MARIANA MOUNDS PRELIMINARY CRUISE REPORT

ATLANTIS II 118-16

JUNE 6-26, 1987

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SUMMARY

Advection of seawater through oceanic crust in free convection cells is thought to occur for millions of years after the formation of the crust at mid-ocean ridges. Most information about such convection comes from investigations of high heat flow "mounds" areas in the equatorial Pacific where rapidly accumulating biogenic sediments quickly bury the spreading center. Sampling and measurements conducted on a recent cruise with the submersible, ALVIN, were designed as a multidisciplinary study of off-axis hydrothermal convection in an area (18° 01-03'N; 144° 16-18'W) which is thinly covered with dominantly non-biogenic pelagic sediment. The area is on 3 MY old crust west of the Mariana Trough, the back-arc spreading center behind the Mariana arc-trench system.

Previous heat flow studies of the area suggested that advection of very warm waters was occurring in localized areas. The ALVIN diving program indicated that there was vertical advection associated with very high heat flow (up to 10 W/m^2) in several localized areas along a N-S trending ridge. The highest heat flow appears to be associated with faults which result in vertical offsets of the unconsolidated sediment of up to 5 m.

The morphological features associated with these areas of high heat flow are unlike the Mn-encrusted mounds and pillars to 10 m in height which are present in the Galapagos Mounds Area. The features of the Mariana Mounds hydrothermal area associated with high heat flow range from nearly perfect conical sediment mounds 1-2 m high, to pock-marked or "swiss cheese" mounds, the tops of which are riddled with holes, to hummocky features ~ 1 m high. There is some evidence that this sequence represents the evolution of the features with age. The highest heat flow occurs along semi-linear depressions about 10-20 m long. None of the features we observed had Mn-encrustations or carapaces. All of the conical and hummocky features consist of brown silty clay similar to that of the low heat flow areas. The linear depressions are generally filled with coarse sand and gravel deposits of semi-lithified sediment, Mn-crust fragments, abundant benthic forams and pteropods which appear to be a lag deposit left after fine sediment is removed by rapid vertical fluid flow.

Detailed heat flow surveys made from ALVIN of the individual types of constructional features and of the area in general suggest that the heat flow decreases nearly exponentially away from the center of the mounds fields. The mounds themselves have complex heat flow. For example, pock-marked mounds have highest heat flow with curved temperature gradients at their edges, and moderate heat flow with linear gradients in their centers.

Pore water profiles of major elements such as Ca and Mg, as well as profiles of nutrients such as NO_2, PO_3, SiO_2 also show evidence of systematic offsets due to fluid flow in areas of high heat flow.

Advective fluid flow through sediments should also result in excess pore fluid pressure, but previous experimental evidence for this has been equivocal. This aspect of hydrothermal circulation was examined in a series of *in situ* pore pressure measurements using the Institute of Oceanographic Sciences (IOS) Pop-Up-Pore-Pressure-Instrument (PUPPI). These measurements, the first in an area of high heat flow and chemical gradients, showed signficant vertical pore pressure gradients (>1000 mpas) in the mounds fields. In a unique experiment ALVIN deployed and connected a remote probe to a previously deployed PUPPI to determine whether the advective flow created a lateral gradient in pore pressure. The measurments showed a lateral gradient over a distance of ~ 25 m which decreased from the center of a mound group outward.

Little is known of how such convective systems vary on either short or long time scales, although many intuitive arguments could be cited to suggest that flow would be influenced by physical circulation effects such as tidal or inertial forces, or by tectonic events. In an effect to constrain the short term variability in flow we deployed a new heat flow monitoring instrument developed for the cruise by M. Yamano of the U. Tokyo Earthquake Research Institute (ERI). The instrument recorded hourly data from thermistors on 3 heat flow probes set in high, medium and low heat flow environments. Only the high heat flow probe showed fluctuations in temperature and heat flow.

None of the sediments collected by ALVIN or with conventional piston cores showed visible evidence of alteration or of accumulations of alteration minerals such as the nontronite gravels recovered from the Galapagos Mounds by ALVIN and by the Deep Sea Drilling Project Leg 70. This is in agreement with the hypothesis that such smectites were formed with the SiO_2 supplied from dissolving siliceous biogenic sediment. Such biogenic sediment is a very minor component of the Mariana mounds area sediments.

INTRODUCTION

The Mariana Mounds ALVIN cruise (R/V Atlantis II 118-16; June 6-26; Guam-Saipan) completed an intensive measurement and sampling program in an area located on ~3 million year old crust about 50 km west of the Mariana Trough spreading center (Fig. 1) which previous studies (Anderson, et al., 1981; Hobart, et al., 1983) had established had very high heat flow.

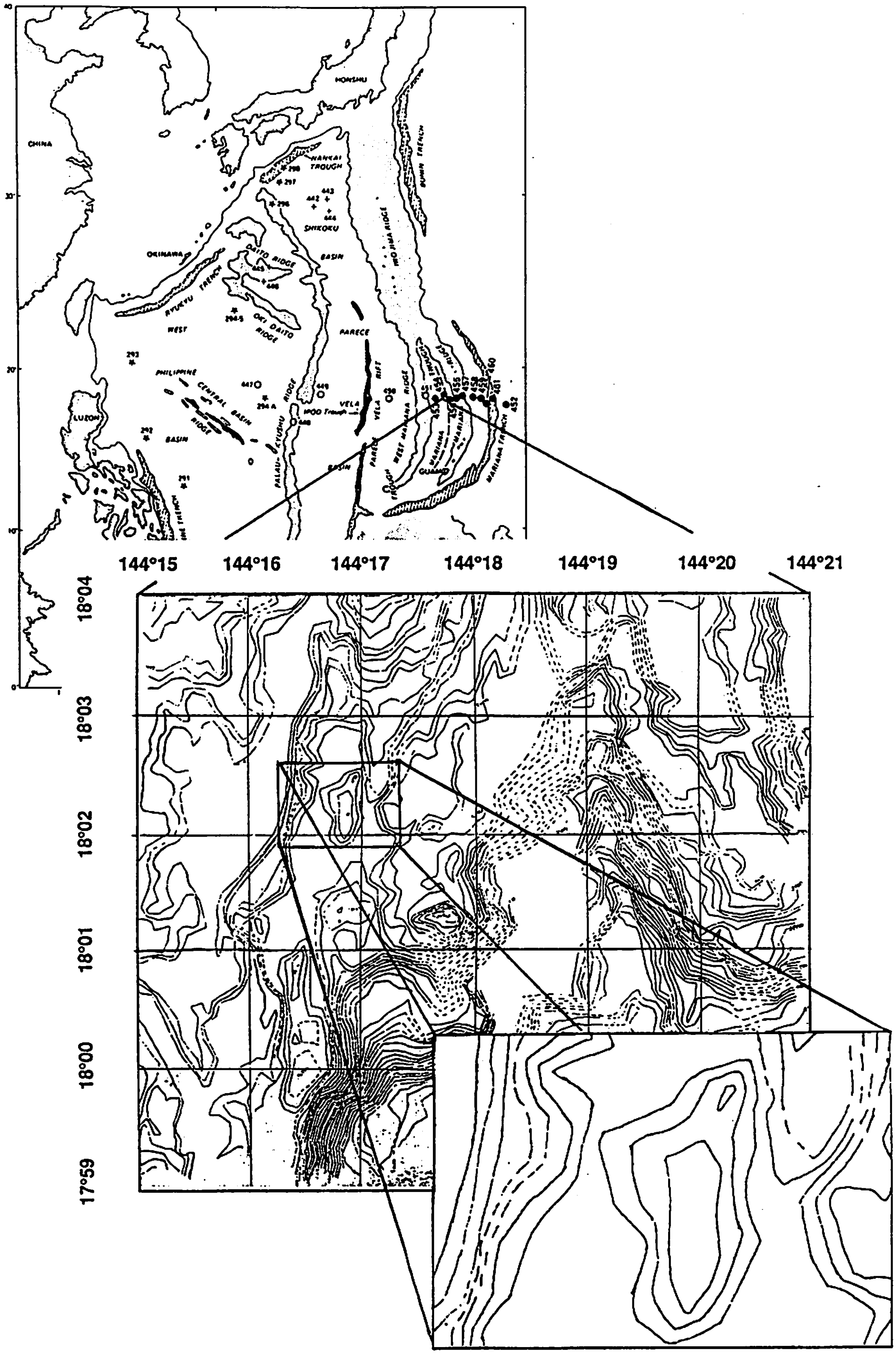
Our goals were:

1) to examine the morphology and geologic setting of features associated with the high heat flow region; and
2) to complete a sampling program which would allow us to characterize the hydrothermal system in the study area.

We proposed to do the latter by assessing the nature and physical properties of the underlying sediment, by measuring pore water compositon and gradients, by evaluating both regional and local gradients in heat flow, by determining the vertical and horizontal pore pressure gradients, and by assessing the temporal variability in heat flow.

The cruise combined conventional sampling and measurement techniques from ALVIN and from the ATLANTIS II with several innovative instrumental measurements, notably a horizontal assessment of *in situ* pore pressures using the Pop-up-Pore-Pressure-Instrument (PUPPI) developed at the Institute of Oceanographic Sciences (U.K.) and an assesment of short term temporal variability in heat flow using an *in situ* heat flow measuring instrument developed for this cruise by M. Yamano of the U. Tokyo Earthquake Research Institute. This study is a part of the cooperative U.S.-Japan Joint Program for submersible investigation of the western Pacific.

Fifteen ALVIN dives (#1863-1877) were completed during the cruise. A timeline of all operations during the cruise is shown in Table 1. In addition to geological observation and mapping, 46 push cores and 15 rock samples were collected and 85 heat flow measurements were made by ALVIN during this cruise. Fifteen piston cores, 3 gravity cores, 8 dredges, 5 multipenetration heat flow runs were completed from Atlantis II during evening and night operations and 6 *in situ* pore pressure measurements were made.



MARIANA MOUNDS AREA

Table 1. Timeline of Operations, Atlantis II-118-16, June 8-26, 1987

DY (HR 1–24)	Operations
8	Transit from Guam to Study Area
9	Transponder Survey
10	Heat Flow; ALVIN Dive 1863; Survey; PUPPI
11	Heat Flow; ALVIN Dive 1864; PUPPI; Dredge
12	ALVIN Dive 1865; Heat Flow; PUPPI
13	Piston Core; ALVIN Dive 1866; PUPPI; Dredge
14	Piston Core; ALVIN Dive 1867; Piston Core; Dredge
15	PUPPI; ALVIN Dive 1868; Dredge
16	Heat Flow; ALVIN Dive 1869; Gravity Core; Piston Core
17	Piston Core; Gravity Core; ALVIN dive 1870; Dredge
18	PUPPI; ALVIN Dive 1871; Piston Core
19	Heat Flow; PUPPI; ALVIN Dive 1872; Piston Core
20	Piston Core; Piston Core; ALVIN Dive 1873; Piston Core; Piston Core
21	Piston Core; ALVIN Dive 1874; PUPPI; Heat Flow; Dredge
22	Gravity Core; ALVIN Dive 1875; Piston Core; Piston Core
23	Piston Core; ALVIN Dive 1876; PUPPI; Dredge
24	Dredge; ALVIN Dive 1877; Transit from Study Area to Saipan
25	

PRELIMINARY CRUISE RESULTS

Dive Summary

A total of fifteen ALVIN dives were completed during AII-118-16. Dives 1863 and 1864 completed reconnaisance geological and heat flow surveys of the northern and eastern portion of the area of high heat flow (Figure 1, 3) identified by previous cruises (Anderson, et al., 1981; Hobart, et al., 1983). These dives identified a mounds field at the northern end of a N-S trending ridge. During dives 1865 and 1866, heat flow measurements and cores were taken in the northern mounds field. Dive 1868 completed heat flow studies in the northern mounds field and made a transect to the southern end of the ridge on which the mounds occurred. A second field of high heat flow mounds was found on this dive. Dives 1871, 1872, 1874-1877 focused on the southern mounds field, completing reconnaissance surveys and coring, as well as heat flow and pore pressure measurements.

Dive 1866 deployed the first long-term heat flow measuring instrument. This instrument was dropped into the area by free fall from the ship, relocated by ALVIN and three probes attached to the instrument by cables were deployed in various heat flow environments in the northern mounds area.

During dive 1870, the first horizontal pore pressure gradient experiment was successfully conducted by linking a PUPPI deployed several days earlier from the ship to a remote probe deployed by ALVIN. A second remote probe deployed by ALVIN was placed in an area of very high heat flow to measure pore pressure in the high flow rates observed in the area.

Dives 1867 and 1869 examined a steep scarp located south of the mounds field (Figs. 1, 3). A vertical sampling transect of the scarp between 3800-4000m was started during dive 1867; dive 1869 completed the vertical transect of this scarp (3600-3950m). A scarp to the northeast of the study area was surveyed and sampled during Dive 1873.

The ALVIN diving program indicated that there was vertical advection associated with very high heat flow (up to 10 W/m^2) in several localized areas along the N-S trending ridge shown in Figure 1. Many of the highest heat flow area appeared to be associated with faults which resulted in vertical offsets of the unconsolidated sediment by up to 5 m.

The morphological features associated with these area of high heat flow are unlike those found previously during exploration of the Galapagos Mounds Area, which were Mn-encrusted mounds and pillars up to 10 m in height. The Mariana Mounds high heat flow sites range from nearly perfect conical sediment mounds 1-2 m high, to pock-marked or "swiss cheese" mounds the tops of which are riddled with holes, to hummocky features ~ 1 m high. The highest heat flow occurs along semi-linear depressions that are 10-20 m long. None of these features had Mn-encrustations or carapaces. All of the conical and hummocky features consisted of brown silty clay similar to that of the low heat flow areas. The depressions were generally filled with coarse sand and gravel deposits of semi-lithified sediment, Mn-crust fragments and abundant benthic forams which appeared to be a lag deposit left after fine sediment was removed by rapid vertical fluid flow and/or current scour.

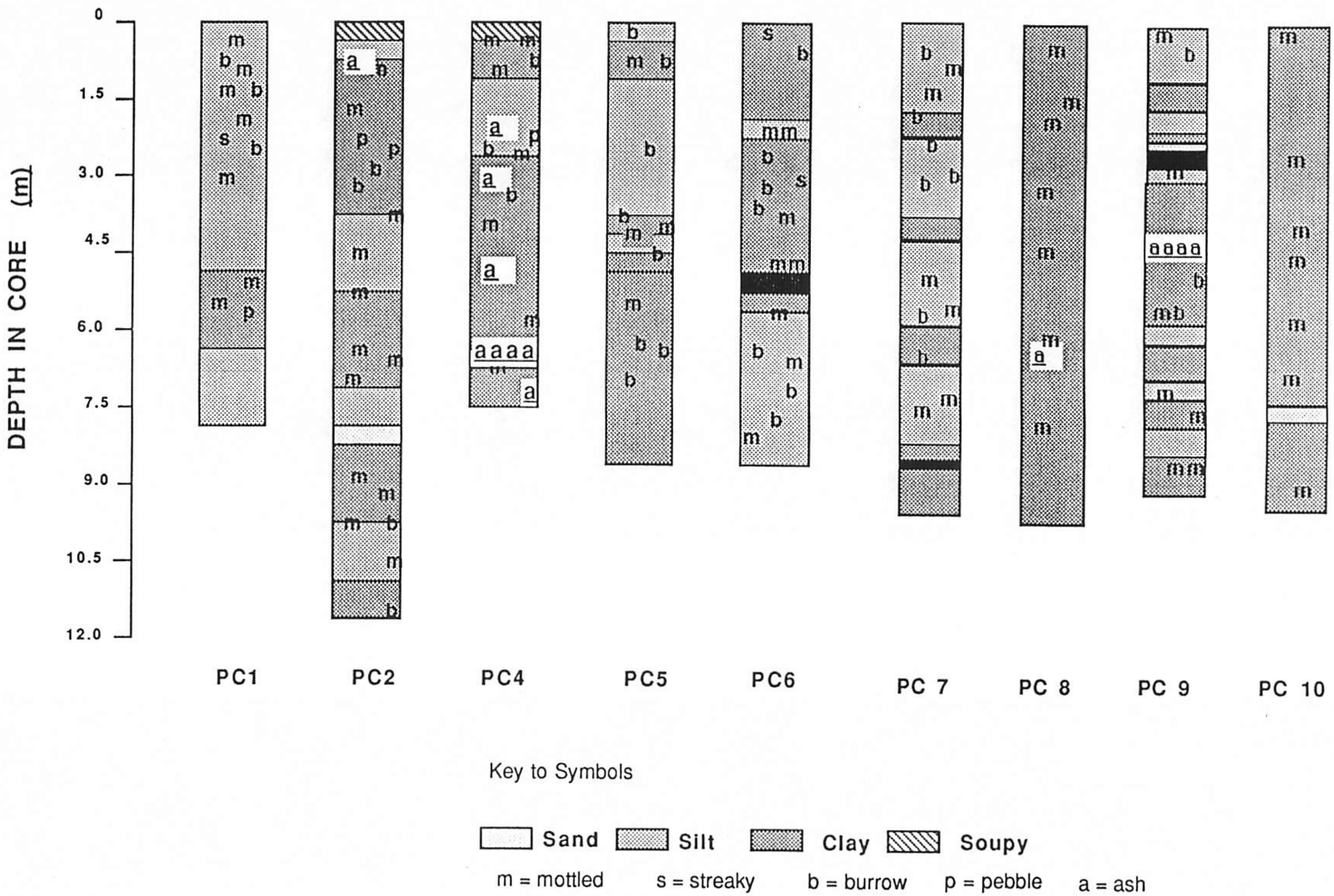
Biological observations were not an objective of the dive program, but several interesting observations were made. The most common bottom fauna in the Mariana Mounds area were holothurians, various stalked organisms (probably coelenterates) called "tulips" by the divers, rat-tail fish (of three types), and ophioroids. Within the high heat flow areas galatheid-type crabs were present, but never abundant. Most high heat flow areas were inhabited by three or four crabs. The highest heat flow areas had no tube worms, clams, shrimp, bacterial mats, or other organisms common to high temperature hydrothermal vents. White sediments observed in early dives and thought to be bacterial mat were actually very abundant benthonic foraminifera. In one linear depression with very high heat flow the sediment was a hash of large (up to 4 cm) pteropod (?) shells. Their abundance was far greater than in any other sediments from the region. No living organisms were present in this shell hash.

More detailed descriptions of individual dives are included in Appendix A. Survey lines of all ALVIN dives are shown in Figure 2; tracks of individual dives are included with the pertinent dive description in Appendix A.

Core Locations and Descriptions

During 118-16, a total of 26 cores were taken from the Atlantis II including 14 piston cores, 3 gravity cores and 9 trigger weight cores (Table 2, Fig. 4). All piston cores were equipped with heat flow thermistors.

Because the high heat flow areas were known to be very localized, we wanted to determine the exact location of piston cores with respect to other heat flow measurements and with respect to morphological features in the mounds area. To do this we used a special trigger weight corer equipped with a marking device. When the trigger weight corer touched bottom it deployed a marked weight attached to a 10' nylon line and numbered syntactic foam float. These floats made sonar targets for the submarine and were located by the submersible subsequent to coring. These observations also allowed the first evaluation of the disturbance of a


DEPTH IN CORE (m)
0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
PC1
PC2
PC4
PC5
PC6
PC 7
PC 8
PC 9
PC 10
Key to Symbols
Sand
Silt
Clay
Soupy
m = mottled
s = streaky
b = burrow
p = pebble
a = ash

core location by a piston coring device and the depth of overpenetration of the coring device.

All piston cores, gravity core #2 and trigger weight core #3 were sectioned and split at sea in order to complete physical property measurements. The cores were described and photographed.

Sediments recovered in the cores were dominantly silty clays ranging in color from yellowish brown to dark brown. They appear to be dominated by non-biogenic pelagic sediments, but contain some foraminifera. Most sediments are slightly to intensely burrowed. The cores penetrated 2 - 3 prominent very dark brown ash (?) layers and one layer of pumice fragments and pebbles. Preliminary summary descriptions of piston cores are shown in Figure 5. Complete core descriptions are included in Appendix B.

The cores were sampled for pore waters, mineralogy and geochemistry at 25 cm intervals and for bulk density and vane shear strength at 50 cm intervals. Vane shear and formation factor (resistivity) measurements were made at 25 cm intervals and water content samples were taken at the same sample depths as the resistivity measurements. Samples for consolidation testing and permeability measurements were taken at 150 cm intervals as whole core sections before splitting.

A total of 46 push cores were taken during ALVIN dives. The locations and lengths of all push cores are given in Table 3. (See also Figure 5). Several ALVIN cores were split, described, and sampled at sea (Table 3; Appendix B). The lithologies of these cores were very similar to the upper sections of the piston cores.

Pore Water Studies

The top sections of all trigger weight cores were sampled for interfacial pore water gradients at sea using a whole core squeezer. This sampler provides 30 sequential samples from the upper 3 cm of the core. Each sample is ~3ml in volume and represents ~1mm depth in the core. All ALVIN push cores for which squeezing of interfacial pore waters was appropriate (30 cores) were also processed.

Pore waters were also extracted from sediment samples taken every 25 cm downcore in the piston cores by centrifugation in a refrigerated van at temperatures of 2 to 4°C. All samples were analyzed for nutrients and a subset of samples were analyzed for alkalinity on board ship. Sealed ampules were prepared for analysis of alkalies, alkaline earths, transition elements, ∂O^{18} and Cl^- in the shore laboratory.

TABLE 3. ALVIN Push Core Log

CORE ID	LENGTH (cm)	X	Y	DEPTH (m)	SQUEEZED	CUT	DESCRIBED	NOTES
1863/C-1	50.0				*	*		
1864/C-1	7.7	6388	4368	3621	*	*		Hth depression
1865/C-1	18.0	6267	4285	3625	*	*		depression
1865/C-2	26.0	6267	4285	3625	*	*		depression with white sediment
1865/C-3	27.0	6310	4372	3625	*	*		"jello" sediment
1868/C-3	33.0				*		*	S. Mounds
1868/C-4	28.5				*	*	*	S. Mounds
1868/C-5	28.5				*	*	*	depression
1868/C-6	12.0	5857	3769	3634	*	*		Marker A, depression
1868/C-7	33.0	6247	4420	3607	*		*	rubble-filled depression
1868/C-8	33.0	6323	4402	3597	*		*	mound
1868/C-9	26.5	6319	4380	3611	*	*	*	depression
1868/C-10	28.8	6352	4365	3613	*	*	*	20m S Puppi 3
1868/C-11	28.8	6371	4438	3604	*	*	*	PUPPI 3
1870/C-1	26.0	6557	4383		*	*		P.C. Marker 6
1870/C-2	24.0	6557	4383		*	*		P.C. Marker 6
1871/A-1	26.0	6384	3851	3642	*	*		mounds cored on 1868(#3, #4)
1871/A-2	28.0	6454	3986	3637	*	*		white sediment
1871/A-3	8.0	6437	4029	3628	*	*		depression with high heat flow
1871/A-4	15.0	6437	4025	3627	*	*		depression with high heat flow
1872/C-1	18.5				*	*		
1872/C-2	27.0				*	*		
1872/C-3	31.0				*	*		
1872/C-7	23.0				*			
1872/C-8	27.0				*	*		
1872/C-9	31.0				*	*		
1872/C-10	28.0				*			
1874/C-1	25.0				*	*		top of mound
1874/C-3	7.0				*			remote probe site
1874/C-4	33.0				*			mound base
1874/C-5	25.5				*	*		halfway up mound
1874/C-6	28.0				*	*		PUPPI 6
1874/C-7	10.0				*			remote probe site
1875/C-1	33.0							
1875/C-2	29.0							
1875/C-3	24.5							
1875/C-4	24.0							
1876/C-1	33.0					*		PUPPI site
1876/C-2	7.0							hard surface
1877/C-								
1877/C-								
1877/C-								
1877/C-								
1877/C-								
1877/C-								

A comparison of the temperature patterns from heat flow measurements and preliminary analysis the data from the interfacial samples indicated upward advection is extremely focussed.

Heat Flow Studies

Heat flow was measured in four ways: 1) on multipenetration heat flow surveys completed using the U. Miami and U. Tokyo ERI heat flow probes; 2) at piston core locations using thermistors mounted on the piston corer; 3) using the 50 cm ALVIN heat flow probe; and 4) using 3 heat flow probes deployed from a long term heat flow measuring instrument.

Six multipenetration heat flow surveys were completed (19 stations; Table 4). These locations were chosen to fill in gaps in the extensive coverage provided by the earlier studies. The locations of heat flow measurements made during these surveys are shown in Figure 6.

Thirteen piston cores taken in the areas were equipped with thermistors to measure heat flow. These measurements indicated that at least two cores (PC 5 and 10) were taken in high heat flow areas, three cores (PC 2, 9 and 7) were taken in moderate heat flow areas, and five cores (PC 1, 8, 4, 6 and 3) were from low heat flow areas. These data were relative and exact heat flow values must be determined ashore. The data for two other cores could not be telemetered and will not be available until the core head recorder data are analyzed.

Detailed heat flow surveys made from ALVIN of the individual types of constructional features and of the area in general suggest that the heat flow decreases nearly exponentially away from the center of the mounds fields. The mounds themselves have complex heat flow profiles. For example, pock-marked mounds have curved temperature gradients with high heat flow at their edges, while they have linear temperature gradients with moderate heat flow in their centers.

A long-term heat flow monitoring system was developed for this cruise by Dr. M. Yamano of the U. Tokyo Earthquake Research Institute. This system was designed to investigate possible temporal variations in hydrothermal circulation and heat flow in the area. The instrument was deployed by free fall from the Atlantis II on June 12. A 7.5 KHz transponder was attached to a float on the instrument to make it easy to relocate the instrument on the bottom with ALVIN. During ALVIN dive 1866 (June 13), the system was located on the bottom (about 30 m from the center of the mounds field) and carried to a mound complex that had been surveyed using the ALVIN heat flow probe earlier (tagged with Marker B on Dive1865). Three heat flow probes attached to the instrument by 30 m cables were then inserted into specific features which had been surveyed previously. One

Table 4. Locations of multipenetration heat flow stations, AII-118-16

Date	Station	Lat. or X	Long. or Y	Depth (m)
6/10	1-1	18°02.04*	144°16.56	3750
	1-2	18°01.70	144°17.23	3650
	1-3	18°01.69	144°17.75	3640
	1-4	18°01.53	144°18.45	3595
6/11	2-1	5891	4261	3650
	2-2	7209	3951	3625
	2-3	7719	3884	3610
6/16	3-1	7865	3540	3540
	3-2	7882	3575	3575
	3-3	7980	3595	3595
	3-4	7556	3425	3605
	3-5	7300	3705	3600
	3-6	7465	4053	3600
6/18	4-1	6721	3006	3006
	4-2	4895	3153	3153
	4-3	5164	3489	3489
6/21	5-1	5442	4120	3730
	5-2		4004	3675
	5-3		4050	3670

*Loran C

TABLE 4. ALVIN Heat Flow Measurements

DIVE/HF#	Tape/Frame	X	Y	DEPTH (m)	T1	T2	T3	T4
1863/1-1	1/1800				1.456	1.566	1.581	1.502
1864/2-1	1/1550	6456	4075	3621				
1864/2-2	2/1500	6388	4368	3621				
1865/3-1	1/3650	6267	4285	3625	1.461	1.776	2.497	7.067
1865/3-2	2/1150	6337	4365	3623	1.447	2.089	3.794	5.257
1865/3-3	2/1600	6328	4360	3623	1.448	1.56	1.523	1.425
1865/3-4	2/2100	6310	4372	3622	1.442	1.667	2.107	2.387
1865/3-5	2/3200	6270	4380	3618	1.442	1.62	1.611	1.552
1865/3-6	2/3900	6220	4399	3610	1.443	1.574	1.684	1.567
1865/3-7	3/1150			3620				
1865/3-8	3/3000			3630	1.445	1.548	1.579	1.55
1866/4-1	2/3800	6300	3616	3626	1.448	1.546	1.692	1.828
1866/4-2	3/800	6300	3616	3626				
1866/4-3	3/1800	6300	3616	3525				
1866/4-4	3/3000							
1868/6-1		6371	4438	3604				
1868/6-2		6352	4365	3613				
1868/6-3		6319	4380	3611				
1868/6-4		6323	4402	3597				
1868/6-5		6247	4420	3607				
1868/6-6		5857	3769	3634				
1868/6-7								
1868/6-8								
1870/8-1	2/1250	6343	4405	3610	1.43	1.555	1.538	1.437
1870/8-2	2/2350	6296	4405	3614	1.442	1.553	1.502	1.421
1870/8-3	2/3200				1.45	1.617	1.78	1.919
1870/8-4	3-2300				1.466	1.557	1.584	1.439
1871/9-1	1/1950	6381	3871	3655				
1871/9-2	1/2450	6384	3851	3642				
1871/9-3	2/1300	6454	3986	3637				
1871/9-4	2/2450	6437	4029	3628				
1871/9-5	2/3200	6437	4025	3627	1.55	2.26	8.63	9.09
1872/10-1		6430	4032	3623				
1872/10-2								
1872/10-3		6419	4035	3639				
1872/10-4		6412	4028	3647				
1872/10-5		6549	4168	3654				
1872/10-6		6552	4788					

Table 5. Locations of *in situ* heat flow monitoring instrument (Yamano Probe)

Event	X Co-ordinate	Y Co-ordinate	Depth (m)
Initial deployment	6332	4370	3635
Sited on seafloor	6371	4376	3627
Moved to final site	6300	4347	3616

probe was inserted in the top of the Marker B mound, the other two probes at points about 5m and 20m away from the mound. The three probes were expected to record high, medium and low heat flow, based on the results of the ALVIN heat flow measurements. At the end of the 10 day deployment the heat flow in each of the mounds was determined using the ALVIN heat flow probe to provide an inter-calibration. A push core was taken in each of the mounds in order to provide samples for thermal conductivity measurements. The heat flow measuring instrument was then recovered with an acoustic release system. The instrument recorded temperatures in an EPROM at a preset time interval. On this cruise, temperatures were measured every hour at 11 thermistors installed in the three 1m-long probes and at one bottom temperature sensor on the instrument. A preliminary analysis of the time series data indicates that temperatures at two thermistors on the heat flow probe in the Marker B mound varied by 0.15 and 0.29°C. This variation may be a natural one or it may represent the effect of probe penetration on the ambient hydrothermal pattern. Temperatures at the other two stations were very stable.

Pop-up Pore Pressure Instrument (PUPPI) Deployments

The objective of the Pop-Up Pore Pressure Instrument (PUPPI) program was to determine differential pore pressure in and around the mounds field accurately and to use this data to estimate the nature of any pore water advection in the area. To achieve this objective 6 PUPPI deployments were made using three instruments. PUPPI station 3 was in the northern mounds field, PUPPI stations 1 and 2 were about 100 m outside of this field. PUPPI stations 4, 5 and 6 were in and near the southern mounds field (Fig. 7, Table 6).

PUPPI's 1, 2, 4, and 5 were rigged with pressure transducers at both the two and four meter ports connected to measure the vertical differential pore pressure. The probes were rigged with glass spheres for flotation and were recalled after 3-4 day deployments with an acoutic release.

PUPPI's 3 and 6 were rigged with syntactic foam instead of glass spheres in order to allow ALVIN to approach the instruments on the sea floor and for each each probe make a hydraulic connection to a 3 meter long remote probe. These remote probes were carried to the seafloor by ALVIN which released them from a height of 11 m above a chosen target on the sea floor. In this way PUPPI 3 measured the lateral pressure gradient over a distance of about 11 m and PUPPI 6 measured the vertical pressure gradient at a specific target.

PUPPI 3 was dropped into the northern mounds field by free fall and landed about 20 m away from the Yamano heat flow measuring instrument. The 77 lb, 3 m remote probe for PUPPI 3 was deployed from ALVIN on Dive 1870. After locating and marking the target with a syntactic foam float on an

Table 6. Locations of PUPPI drop co-ordinates and locations, AII 118 - 16.

Station #	Drop Co-ordinate	Located	Depth (m)
1	6493, 4462		
2	6200, 4570		
3	6368, 4371	6345, 4378	
4	6436, 3832	6434, 3902	
5	6337, 3878	6348, 3925	
6	6430, 4005	6446, 4005	

11 m tether, ALVIN unwrapped 25 m of nylon hydraulic pipe from the host (PUPPI 3) and made a connection between the pipe and the remote probe. The submersible then rose to the altitude of the float and dropped the remote probe, which penetrated 2.5 m into the sediment. The results of this experiment indicated that PUPPI 3 and its remote probe were deployed in an area of significant vertical pore pressure gradients indicating upward pore water advection. The horizontal gradient indicated lateral flow outward from the mounds area.

PUPPI 6 was dropped into the southern mounds field by free fall and landed about 15 m away from a very high heat flow area surveyed on previous dives. The 3 m remote probe for PUPPI 6 was deployed from ALVIN on dive 1874. The target for the remote probe was a depression alongside a fault in sediments with a 3 m scarp. The depression had heat flow in excess of 10 W/m^2 and vertical advection sufficient to keep coarse sand-sized sediment suspended in mud "volcanoes". After marking the target the probe was dropped from 11 m, the same altitude as the remote probe for PUPPI 3. The probe penetrated only 30 cm into the sediment but remained vertical. On Dive 1876 the probe was pulled out of the sediment and redeployed into a pock-marked mound about 10 m away from the original remote probe location in an effort to get full penetration of the probe. The probe penetrated about 40 cm into the pock-marked mound. PUPPI 6 recorded very significant vertical pressure gradients indicating significant upward flow of pore water. The data for the remote probe insertions was too complex to analyze at sea.

Dredging

Figure 8 shows the tracklines of dreging surveys completed during this cruise. Table 7 shows the locations of all samples acquired during dredging operations. All dredged rocks recovered from the area were manganese coated pumice except those recovered on Dredge 7, which were greenstones.

ACKNOWLEDGEMENTS

A large measure of the success of this cruise was due to the assistance of the ALVIN group and the very capable crew of the Atlantis-II. We would particularly like to thank the Captain, Paul Howland, the Expedition Leader, Ralph Hollis, and the bosun, Craig Dickson. The cruise was funded by the National Science Foundation through grant #OCE86-00822 to Margaret Leinen.

Table 7. Locations of dredge stations, AII - 118 - 16.

Station #	Latitude	Longitude	Depth (m)	Recovery
1	17° 59'	144° 17'	4130-3700	Mn crust
2	17° 59'	144° 17'	4130-3600	Pumice
3	18° 05'	144° 22'	4390-3300	Lithified Sediments
4	18° 05'	144° 22'	4390-3600	Lithified Sediments
5	17° 59'	144° 18'	4130-3700	No rocks
6	18° 05'	144° 22'	4390-3600	Greenstones
7	18° 01.5'	144° 21'	4200-3600	None, hooked wire (?)

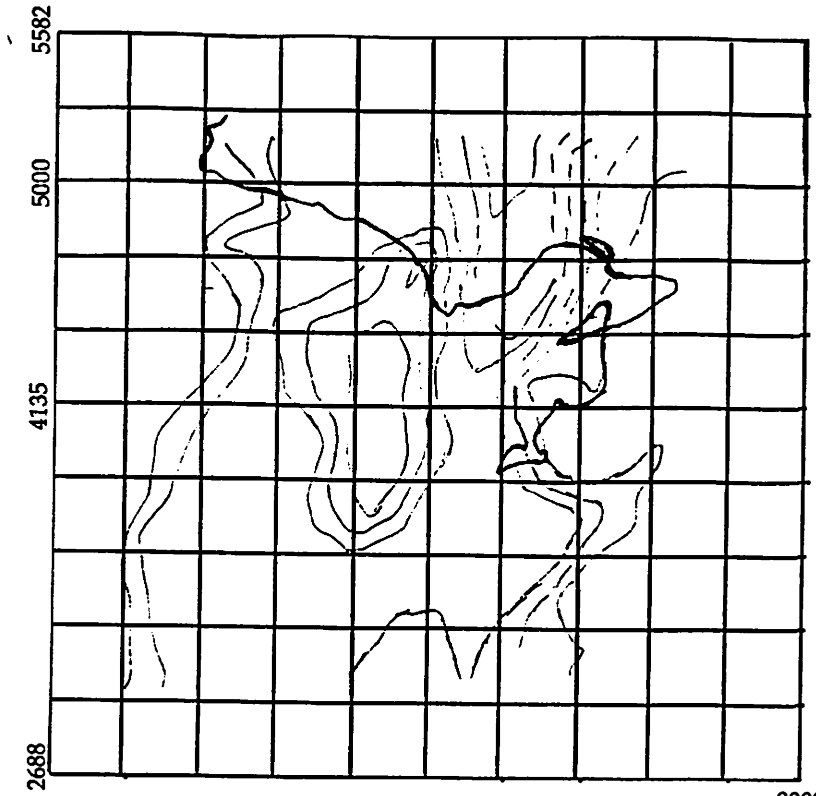
REFERENCES

Anderson, R.A., Hobart, M.A. and Uyeda, S., 1981, Heat flow and hydrothermal convection in the oceanic crust of the Marianas Trough, American Geophysical Union, Chapman Conference.

Hobart, M.A., Anderson, R.N., Fujii, N. and Uyeda, S., 1983, Heat flow from hydrothermal mounds in two million year old crust of the Mariana Trough which exceeds two watts per meter, EOS, Trans. Am. Geophys. Union, 64: 315.

Lonsdale, P. and Hawkins, J., 1985, Silicic volcanism at an off-axis geothermal field in the Mariana Trough back-arc basin, Geol. Soc. Amer. Bull., 96: 940-951.

APPENDIX A. DESCRIPTION OF INDIVIDUAL DIVES



Dive Track During ALVIN Dive 1863

ALVIN DIVE 1863
June 10, 1987

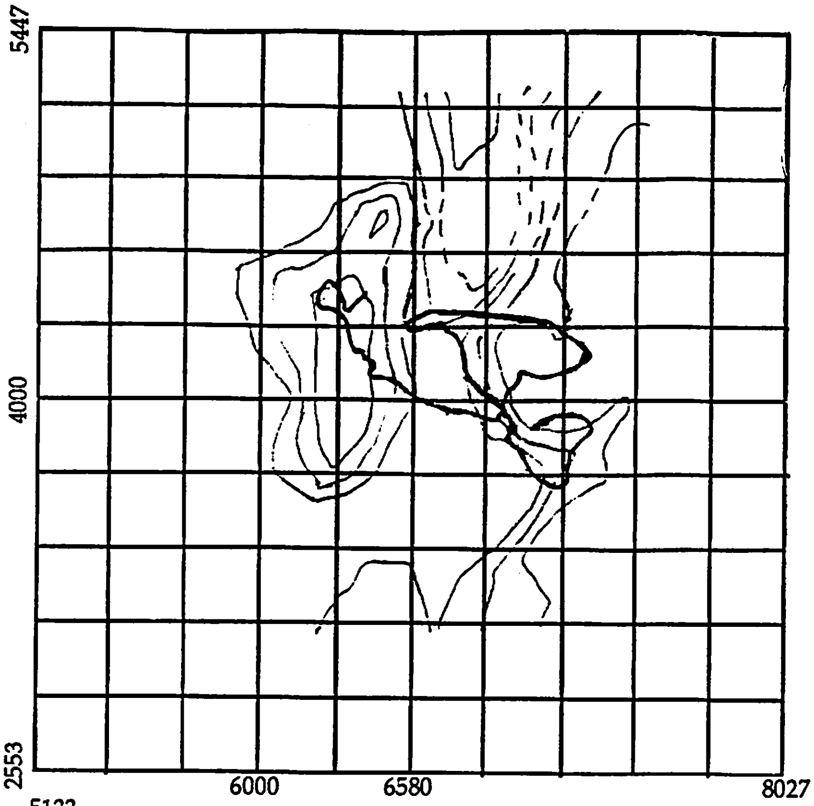
Pilot: D. Gleason
Observers: M. Leinen
R. McDuff

Goal: Initial survey of Mounds Study Area (initial target: 6898x, 3942y)

Samples:
1 push core
1 heat flow

Observors Comments:

On arriving at the seafloor, a reference heat flow and push core were taken (x=6920, y=4140). Reconnaisance of the area followed. "Normal" seafloor is a brown mud with abundant evidence of reworking by burrowing organisms. Reworking is evident in the form of small (1-3 cm), porous, dark brown concretions which litter the surface (typically 25/m^2). Also, halos of dark material, with typical diameters of ~10 cm, with a central burrow (occaisionally occupied) were common (1/100m^2). We noted several small hummocky mounds, but our initial impression was that they were not hydrothermal features. The entire area was sediment-covered, with slopes that were up to 45°. Small scarps were present which offset sediments by about 3-5 m.



Dive Track During ALVIN Dive 1864

ALVIN DIVE 1864
June 11, 1987

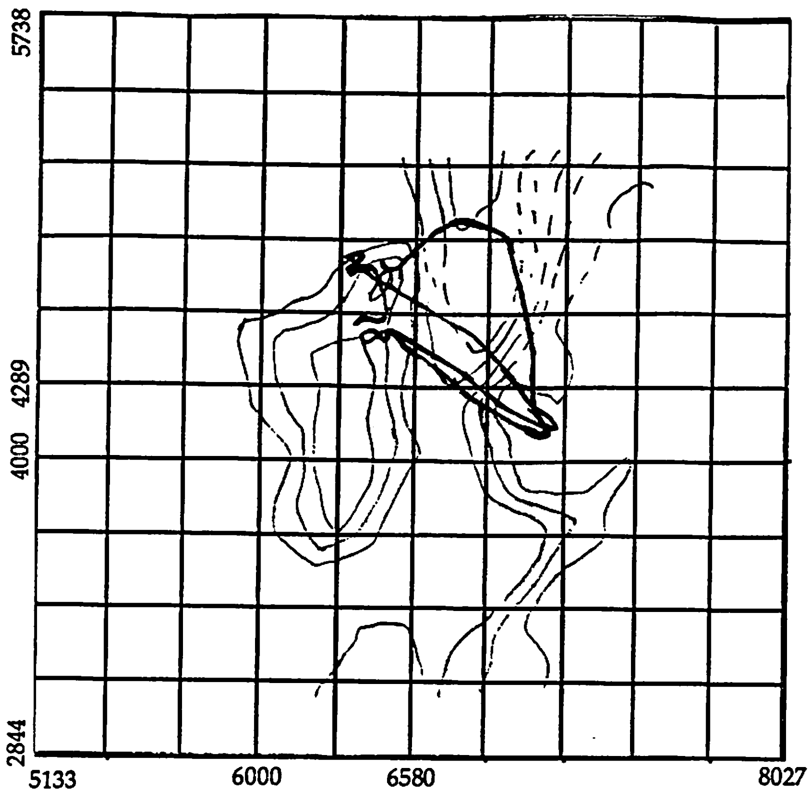
Pilot: R. Hollis
Observors: K. Becker
K. Dadey

Goal: Survey of northern Mounds Area; complete a series of heat flow measurements

Samples:
1 push core
2 heat flow

Observors Comments:

From the initial target, 6400x, 4000y, our survey proceeded to the west. At a small "outcrop", <1m in height, we stopped to take what we thought would be a rock sample and a heat flow measurement. These were done about 50cm from the top of the outcrop. The sample fell apart as it was taken; it appeared to be a crumbly, unlithified sediment. We continued our transect WNW over a knoll, turning left to follow the 3620m contour. After circum-navigating the shallow northeast section of the knoll, we turned toward our next target (6990x, 4000y). Continuing on this eastward course, we noted a 10m long depression, formed of several smaller depressions joined together. This depression contained gravel-sized sediment fill. There were 2 galatheid crabs in the depression. Several small mounds or hummocks were noted in the larger 10m long depression. A second heat flow station was completed here. Full penetration of the heat flow probe was impossible as there was a hard crust underlying the depression at 30cm depth. Maximum temperature recorded on the lowest thermistor was 7.424°C, 6°C higher than ambient. A push core sample was taken in this depression and a marker, A, was set at this location (6374,x, 4344y).



Dive Track During ALVIN Dive 1865

ALVIN DIVE 1865
June 12, 1987

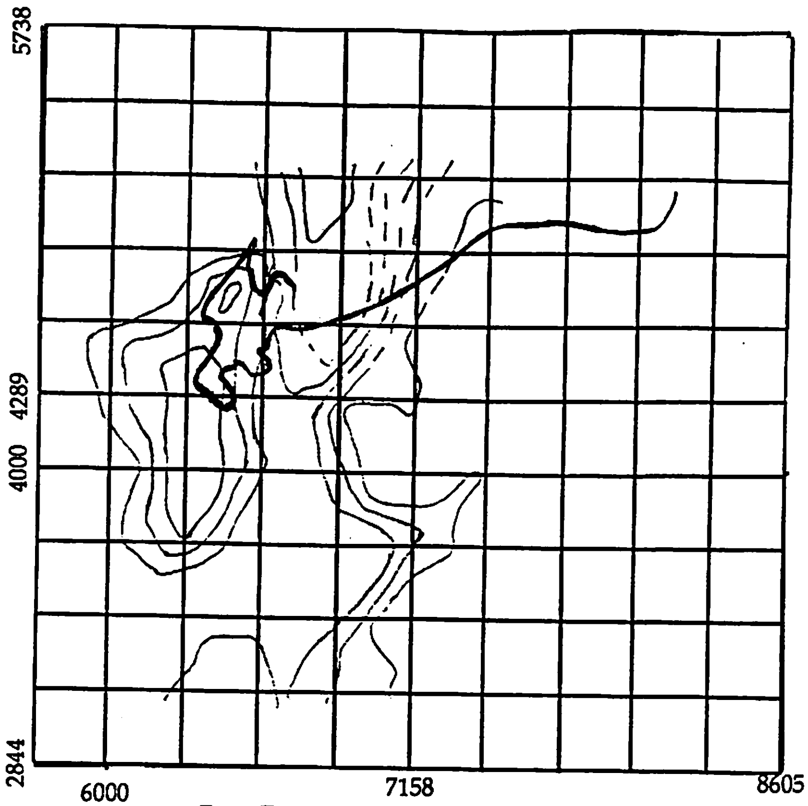
Pilot: P. Tibbetts
Observors: M. Leinen
G. Wheat

Goal: Continue survey of northern Mounds Field

Measurements:
3 push cores
8 heat flow

Observer Comments:

We surveyed the extent of the mounds discovered on the previous dive by circling the mounds features while keeping them in sight on one side of the submersible. We found that the field was approximately 100 m wide and 200 m long. Within it there were several types of hydrothermal features including conical mounds, conical mounds with eroded or cratered tops, cratered mounds with pock markings, irregular hummocks, and depressions. A heat flow survey consisting of 7 measurements made at increasing distances from the depression marked "A" during the previous dive indicated a roughly exponential decrease in heat flow outward from the depression.



Dive Track During ALVIN Dive 1866

ALVIN DIVE 1866
JUNE 13, 1987

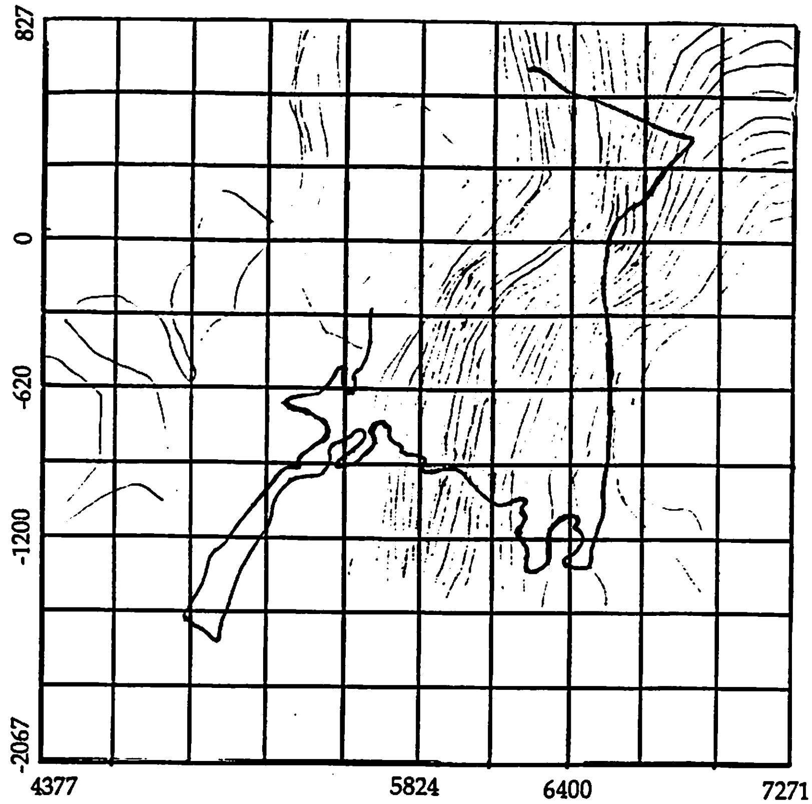
Pilot: D. Foster
Observors: K. Becker
M. Yamano

Goals: Collect a deep water sample; find and deploy the long-term heat flow monitor; locate PUPPIs 1 and 2 and Core Marker 2

Measurements:
4 heat flow
1 rock sample

Observors Comments:

On reaching the bottom, a water sample was taken (depth 3632m; 6475x, 4483y) to serve as a reference for pore water measurements. We next located the long-term heat flow measuring instrument, which had been deployed from the ship. It was located about 50 m from the mounds field. The instrument was moved into the field and was deployed 2.5 m from marker "B", with the main instrument placed 5 m from a small mound. The first probe was inserted immediately adjacent to the instrument. The second probe was inserted 25 m away from the instrument on a bearing of 270°. It was located in an area of normal (non-mound) sediment. The third probe was inserted in a small (<0.5m diameter) mound next to marker "B". Heat flow measurements were made at the first and second probe positions, with gradients of 0.6-0.8 W/m^2 at probe 1 and 0.1-0.2 W/m^2 at probe 2. PUPPI probes were also located, however, because they had glass sphere floatation, they could not be approached with the submarine. A scarp forming an outcrop 2-4 m high was sampled which was composed of sediment and Mn crust.



Dive Track During ALVIN Dive 1867

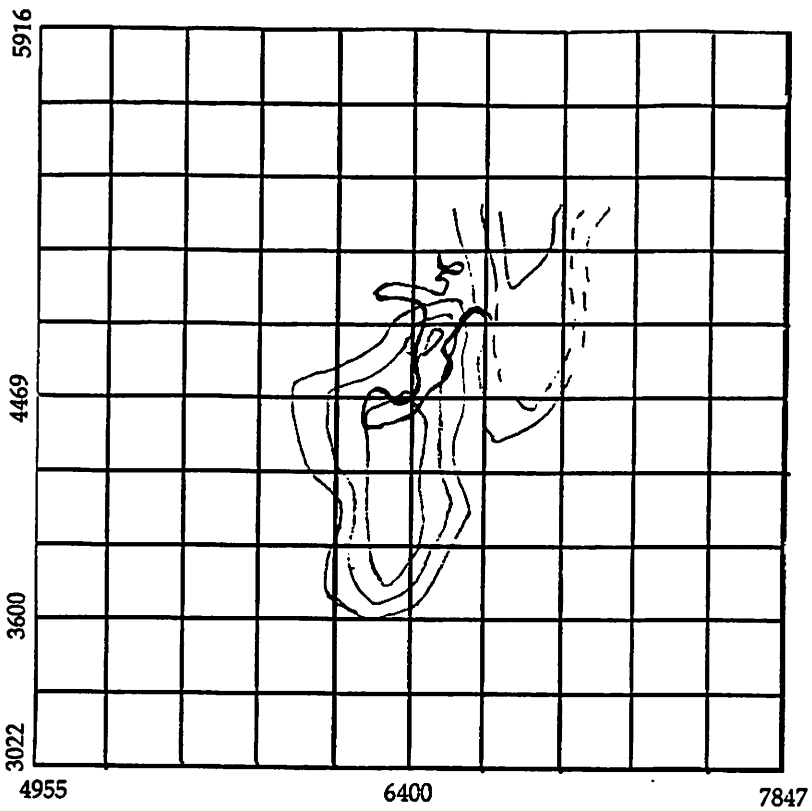
ALVIN DIVE 1867
June 14, 1987

Pilot: D. Gleason
Observors: J. Delaney
pilot trainee

Goals: Begin vertical survey of steep scarp at southwest corner of the re-entrant valley in the area

Samples:
7 rocks

Observors Comments:



Dive Track During ALVIN Dive 1868

ALVIN DIVE 1868
June 15, 1987

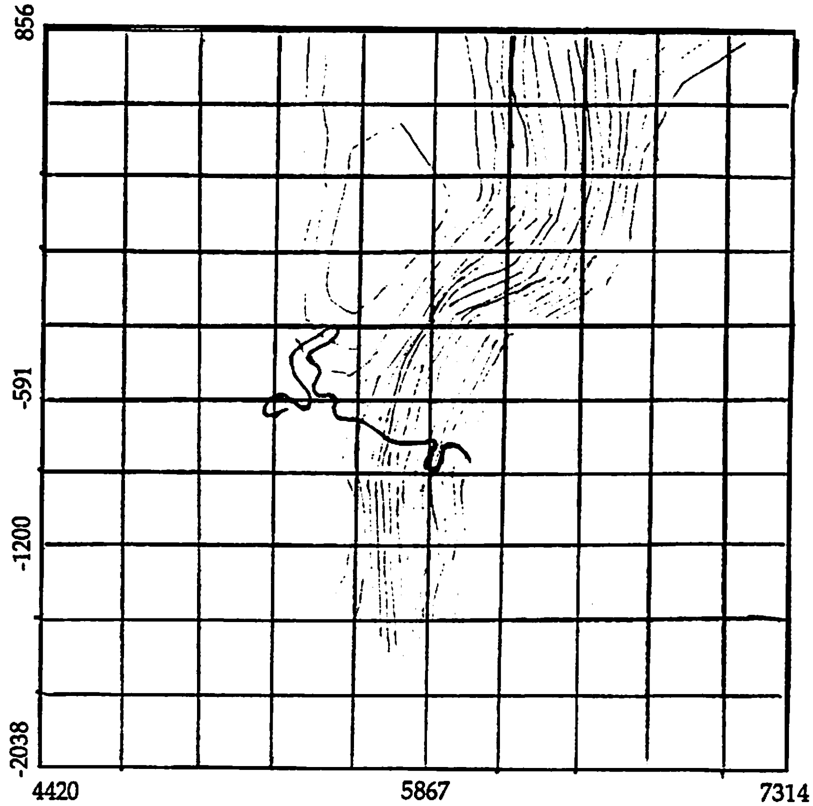
Pilot: R. Hollis
Observors: R. McDuff
A. Isley

Goals: Complete heat flow assessment in northern area; complete a preliminary transect to the southern area

Measurements:
6 push cores
5 heat flow

Observors Comments:

After locating the Yamano heat flow instrument we located PUPPI 3 and found that it had penetrated the sediment fully. Completed a heat flow measurement and a push core at the PUPPI 3 site. The bottom thermistor at the PUPPI 3 site registered 2.590°C, about 1°C above bottom water temperatures. Offset 20 m SE of PUPPI 3 to set a marker for the remote probe deployment to follow on another dive. Took heat flow measurement and a push core and deployed Marker #21 as a target for the remote probe location. Surveyed a linear depressio for a comparison of sediment and heat flow between mounds and depressions. Using a "poker" marked with cm intervals, we found that there was a hard layer about 95 cm below the sediment surface in the depression. After we began to survey to the south of the area w found several "fairy rings"—circular features about 2 m in diameter with dark, rubbly mat around the perimeter and normal looking sediment in the center. Returned to previously sampled depression. Tried excavating the depression to look at the hard layer—no luck. After finishing the attempted excavation, we again surveyed to the south. After some time with no observations of mounds or depressions, we found an area on the eastern slope of the ridge which had many small mounds and a couple of larger mounds. One push core was taken and the area was marked with Marker #22.



Dive Track During ALVIN Dive 1869

ALVIN DIVE 1869
June 16, 1987

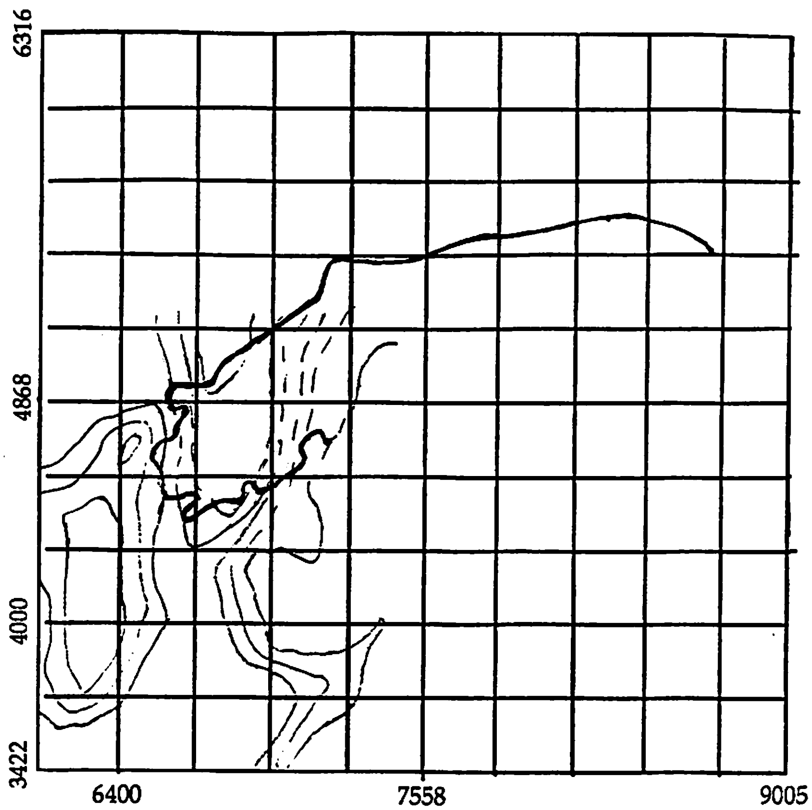
Pilot: P. Tibbetts
Observors: J. Delaney
B. Holmén

Goal: To collect samples from a scarp (500m vertical relief) south of the Mounds Field

Samples:
10 rock samples

Observors Comments:

The dive began at base of the scarp at ~3950m, and traversed the scarp moving upgradient. The outcrop appeared to be draped with a Mn crust. Bulbous Mn-encrusted mud and pumice were sampled with the manipulator. Because this material was so hard, it was impossible to obtain samples below this crust. A change in the morphology of the scarp was obvious near the top of the feature, where more gentle slopes became apparent. We noted vertical surfaces with few fractures in this region, which appeared to be of a texture more like that of basalt. The only way it appeared possible to collect samples of the underlying rocktype was to core horizontally into the cliff. Of the ten rock samples that were collected, all were either Mn-encrusted mud, or pumice blocks with Mn coatings.



Dive Track During ALVIN Dive 1870

ALVIN DIVE 1870
June 17, 1987

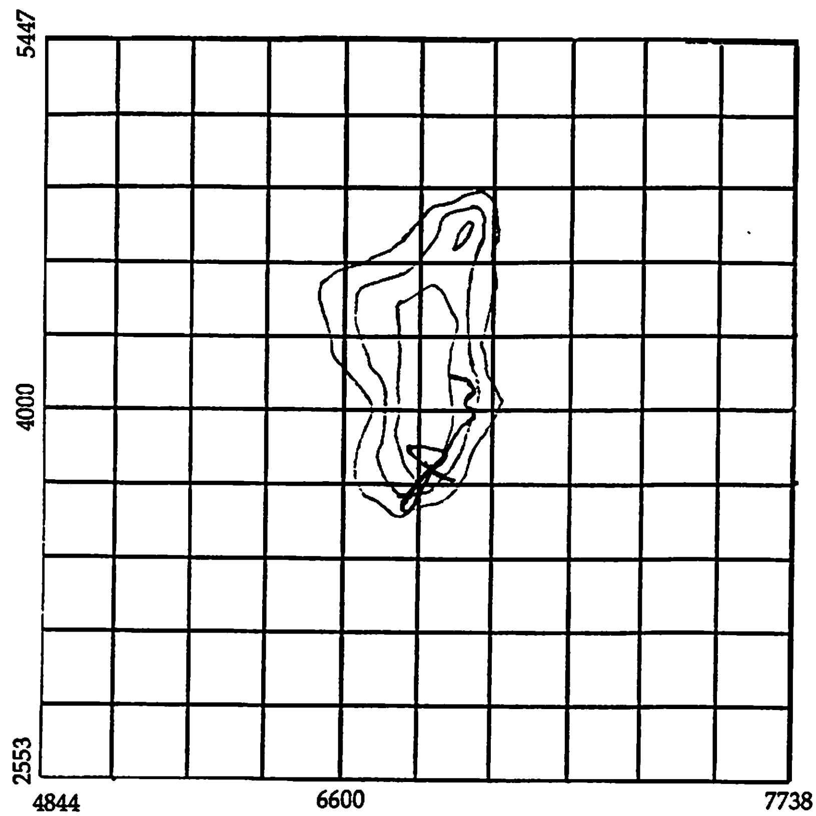
Pilot: D. Foster
Observors: K. Becker
P. Schultheiss

Goal: find and deploy lateral pore pressure experiment; search for other equipment at seafloor

Measurements:
8 heat flow

Observors Comments:

At the onset of the dive, Core Marker 3 was located in a flat area of normal sediment. A survey of the PUPPI/Japanese long-term heat flow monitor site was made next; the PUPPI master, deployed from the ship, had landed about 20m from the long-term monitor. The two instruments were each located near small mound features, and separated by a slight slope/valley with no observable hydrothermal features. To test whether the heat flow in the non-hydrothermal area would be lower, resulting in/from lateral pressure gradients there, the PUPPI slave was deployed in the area between the two instruments.The heat flow survey confirmed lower values in the region between the two instruments (see Table below), and the lateral pore pressure experiment was deployed as planned.
Continuing the survey, we sighted Core Marker 6, shown above, poised on the edge of a 2m high "cliff" of manganese encrusted sediments. Piston Core #5 penetrated about 2m away from the upper level of the cliff.
Two heat flow measurements were made at the base of the ledge to determine if this region might represent a fault which channels fluid flow. Heat flow measurements there were low. Core Marker #5 was searched for, but not located.



Dive Track During ALVIN Dive 1871

ALVIN DIVE 1871
June 18, 1987

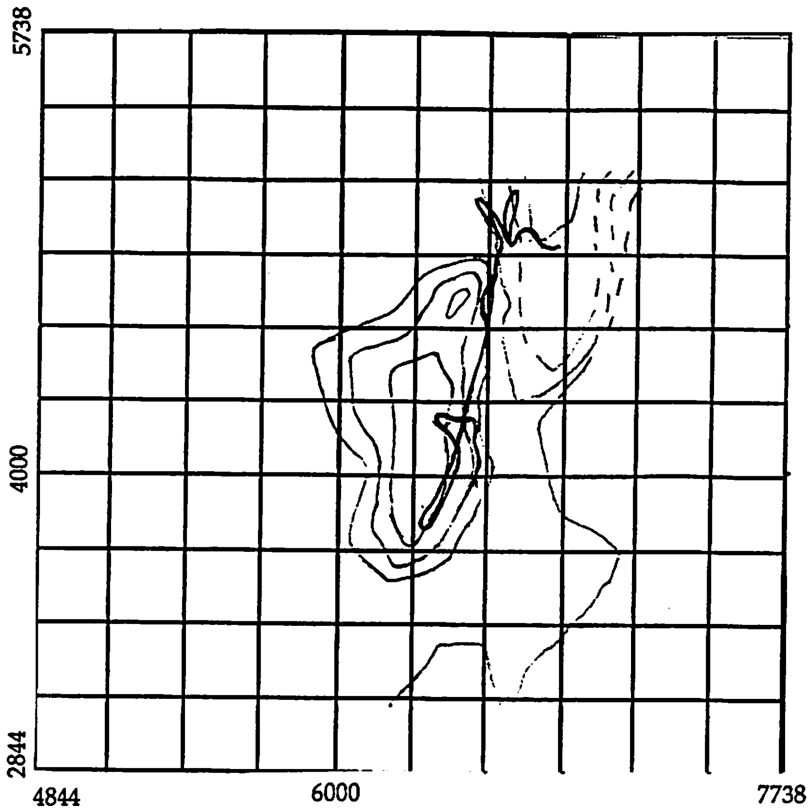
Pilot: D. Gleason
Observors: M. Leinen
M. Robotham

Goal: Survey southern Mounds study area

Measurements:
4 push cores
3 heat flow

Observors Comments:

The survey determined the extent of the southern portion of the Mounds Field. Heat flow studies showed that even relatively small mound features (<30cm diameter) demonstrated high heat flow. Following survey of the area, we progressed northward and found that the mounds field is an unbroken feature between 3600m-3640m on the east side of the bathymetric high we had been concentrating on during previous dives. Moving along the 3640m isobath, we encountered a steeply-dipping scarp. Along this scarp, there was a complex of high heat flow area, concentrations of biogenic activity (crabs) and a region of shimmering water. It was apparent that all features surveyed trended along a N-S strike, concuring with the probable underlying structural trends. We also noted more of the "fairy ring" features, which will be investigated further in following dives.



Dive Track During ALVIN Dive 1872

ALVIN DIVE 1872
June 19, 1987

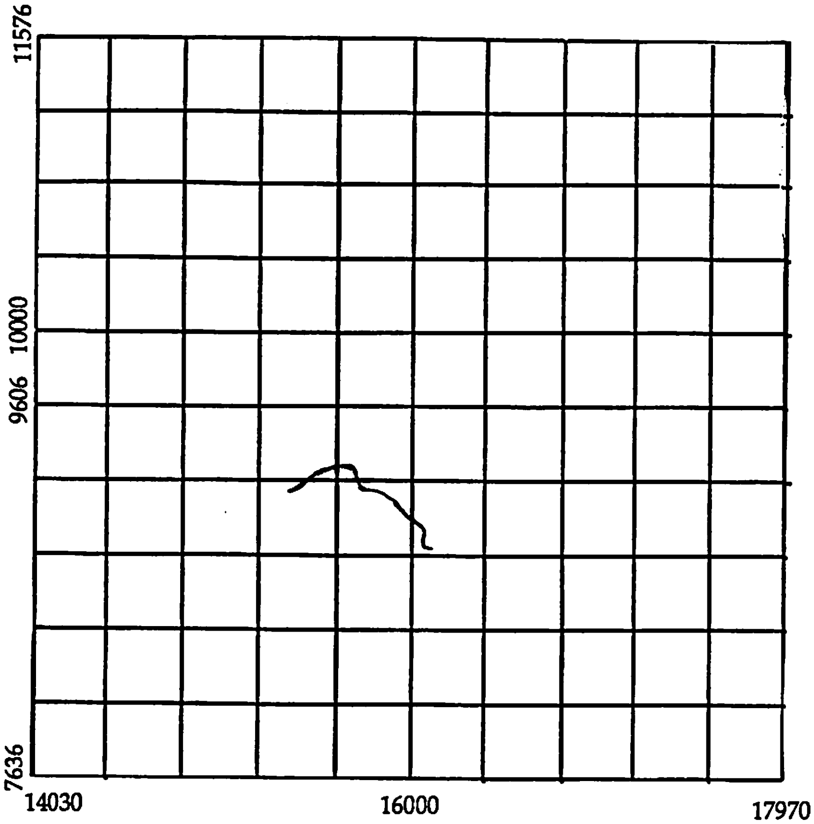
Pilot: R. Hollis
Observors: R. McDuff
J. Broda

Goal: Reconnaisance of area north-east of the Yamano probe field

Measurements:
7 push cores
9 heat flow
1 scoop bag

Observors Comments:

The dive began in the southern mounds field at Marker #20. We surveyed uphill from the marker for a short time and then returned to the marker where we made heat flow measurements, one in the top of a conical mound and a second at the base of the mounds. We also took two push cores at the locations of the heat flow measurements. We followed these measurements with a survey of one of the "fairy rings". The ring was about 2 m in diameter. The rubble defining the ring is 30-100 cm wide and consists of irregularly surfaced, manganese-covered material. The mud inside the ring is much finer grained. We scopped material from the band of the ring, took a heat flow in the ring and a push core in the ring. After sampling we surveyed along the scarp to the north for as far as Marker A in the Yamano probe area. We then turned south and surveyed for about 10 minutes. We returned to a northward course and surveyed for 8 minutes before finding an area of depressions and mounds with galatheid crabs and several more fairy rings. Continuing north, we stopped at an area which had many very small mound-like features. We made a heat flow measurement in this area, but found low heat flow. We continued to the north where we found a small scarp trending 160° which we sampled by taking a horizontal push core. We tried to return to the area of mounds and depressions, but didn't have enough time. We took one last heat flow station in normal sediments.



Dive Track During ALVIN Dive 1873

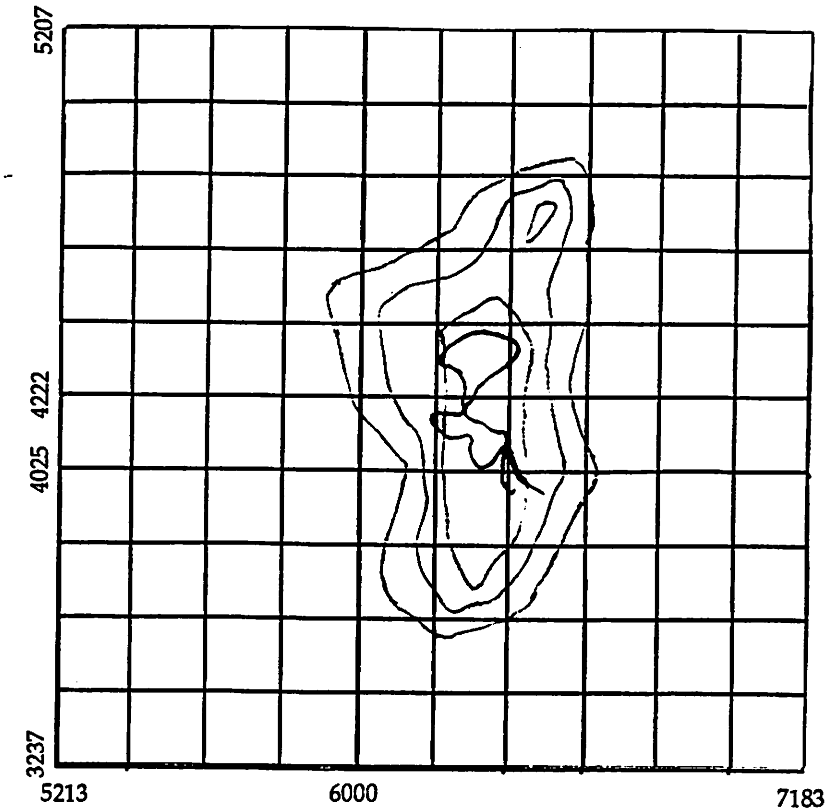
ALVIN DIVE 1873
June 20, 1987

Pilot: P. Tibbets
Observors: J. Delaney
R. Schilling

Goal: Survey the northern scarp and obtain rock samples

Samples:
rock samples
one laterally drilled core

Observors Comments:



Dive Track During ALVIN Dive 1874

ALVIN DIVE 1874
June 21, 1987

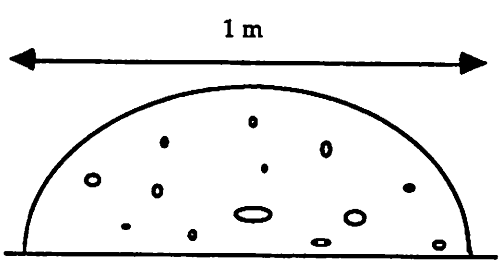
Pilot: D. Foster
Observors: P. Schultheiss
B. LaFlamme

Goal: complete a vertical pore pressure experiment; do further heat flow studies; locate instrumentation on bottom

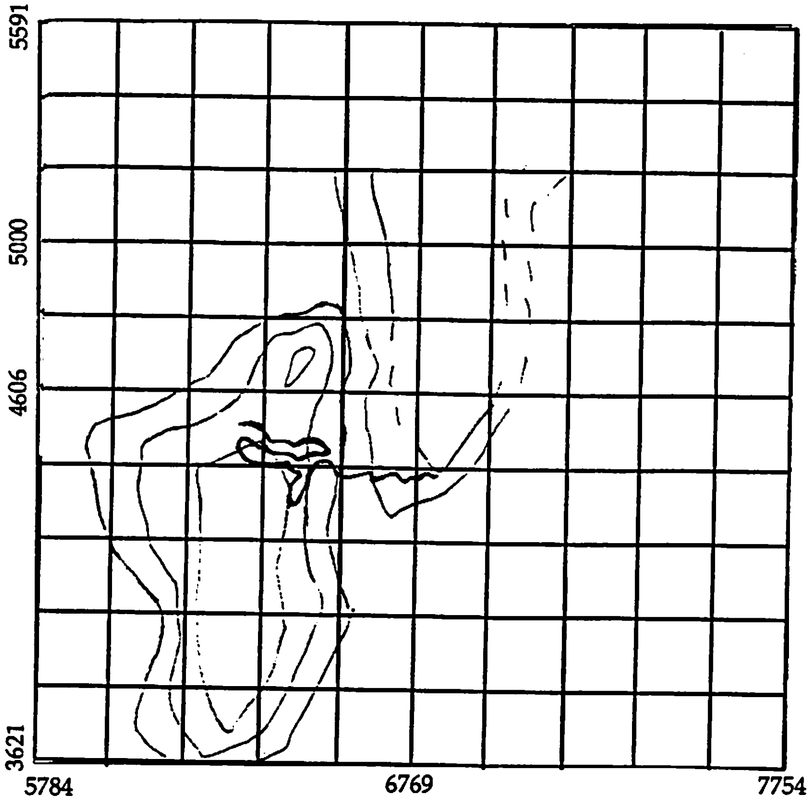
Measurements:
6 push cores
8 heat flow

Observors Comments:

PUPPI 6 was located on this dive; it had made full penetration. A heat flow station was made adjacent to PUPPI 6 (1.77 C, max. T), as well as a push core. Proceeding east, an area of "boiling mud" was sighted. Heat flow measurements showed 7 C at a depth of 1". The probe could not penetrate further into the sediment. The PUPPI remote probe target marker (#18) was deployed at the boiling mud site; when the remote probe was deployed, it penetrated only 14". A third heat flow measurement was made adjacent to the PUPPI remote probe (max. T = 8.9 C). Continuing east, a mound approximately 1m in diameter and 0.5m high, whose surface was pocked in a way that resembled swiss cheese was found. Five heat flow stations were made at this mound, with results shown in the figure below. Three push cores were made at this mound (one at the base, one about half way up the mound, and one at the top). Attempts to locate core markers met without success, however PUPPI 5 was sighted.



	Temp. Max.	
HF	7.7 C	10" Penetration
HF	6.8 C	Full Penetration
HF	4.3 C	Full Penetration
HF	4.8, 6.9 C	



Dive Track During ALVIN Dive 1875

ALVIN DIVE 1875
June 22, 1987

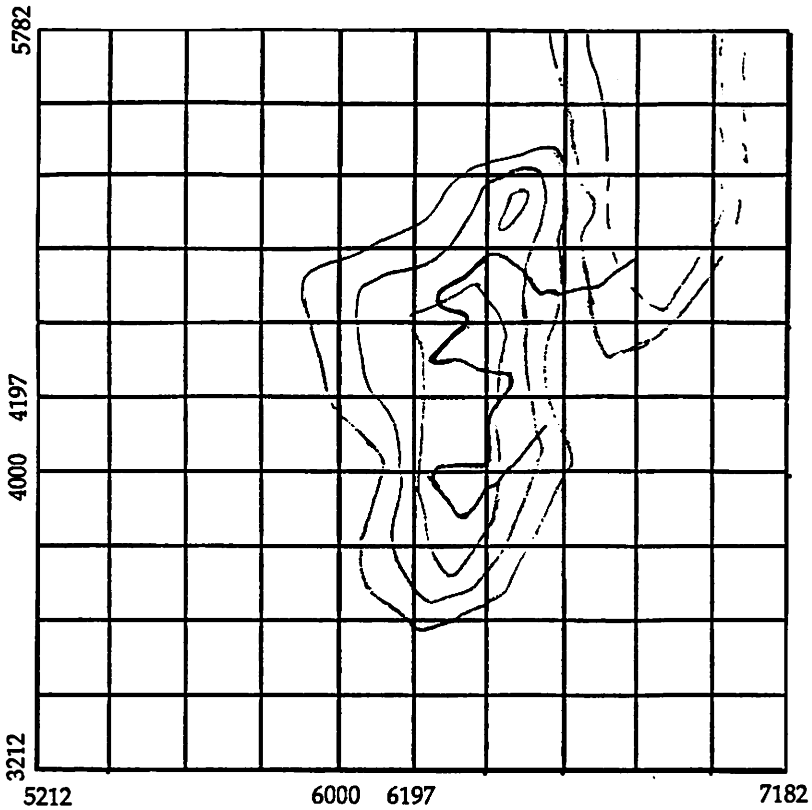
Pilot: D. Gleason
Observors: R. McDuff
T. Walsh

Goal: Locate and describe settings of core markers 2 and 5; survey general area of scarp along which the southern area is located; make a second mound morphotype heat flow survey

Measurements:
4 push cores
8 heat flow

Observors Comments:

Surveyed the valley east of the hydrothermal features while looing for core markers 2. We had to give up the search for core marker #2 after no results. We then began searching for core marker #6. We crossed a "fairy ring" that had been surveyed by ALVIN, but apparently not sampled. We also found several small scarplets which offsets of about 1 m. After an hour we gave up searching for core marker #6. We decided to do a heat flow survey of a scarp. Heat flow measurements were completed 20 m downhill from the scarp (low), 10 m downhill from the scarp (low), 5 m downhill from the scarp (low), base of scarp (moderately low), top of scarplet (low). We then continued with a second scarplet. Measured heat flow at top of second scarplet (low), 5 m beyond scarp (low) and 10 m beyond scarp (also low). Push cores were taken at the locations of heat flow 20 m below scarp, and at the location 5 m beyond the second scarp.



Dive Track During ALVIN Dive 1876

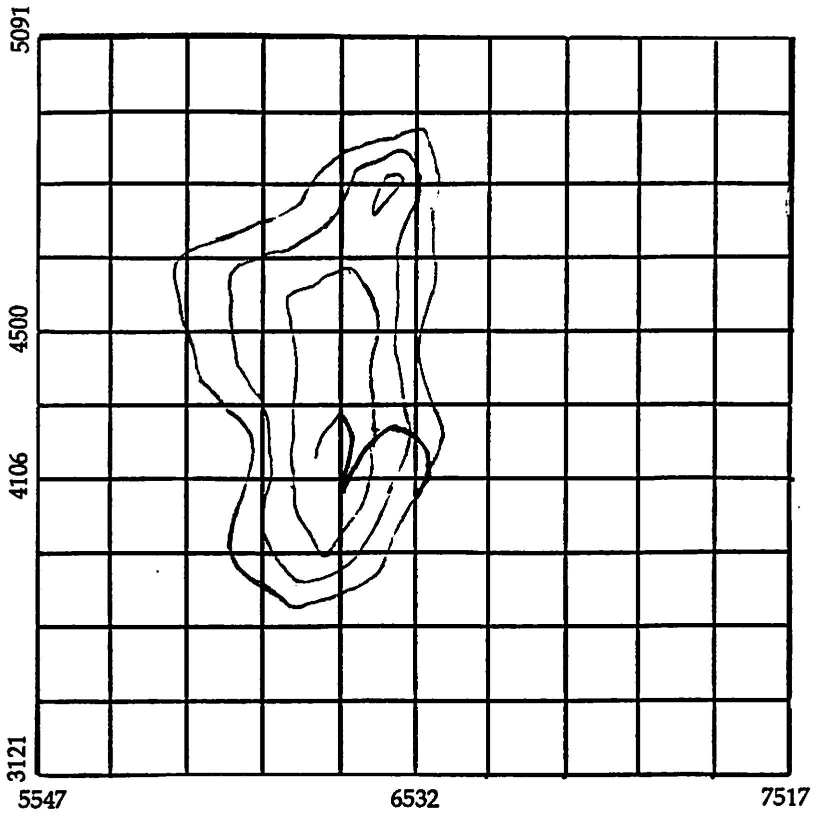
ALVIN DIVE 1876
June 23, 1987

Pilot: R. Hollis
Observors: N. Fujii
pilot trainee

Goal: Recover Yamano probe, reposition remote probe for PUPPI 6

Measurements:

Observors Comments:



Dive Track During ALVIN Dive 1877

ALVIN DIVE 1877
June 24, 1987

Pilot: P. Tibbets
Observors: M. Leinen
S. Nagihara

Goal: Heat flow survey of scarp in southern mounds area
locate PUPPI 5 and PUPPI 4

Measurements:

Observers Comments:

We landed at a target west of the estimated position of PUPPI 5 and looked for it on the sonor. After finding a sonar target we corrected course and located the empty cone of PUPPI 5. We then received a new target for PUPPI 4 and began driving toward it. Along the way we encountered the core marking device and core marker #9, which had been lost during coring operations. After several minutes of surveying we had no targets in view for PUPPI 4 and gave up our search. We then drove to the southern mounds area and began a heat flow survey of the scarp along which shimmering water and bubbling mud have been observed. We made three transects of heat flow measurements, each of which started at the base of the scarp and extended perpendicularly away from the scarp about 4 m. We made two attempts to drill through the resistant layer which lies about 10 cm under the sediment surface at the base of the slope. The second attempt at drilling was successful. We then made heat flow measurements in a pock-marked mound at the southern end of the hydrothermal area. Finally, we located the PUPPI 6 remote probe and PUPPI 6. The remote probe had penetrated about 15 cm into the sediment. We tried pulling the probe over in order to see whether some of the resistant material would be brought to the surface with the tip of the probe. The probe pulled over with difficulty, but its tip was still obscured by sediment.

AII 118 - 16

CORE	DATE	X (m)	Y (m)	LATITUDE	LONGITUDE	DEPTH (m)	LITHOLOGY	LENGTH (m)
PC 1	6/13/87	6698	4251	18 1.96	144 17.51		BR. SILTY CLAY	7.72
PC 2	6/14/87	6268	4460	18 2.08	144 17.27	3620	BR. SILTY CLAY	11.49
PC 4	6/16/87	6670	4380	18 2.03	144 17.50	3698	BR. SILTY CLAY	4.52
PC 5	6/17/87	6557	4355	18 2.02	144 17.43	3670	BR. SILTY CLAY	8.79
PC 6	6/18/87	6098	3511	18 1.56	144 17.17	3643	BR. SILTY CLAY	8.77
PC 7	6/19/87	6406	4009	18 1.83	144 17.35	3627	BR. SILTY CLAY	8.75
PC 8	6/20/87	6533	3900	18 1.77	144 17.42	3679	BR. SILTY CLAY	8.80
PC 9	6/20/87	6440	3990	18 1.82	144 17.37	3622	BR. SILTY CLAY	8.55
PC 10	6/20/87	6360	3890	18 1.77	144 17.32	3644	BR. SILTY CLAY	8.74
PC 11	6/20/87	6414	3831	18 1.73	144 17.35	3663	BR. SILTY CLAY	8.78
PC 12	6/21/87	6210	4580	18 2.14	144 17.24	3654	BR. SILTY CLAY	8.77
PC 13	6/22/87	6030	4416	18 2.05	144 17.14	3606	BR. SILTY CLAY	8.63
PC 14	6/22/87	6240	4100	18 1.88	144 17.25	3635	BR. SILTY CLAY	8.70
PC 15	6/23/87	6139	3790	18 1.71	144 17.20	3630	BR. SILTY CLAY	8.70
TWC 3	6/14/87	6500	4530	18 2.12	144 17.40	3620	BR. SILTY CLAY	0.56
TWC 4	6/16/87	6670	4380	18 2.03	144 17.50	3698	BR. SILTY CLAY	0.50
TWC 6	6/18/87	6098	3511	18 1.56	144 17.17	3643	BR. SILTY CLAY	0.82
TWC 7	6/19/87	6406	4009	18 1.83	144 17.35	3627	BR. SILTY CLAY	0.42
TWC 9	6/20/87	6440	3990	18 1.82	144 17.37	3622	BR. SILTY CLAY	1.31
TWC 11	6/20/87	6411	3821	18 1.73	144 17.35	3663	BR. SILTY CLAY	1.39
TWC 12	6/21/87	6208	4579	18 2.14	144 17.24	3654	BR. SILTY CLAY	1.29
TWC 13	6/22/87	6030	4416	18 2.05	144 17.14	3606	BR. SILTY CLAY	1.44
TWC 14	6/22/87	6240	4100	18 1.88	144 17.25	3635	BR. SILTY CLAY	1.20
TWC 15	6/23/87	6139	3790	18 1.71	144 17.20	3630	BR. SILTY CLAY	1.19
GC 1	6/16/87	6529	4501	18 2.10	144 17.42	3620	BR. SILTY CLAY	2.55
GC 2	6/17/87	6350	4300	18 1.99	144 17.32	3583	BR. SILTY CLAY	1.74
GC 3	6/22/87	6331	4329	18 2.01	144 17.31	3620	BR. SILTY CLAY	1.18
1863/C-1	6/10/87	6905	4140	18 1.90	144 17.63	3705	BR. SILTY CLAY	0.50
1864/C-1	6/11/87	6330	4362	18 2.02	144 17.31	3621	BR. SILTY CLAY	0.08
1865/C-1	6/12/87	6351	4356	18 2.02	144 17.32	3624	BR. SILTY CLAY	0.18
1865/C-2	6/12/87	6334	4361	18 2.02	144 17.27	3623	BR. SILTY CLAY	0.26
1865/C-3	6/12/87	6264	4385	18 2.04	144 17.27	3618	BR. SILTY CLAY	0.27
1868/C-3	6/15/87	6384	3843	18 1.74	144 17.34	3656	BR. SILTY CLAY	0.33
1868/C-4	6/15/87	6377	3851	18 1.75	144 17.33	3656	BR. SILTY CLAY	0.29
1868/C-5	6/15/87	6370	3848	18 1.75	144 17.33	3656	BR. SILTY CLAY	0.29
1868/C-6	6/15/87	6314	4291	18 1.99	144 17.30	3622	BR. SILTY CLAY	0.12
1868/C-7	6/15/87	6247	4419	18 2.05	144 17.26	3621	BR. SILTY CLAY	0.33
1868/C-8	6/15/87	6322	4397	18 2.04	144 17.30	3620	BR. SILTY CLAY	0.33
1868/C-9	6/15/87	6319	4387	18 2.04	144 17.30	3620	BR. SILTY CLAY	0.27
1868/C-10	6/15/87	6349	4365	18 2.03	144 17.32	3625	BR. SILTY CLAY	0.29
1868/C-11	6/15/87	6342	4386	18 2.04	144 17.31	3623	BR. SILTY CLAY	0.29
1870/C-1	6/17/87						BR. SILTY CLAY	0.26
1870/C-2	6/17/87						BR. SILTY CLAY	0.24
1871/C-1	6/18/87	6383	3872	18 1.76	144 17.34	3658	BR. SILTY CLAY	0.26
1871/C-2	6/18/87	6449	3990	18 1.82	144 17.37	3654	BR. SILTY CLAY	0.28
1871/C-3	6/18/87	6439	4029	18 1.84	144 17.37	3628	BR. SILTY CLAY	0.08
1871/C-4	6/18/87	6440	4023	18 1.84	144 17.37	3628	BR. SILTY CLAY	0.15
1872/C-1	6/19/87	6428	4035	18 1.85	144 17.36	3643	BR. SILTY CLAY	0.19
1872/C-2	6/19/87	6419	4033	18 1.85	144 17.36	3643	BR. SILTY CLAY	0.27
1872/C-3	6/19/87	6423	4006	18 1.83	144 17.36	3642	BR. SILTY CLAY	0.31
1872/C-7	6/19/87	6537	4845	18 2.29	144 17.42	3674	BR. SILTY CLAY	0.23
1872/C-8	6/19/87	6437	4004	18 1.83	144 17.37	3642	BR. SILTY CLAY	0.27
1872/C-9	6/19/87	6462	4093	18 1.88	144 17.38	3641	BR. SILTY CLAY	0.31
1872/C-10	6/19/87	6459	4075	18 1.87	144 17.38	3641	BR. SILTY CLAY	0.28
1874/C-1	6/21/87	6423	4020	18 1.84	144 20.19	3643	BR. SILTY CLAY	0.25
1874/C-3	6/21/87	6425	4032	18 1.85	144 20.19	3644	BR. SILTY CLAY	0.07
1874/C-4	6/21/87	6431	4021	18 1.84	144 20.19	3644	BR. SILTY CLAY	0.33
1874/C-5	6/21/87	6429	4021	18 1.84	144 20.19	3644	BR. SILTY CLAY	0.26
1874/C-6	6/21/87	6465	3998	18 1.83	144 20.21	3641	BR. SILTY CLAY	0.28
1874/C-7	6/21/87	6426	4032	18 1.85	144 20.19	3644	BR. SILTY CLAY	0.10
1875/C-1	6/22/87	6502	4467	18 2.08	144 17.40	3651	BR. SILTY CLAY	0.33
1875/C-2	6/22/87	6501	4466	18 2.08	144 17.40	3651	BR. SILTY CLAY	0.29
1875/C-3	6/22/87	6501	4474	18 2.08	144 17.40	3651	BR. SILTY CLAY	0.25
1875/C-4	6/22/87	6497	4444	18 2.07	144 17.40	3646	BR. SILTY CLAY	0.24
1876/C-1	6/23/87	6345	3903	18 1.78	144 17.31	3642	BR. SILTY CLAY	0.33
1876/C-2	6/23/87	6441	4004	18 1.83	144 17.37	3643	BR. SILTY CLAY	0.01
1877/C-1	6/24/87					3640	BR. SILTY CLAY	0.32
1877/C-3	6/24/87					3642	BR. SILTY CLAY	0.32
1877/C-4	6/24/87					3643	BR. SILTY CLAY	0.32
1877/C-5	6/24/87					3643	BR. SILTY CLAY	0.22
1877/C-6	6/24/87	6334	3914	18 1.78	144 20.14	3642	BR. SILTY CLAY	0.12
1877/C-7	6/24/87	6434	4036	18 1.85	144 18.50	3637	BR. SILTY CLAY	0.13