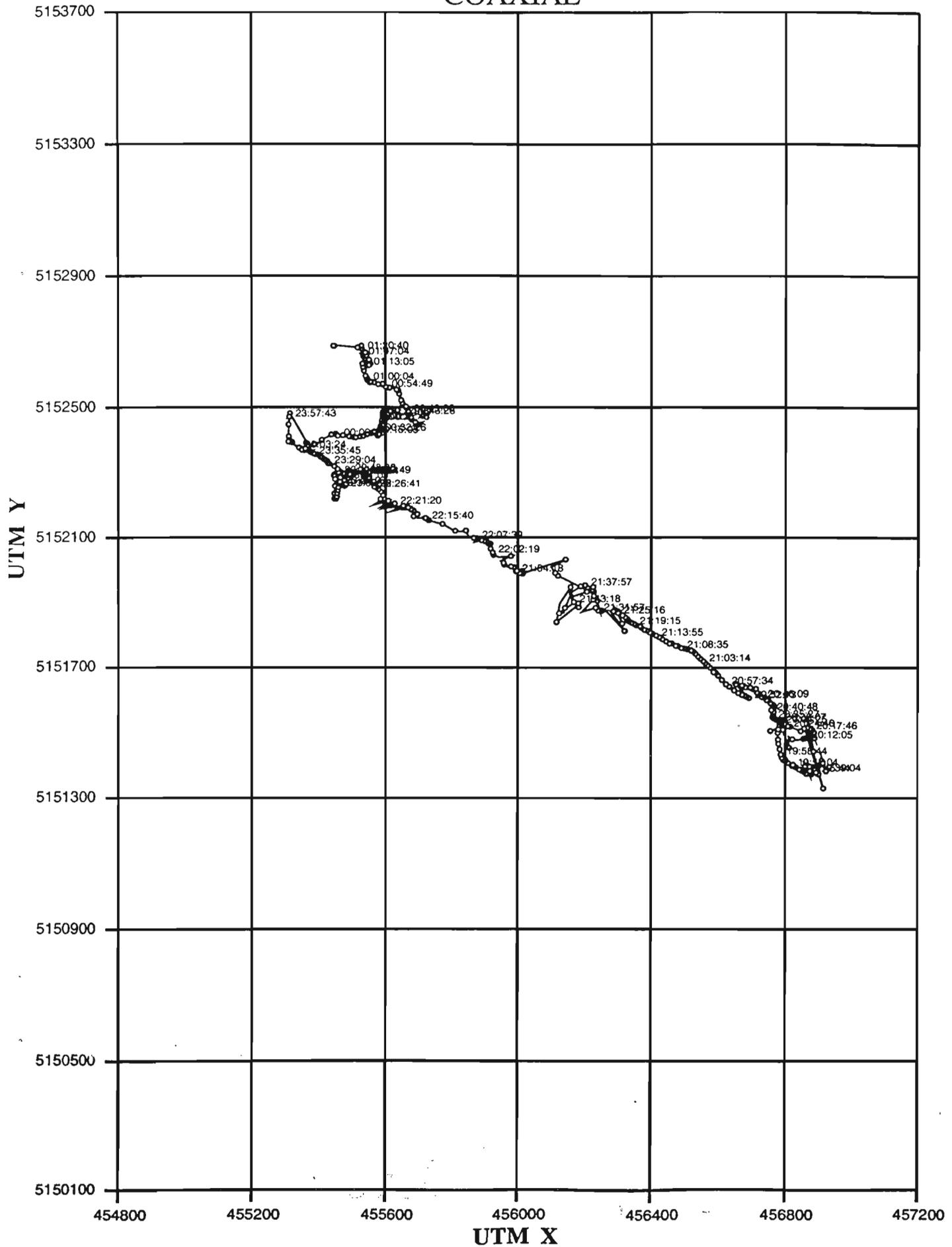
# NORTH CLEFT SEGMENT



Detailed dive tracks (in UTM) follow on pages 50-54 & 57-59.

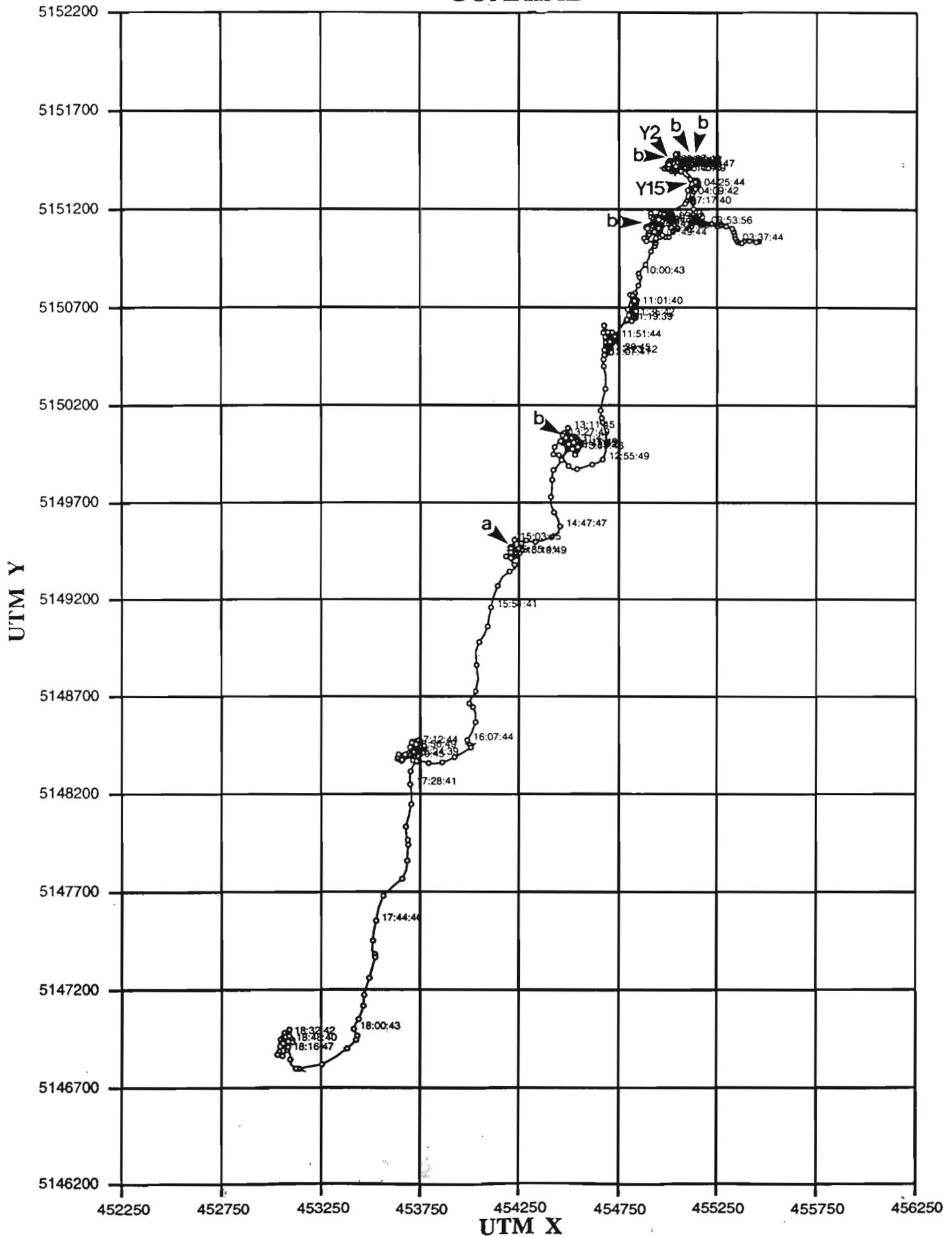
# HYS219 - ROPOS

## COAXIAL



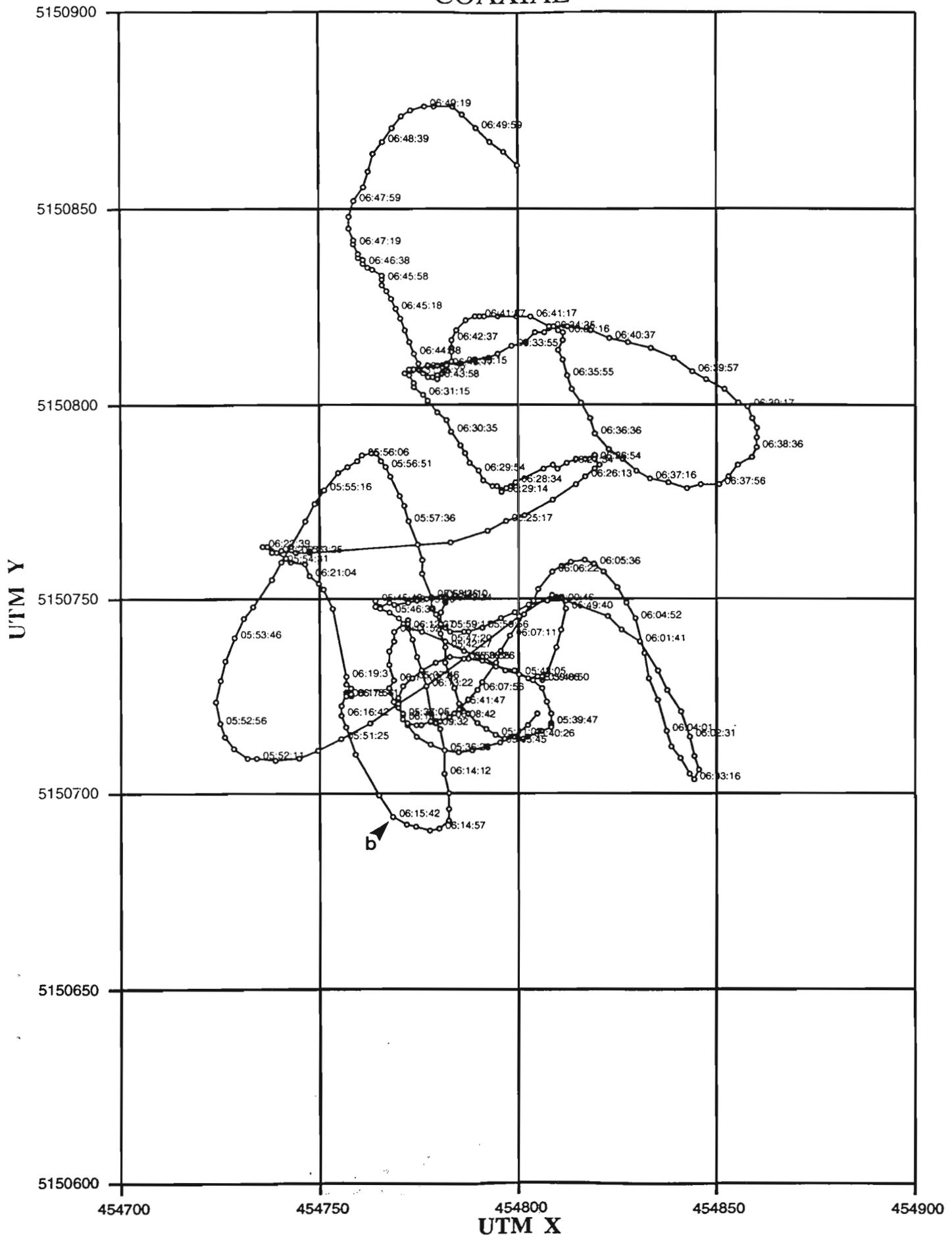
# HYS221 - SHIP

## COAXIAL



# HYS222 - SHIP

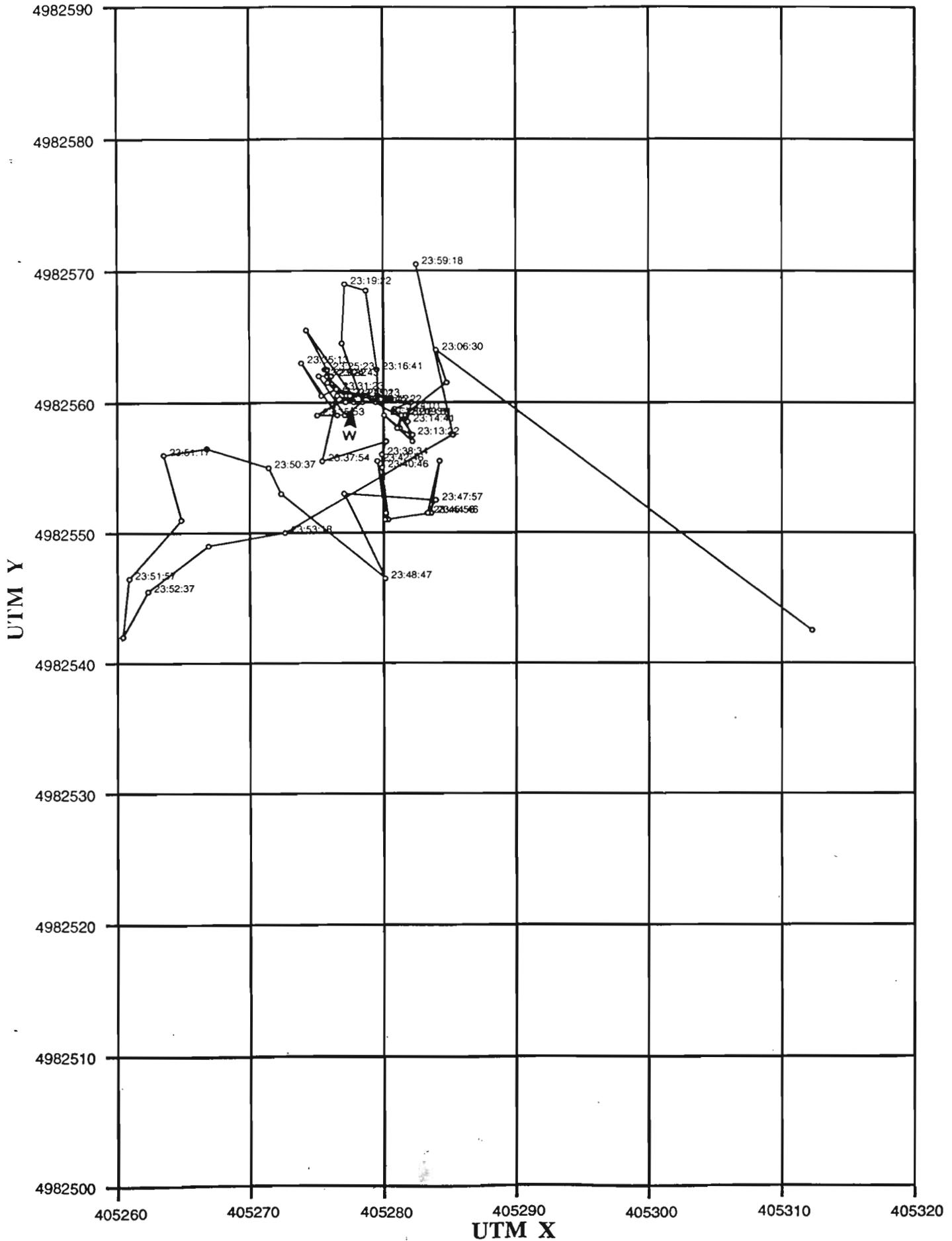
## COAXIAL



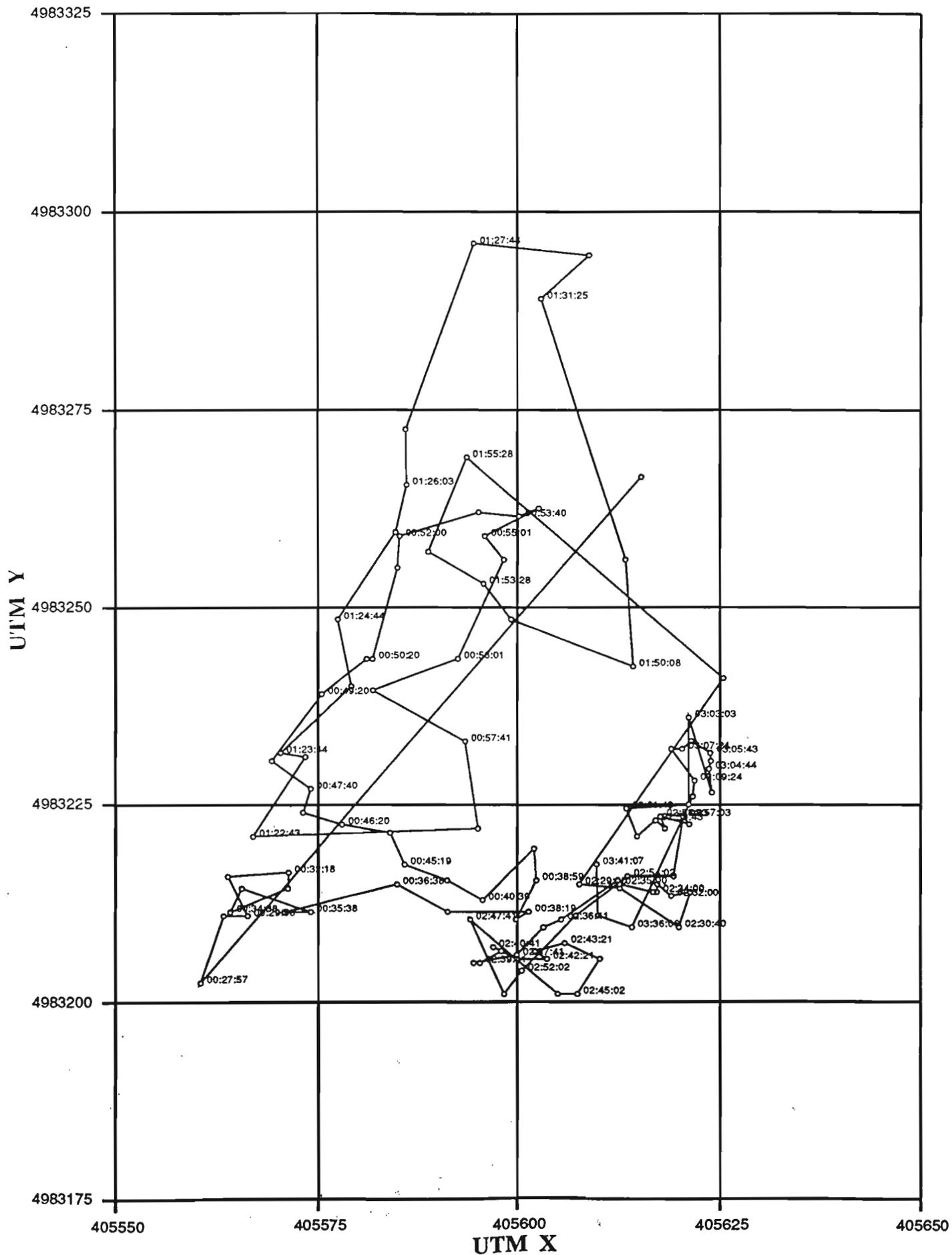


# HYS226 - ROPOS

## MONOLITH

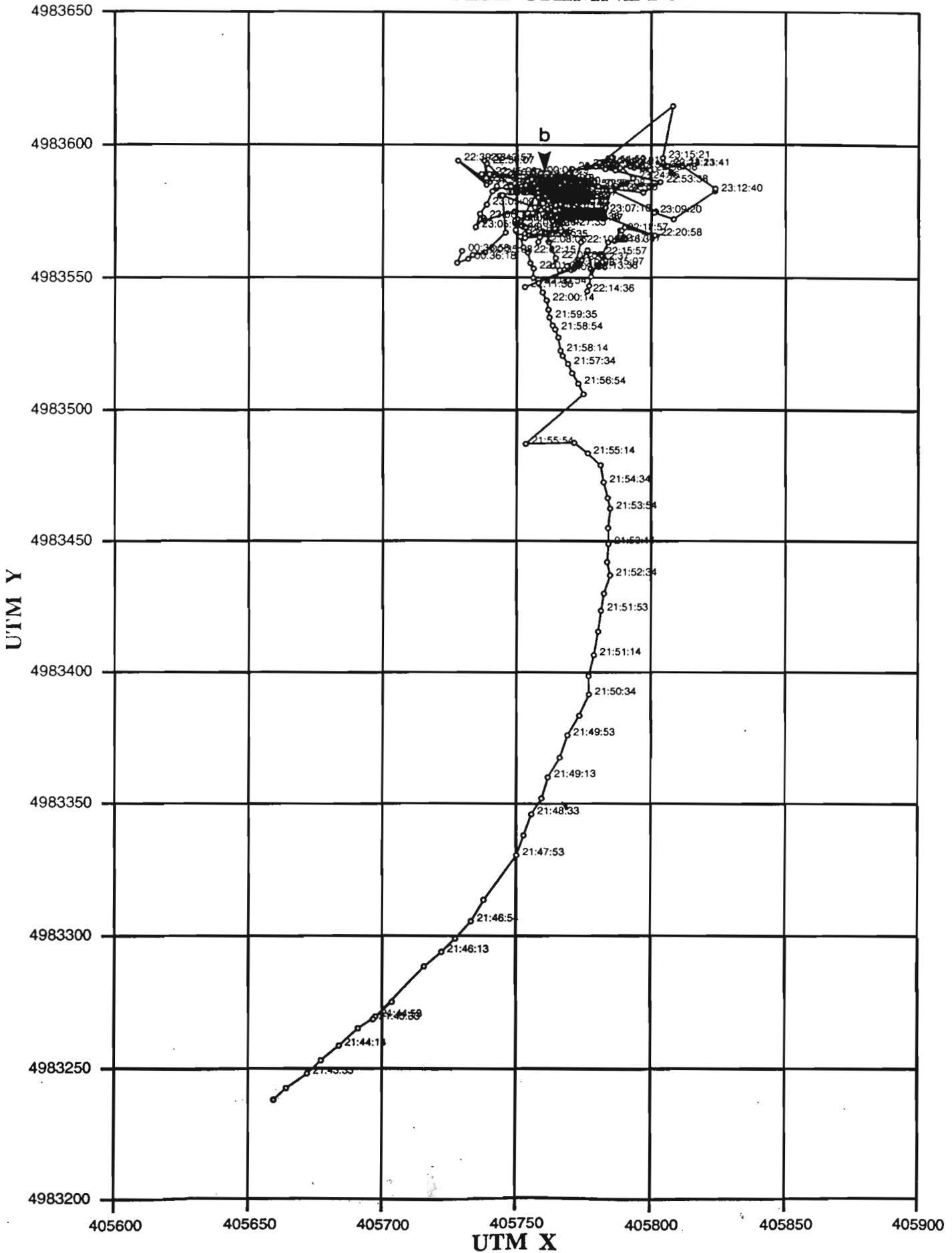


# HYS227 - ROPOS FOUNTAIN



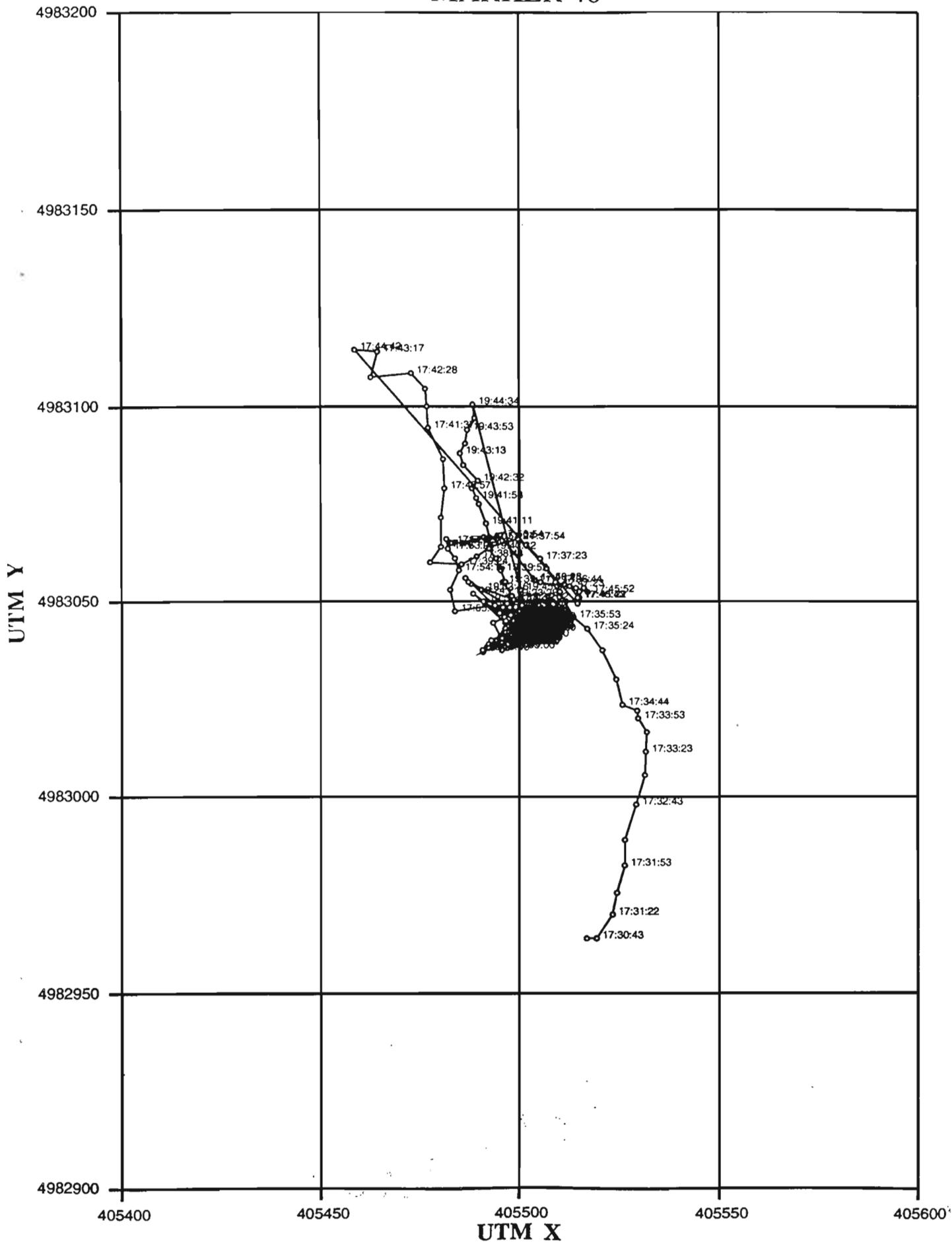


# HYS229 - ROPOS DEADFALL CHIMNEYS



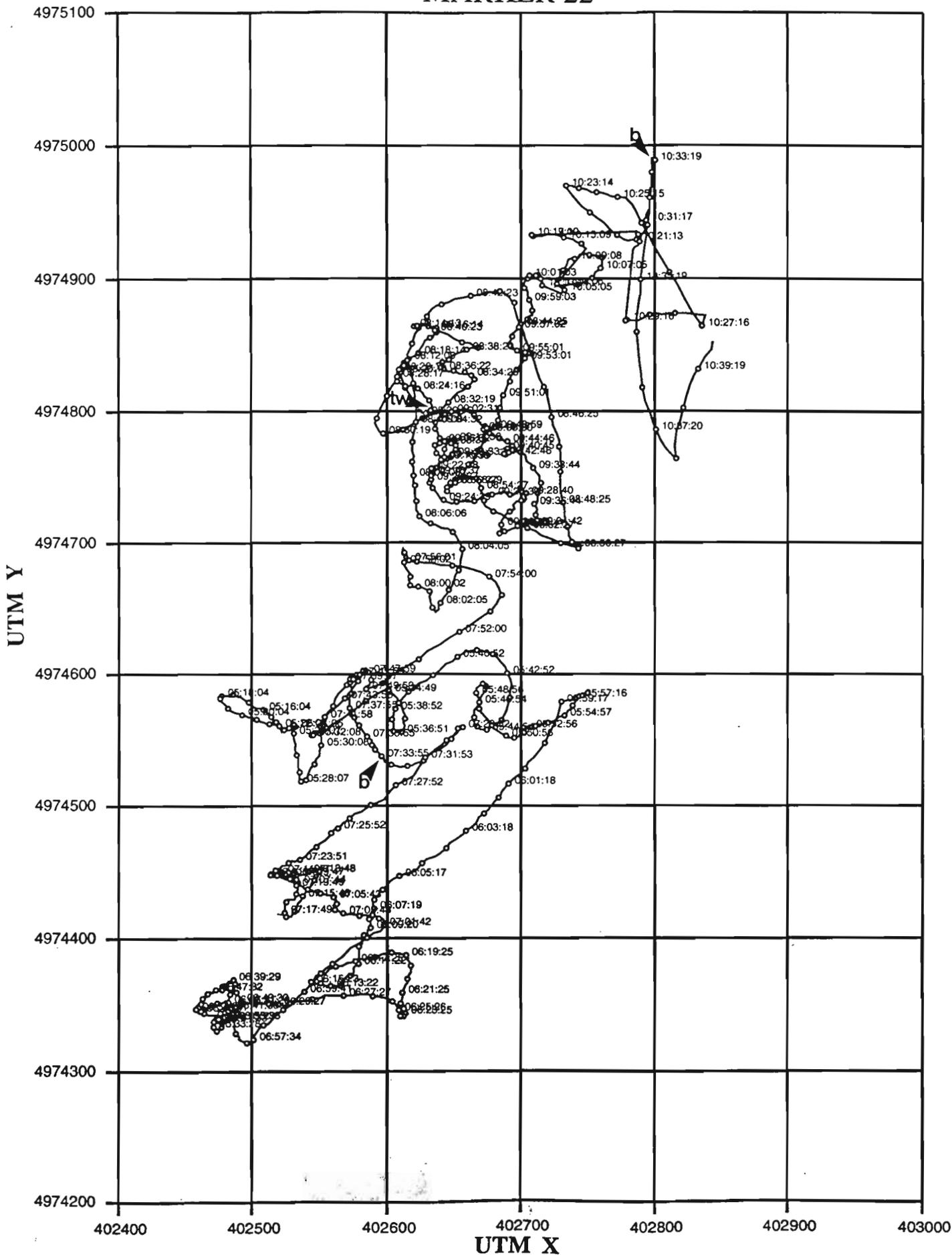
# HYS230 - ROPOS

## MARKER 46

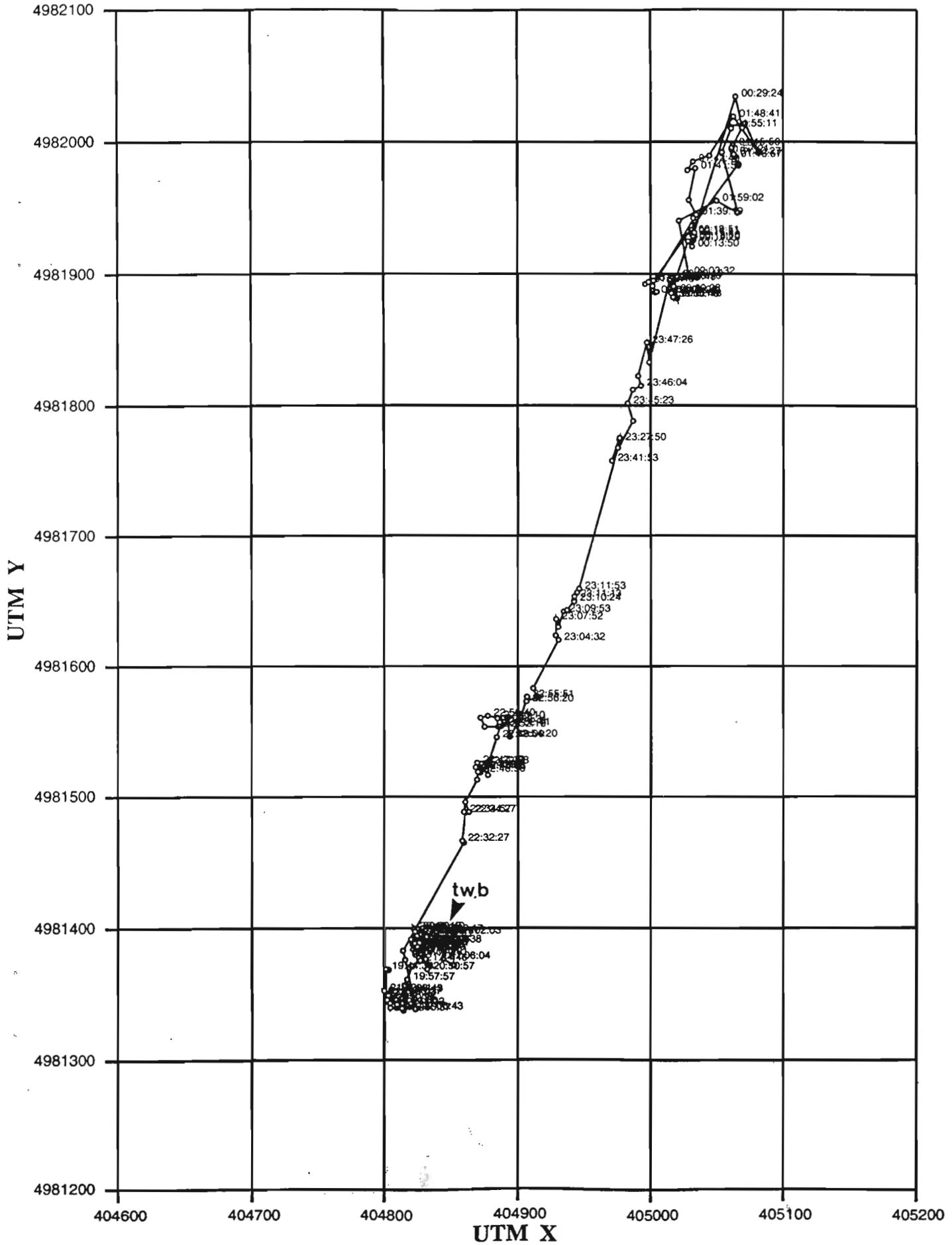


# HYS231 - SHIP

## MARKER 22

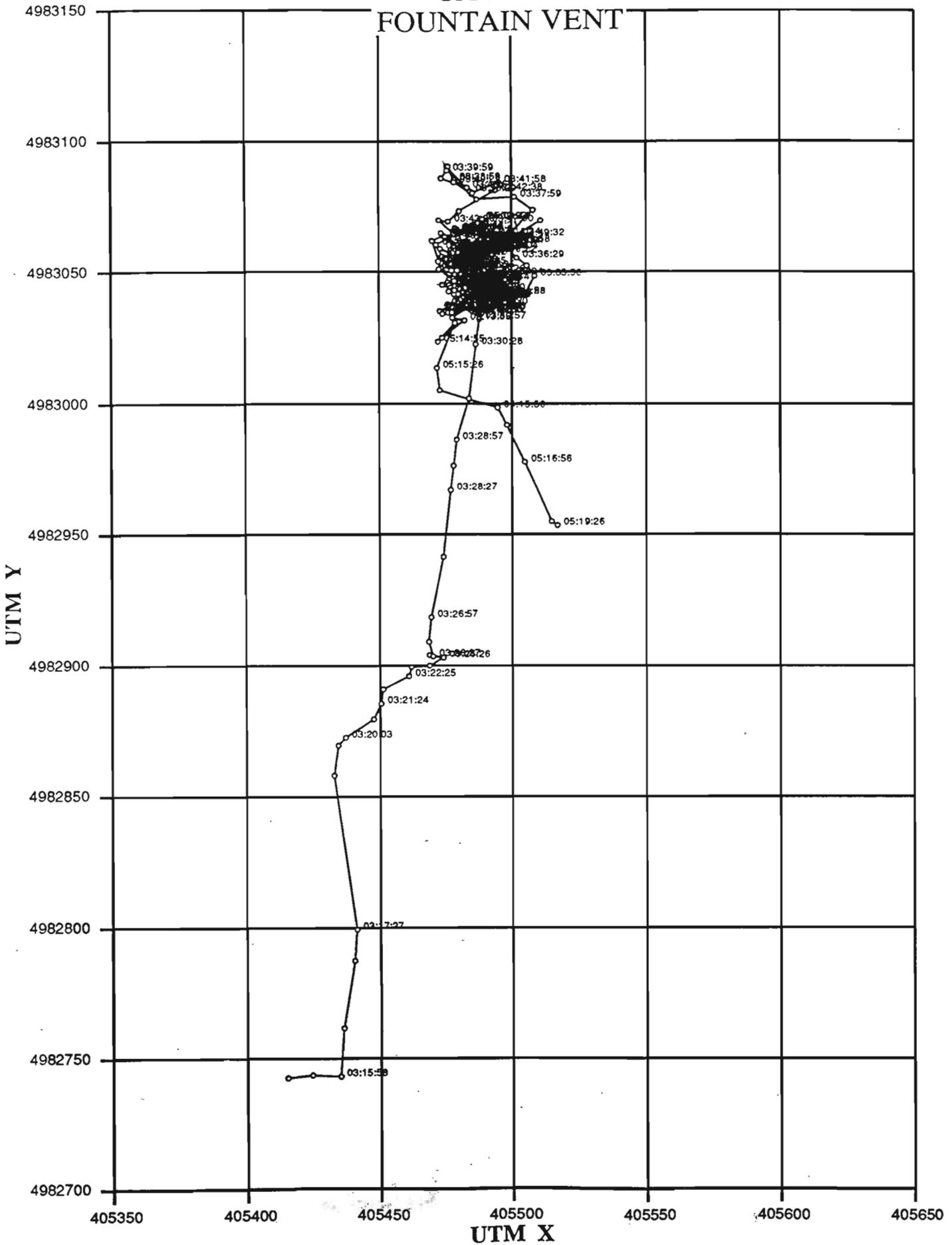


# HYS232 - ROPOS MARKER 4

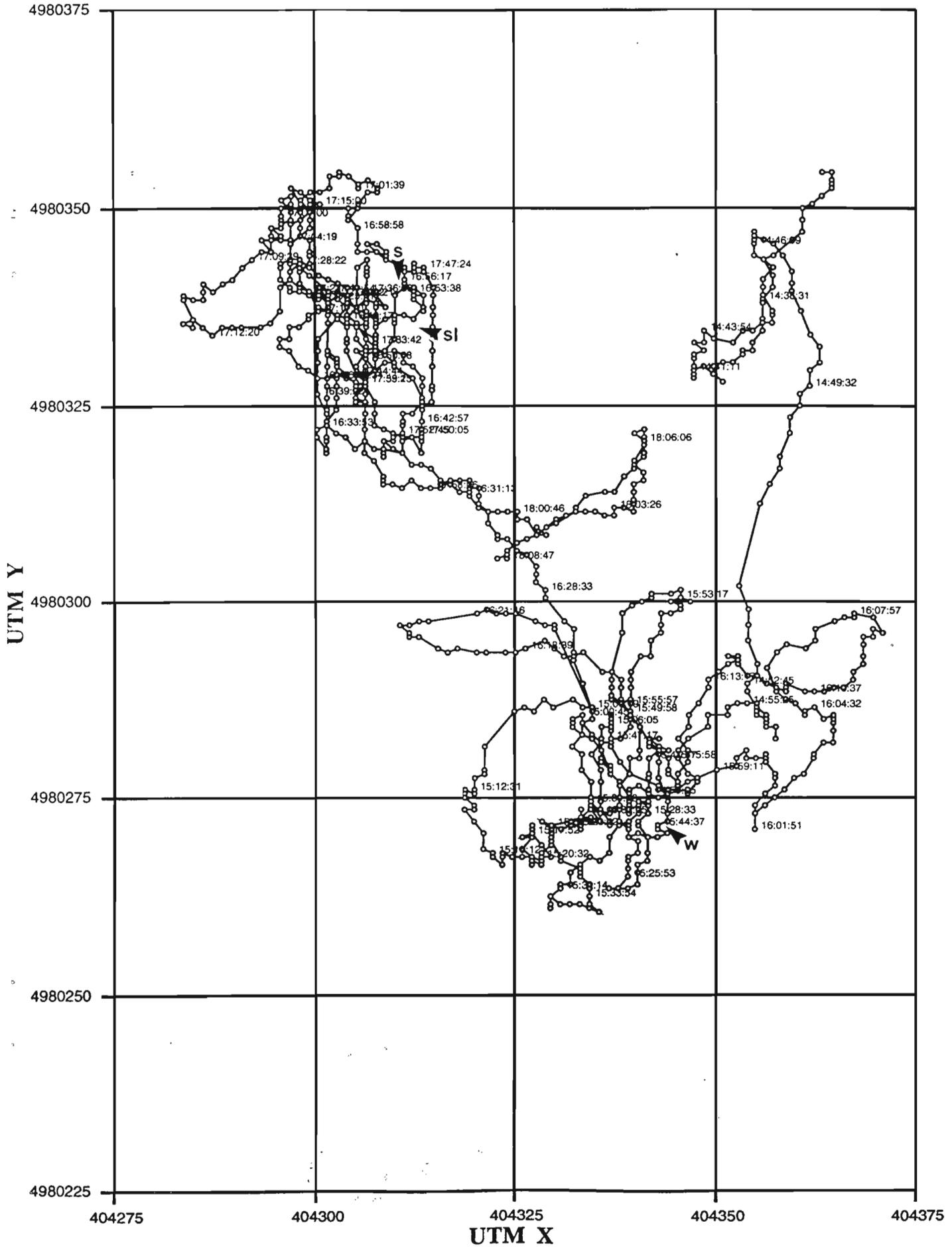


# HYS232 - ROPOS

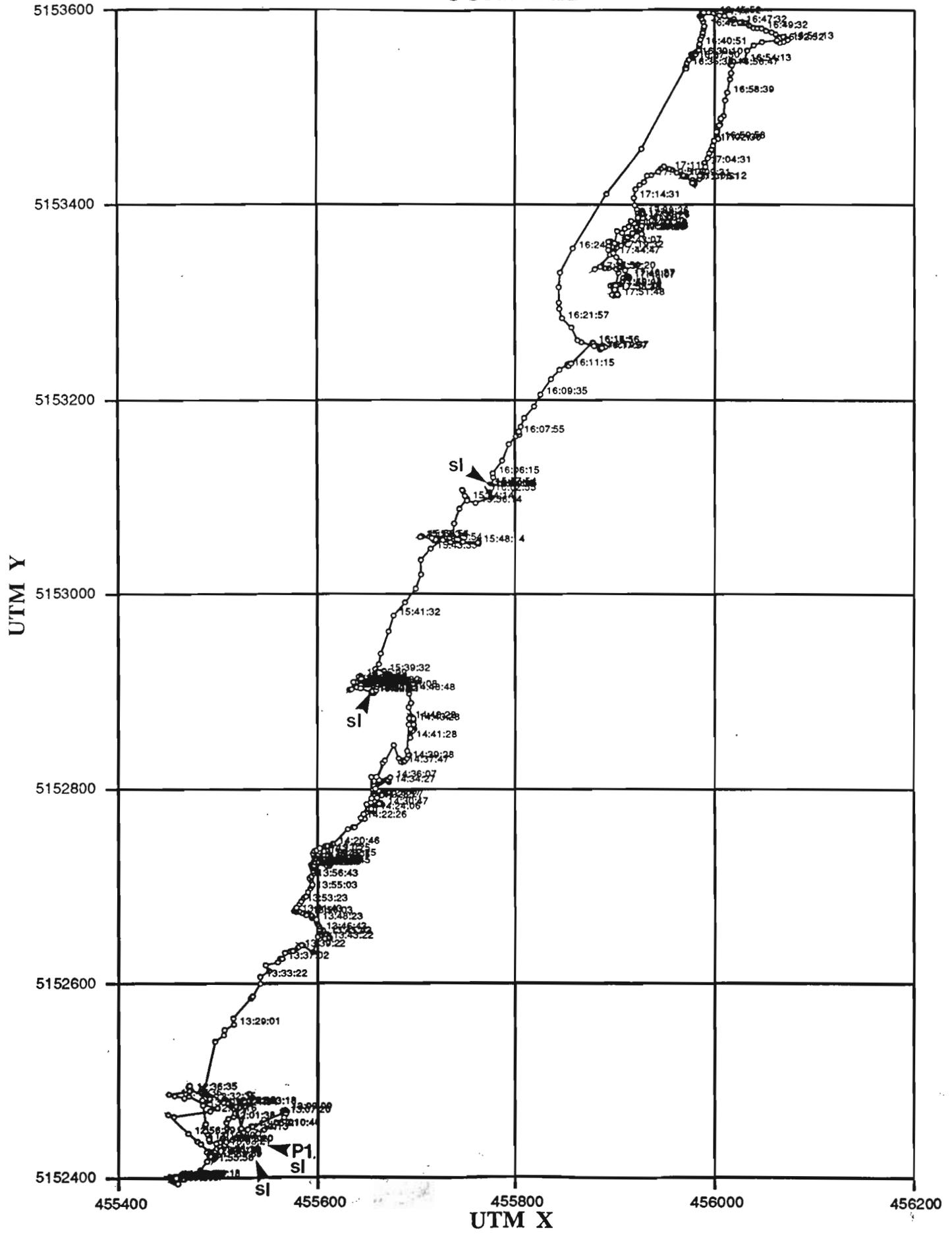
## CAVERN FOUNTAIN VENT



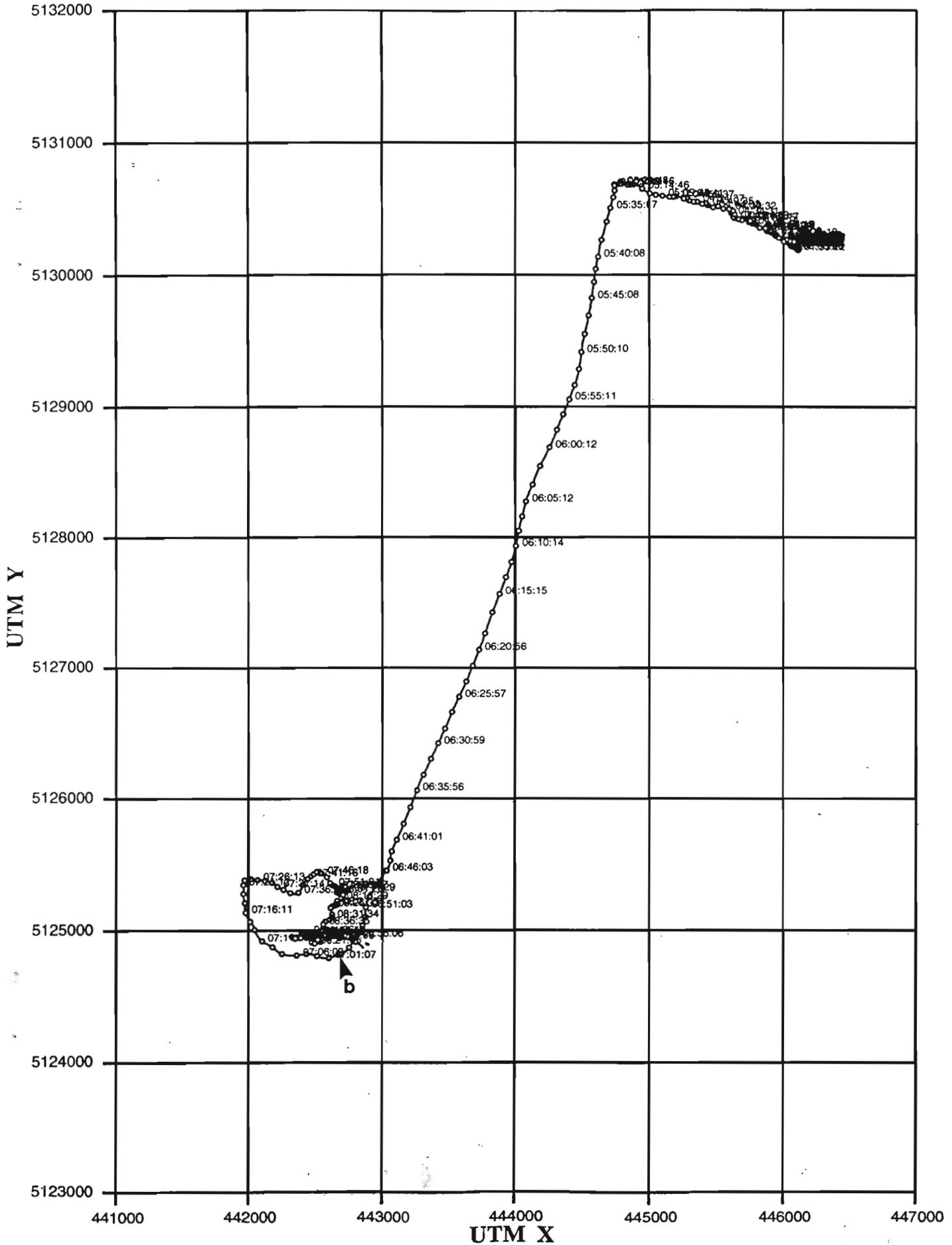
# HYS233 - SHIP PIPE ORGAN



# HYS234 - ROPOS COAXIAL



# HYS235 - SHIP



**TABLE 8: ROCK CORE STATIONS**

Rock Core Number	Latitude (°N)	Longitude (°W)
1	44°59.55'	130°12.73'
2	44°40.60'	130°23.34'
3	44°41.50'	130°20.70'
4	44°43.33'	130°19.92'
5a	44°46.52'	130°18.55'
5b	44°46.50'	130°18.60'
6a	44°48.20'	130°17.75'
6b	44°48.19'	130°17.73'
7	44°58.22'	130°14.63'
8a	44°58.01'	130°13.99'
8b	44°58.80'	130°13.98'
9a	44°57.80'	130°13.27'
9b	44°57.79'	130°13.32'
10a	44°57.60'	130°12.71'
10b	44°57.59'	130°12.69'
11	44°57.47'	130°11.88'
12a	44°57.26'	130°11.40'
12b	44°57.26'	130°11.40'
13a	44°57.08'	130°10.78'
13b	44°57.08'	130°10.77'
14	44°56.90'	130°10.18'
15a	44°59.01'	130°11.21'
15b	44°59.99'	130°11.21'
16a	44°44.91'	130°19.17'
16b	44°44.91'	130°19.11'
17a	44°49.37'	130°17.05'
17b	44°49.38'	130°17.03'
18	44°58.63'	130°10.03'
19a	44°58.80'	130°10.54'
19b	44°58.82'	130°10.55'
20a	44°59.71'	130°13.60'
20b	44°59.69'	130°13.61'
21	44°59.10'	130°11.65'
22	44°51.23'	130°16.31'
23	44°51.39'	130°16.39'
24a	44°52.50'	130°15.25'
24b	44°52.51'	130°15.26'
25	44°54.39'	130°14.36'
26a	44°56.92'	130°10.19'
26b	44°56.90'	130°10.19'
27a	44°58.51'	130° 9.30'
27b	44°58.51'	130° 9.31'

# ROCK CORE STATIONS

