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Astrobiology Hydrothermal Vent Technology Development

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NASA Ames Research Center

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ABSTRACT

The study of life in extreme environments provides an important basis from which we can undertake the search for extraterrestrial life. This paper provides a description of a program focused on developing technologies which are necessary to evaluate the potential for the existence of a deep sub-seafloor biosphere.

INTRODUCTION

Recent evidence of salt water oceans beneath the ice crusts of Europa and Callisto has fostered speculation that these satellites may harbor life. But could life exist beneath tens of kilometers of ice? On today's Earth the energy required to support life is primarily provided by sunlight (through the process of photosynthesis). However, prior to the establishment of photosynthesis, life on Earth depended on abiotic sources of chemical energy in the form of the disequilibrium of redox reactants. Since these redox pairs are rapidly depleted by both abiotic and biotic reactions, chemical equilibrium constraints will ultimately extinguish such life forms on a global scale. Since the putative oceans of both Europa and Callisto are believed to be isolated from sunlight this hypothesis may provide constraints upon the viability of life on these icy satellites.

But could such "abiotic life forms" exist on a limited scale in micro-environments? Do terrestrial forms of these organisms exist on Earth today in some long ago isolated and forgotten macro-environment? The goal of this activity is to develop the technologies necessary to begin to answer these questions.

BACKGROUND

Based on past terrestrial research we know that life flourishes on Earth in a wide range of environments. Novel life forms have been observed in extreme environments such as high-salt deserts, volcanoes,

thermal vents, polar ice, and ultra high radiation environments. But are these environments analogs to extraterrestrial environments? Are of these life forms decoupled from the influence of photosynthesis?

The deep subsurface biosphere is one environment that may, in fact, be decoupled from photosynthesis. The subsurface biosphere is defined in this context as a subterranean environment where the flux of geochemical energy from the core of the Earth is sufficient to drive metabolic processes. The existence of such an environment is by no means a given. In fact, little direct evidence of a substantial deep hot biosphere has been obtained so far (Jannasch, 1995).

Consider that organics and oxygen derived from photosynthesis currently dominate terrestrial environments. The vast majority of all known life forms utilize metabolic processes that are in some way coupled to photosynthesis. However, this was not always the case. Early in the history of Earth it is believed that our distant ancestors evolved in an environment devoid of photosynthesis (Sleep, 1992).

Although there are no environments on Earth today which are truly devoid of oxygen some provide sufficient barriers to oxygen to approximate conditions which might have existed on an early Earth. The subsurface biosphere is believed to be such an environment. This environment could provide a barrier to the flux of oxygen through layers of geologic formations. In addition, these formations are often reactive to oxygen and, in near surface zones, support vibrant communities of aerobic microorganisms which will remove oxygen from subsurface fluid flows. In locations where magma chambers are close to the surface the downward flux of oxygen and organics can be limited by outward energy fluxes and associated buoyancy driven flows. In some locations it has been postulated that magma off gassing can contribute substantially to this outward flux (Lupton, 1991). It is believed that these environments may

support macro-environments which are analogues to that which existed on early Earth and may exist today on Jupiter's moon Europa.

For example, research centered around deep ocean hydrothermal vents has provided important data to validate theories for the origin of life. For example, RNA analysis suggests that a common ancestor for all terrestrial life is thermophilic chemoautotrophs (Woese, 1990). Current theories place the origin of life on Earth at some time between 3.8 to 4.3 Ga. During this period the Earth was subject to sustained bombardment by asteroidal bodies. Deep benthic and sub-sea floor habitats were potentially the least impacted environments during this period and possibly the only ones capable of sustaining life (Sleep, 1992). Whether these environments were the point of origin for life, a choke point in its evolution, or only a unique micro environment is a point of debate.

A key element of this debate is the answer to the question, does the deep subsurface biosphere actually exist? At this time there is little direct evidence that it in fact does (Jannasch, 1995).

OBJECTIVES

The objective of this work is to develop the technologies which will facilitate scientific investigation into the deep biosphere. Specifically we are focusing on deep ocean basins where access to this environment is facilitated by the depth of the ocean.

The ocean basins provide a point of access which is already 2000 to 4000m deep. Ocean basins cover nearly 60% of the Earth surface. They are underlain by 5 to 6 km of ocean crust. Within this crust the Earth's mantle produces pools of molten basalt.

Within the ocean basin structures the mid-ocean ridge systems provide a particularly unique environment. These ridge systems are a series of divergent plate margins. As the tectonic plates making up the outer surface of this planet spread apart, parts of the underlying mantle undergo decompressional melting. The resulting partially molten upper mantle material is more buoyant than the surrounding rock, and wells upward, ultimately intruding into the shallow seafloor in the form of shallow magma chambers and dikes. Often these structures can be as shallow 1-3 km below the seafloor (Schultz, 1997).

It is in this 1-3 km zone within which it has been postulated that the conditions exist which are conducive to the existence of a biosphere dependant solely on the input of geochemical energy and abiotic chemistry (Delany, 1998). The objectives of this program are to develop methods to access this sub-sea floor zone and acquire data in order to characterize any biotic environments and organisms which might exist there.

There are two primary methods to access this environment. through naturally occurring episodic events, such as Hydrothermal vents, and through deep drilling directly into this zone.

Hydrothermal Vents

The Earth upper mantle is more buoyant than the sub seafloor surrounding rock. This condition creates a natural tendency for the magma to migrate to the surface through dikes (large cracks) in the surrounding rock. This process is particularly prevalent at or near the mid ocean ridges. In these zones seawater is entrained into the seafloor, and circulates down to zones heated by the upwelling magma. The fluids are quickly heated to temperatures near the phase separation point, become highly buoyant, and rise quickly through dikes in the seafloor rock to the surface where they are emitted as hydrothermal vents (black and white smokers) and diffuse flow.

These dikes regularly become blocked through material transport or tectonic movement. As pressure in the blocked dikes rise, dike-eruptions occur. These dike eruption events provide a unique opportunity to sample water that has been captured in the deep subsurface zones and held there for prolonged periods of time (years to decades).

It has been shown that during steady state many hydrothermal vents are the result of a rather shallow recycling of ocean waters. During these periods the biotic environments associated with the vents are dominated by the organic and inorganic material carried through shallow seafloor zones by these transient flows. In other words, the environment is coupled to the ocean biosphere. And this biosphere is dependant on photosynthesis.

However, when these vents are diked this flow essentially stops. It is hypothesized that during these periods biotic compounds and oxygen deposited by ocean flows are eventually consumed by aerobic organisms and reactions with heated rock. Once consumed a unique environment emerges where organics and nutrients are supplied primarily by abiotic geochemical sources. During these periods it is possible that organisms which are not capable of functioning in the oxygen rich environment of the ocean waters begin to metabolize and eventually dominate.

It is believed that when a dike eruption occurs some portion of the contents of the sub seafloor are ejected into the oceans. This material could provide important information to validate the existence and characteristics of the putative subsurface biosphere. The eruption events are short lived, however, and rather quickly the shallow recycling of sea water once again dominates the biology of this environment.

Unfortunately we know very little about what occurs during a dike eruption event. As a result one of the pressing needs in the hydrothermal vent research community is the development of innovative approaches capable of analyzing the initiation of dike eruption events (Delaney, 1998).

Over the past decade we have learned a great deal about the hydrothermal vent environment. However, many of the transient processes remain poorly understood. This has occurred because by the time researchers reach the scene of an eruption, magma transport and plume emissions have generally ceased. In addition, seismicity has stopped, and chronic plumes have reached or passed their peak intensity.

The current approach utilized by most researchers is to target active vents using technologies such as sea floor seismometers and then to respond to events using research vessels and Remotely Operated Vehicles (ROVs). The time lag associated with the identification of vent activity, outfitting the research vessel, and travel to the site of activity has meant that little data is available relevant to conditions during initiation of vent activity. Generally the transitory period of interest lasts only hours to days (Delaney, 1998). As a result our understanding of the sub-sea floor biosphere has been largely deduced from highly diluted plume samples obtained from bulk seawater. The point of origin of these samples is rarely known. Fundamental issues such as whether diking events flush active thermophilic and hypothermophilic biotopes or simply eject nutrients which enhance the growth of dormant oceanic communities have not been adequately investigated.

The goal of this program is to develop instrumentation capable of in situ analysis of conditions during dike eruption events. This instrumentation, a variant of the Medusa sea floor monitoring system, is designed to obtain extensive data sets of coordinated sea floor measurements over the entire lifetime of a diking event. Medusa is an autonomous instrument platform designed to operate in the deep ocean environment for prolonged periods of time. Data acquisition capabilities are sufficient to instrument wide areas of the sea floor bottom. The initial Medusa configuration can record wide area temperature profiles, flows of fluid into and out of the sea floor, and collect fluid samples for later chemical and biological analysis. Future versions of Medusa will include the capability to conduct in situ chemical analysis and analysis of microbial population distributions and specific microbial identification. We are also developing the capability to conduct data transfer remotely from the deep ocean environment to shore based stations.

Deep Ocean Drilling

Another method of accessing the sub-sea floor biosphere is through drilling operations into the seafloor.

The primary method of attaining these types of samples is through the use of previously installed deep ocean bore holes. The majority of these have been installed by the Ocean Drilling Program (ODP). ODP is an international partnership of scientists and research institutions organized to explore the evolution and structure of Earth. The center piece of the ODP program is the drill ship JOIDES. The JOIDES, a converted oil-drilling ship, can drill bore hole hundreds of meters beneath the seafloor bed in ocean depths of up to 8.2 km (ODP Homepage)

These bore holes provide a method of collecting samples from deep beneath the seafloor. The Medusa is designed to integrate with the Woods Hole Institute of Oceanography's bore hole reentry device and provides a capability to evaluate temporal variation in bore-hole effluent.

MESUREMENT REQUIREMENTS

Due to the geologic context of the sub sea floor biosphere, direct access of the relevant environment is problematic. However, these environments are characterized by the presence of geochemical energy. This energy drives heating and the establishment of buoyant forces. These forces result in the flux of material out of the sub sea floor environment. Both the hydrothermal vent environment and the deep bore holes are characterized by this flux of material. Thus a logical first step in evaluating these regions would be to evaluate effluent fluids. These fluids can provide information concerning the depth of the sub-sea floor zone, temperature profiles, information defining connectivity to the bulk ocean, and samples of organisms which have been flushed from deep beneath the sea floor. Three approaches are being pursued.

Hydraulic Flow Patterns

Measuring the flow of fluids into and out of the sea floor environment can be used to calculate hydraulic gradients associated with hydrothermal, lateral, and bore hole effluents (Schultz, 1997). This information can be used to infer the potential origins of such flow. Decoupling of effluent and recharge rates is indicative of large subsurface reservoirs, magma sources of fluids, and isolated subsurface regions. Alternatively, tight coupling or periodic flows are an indication of shallow recycling and tidal driving forces. These types of measurements can also be used to measure residence time and can be correlated with fluid chemistry to infer reaction kinetics of deep subsurface zones.

Effluent Chemistry

The circulation of seawater through the oceanic crust passes through deep areas of high temperatures and pressures where mineral leaching and chemical

reduction occur. These reactions can provide important data reflecting conditions beneath the sea floor. Table 1 provides an example of how the chemical composition of seawater can be altered by flow through the oceanic crust.

Table 1. Variation in Chemical Composition of Vent Effluents as Determined by Their Passage Through Subsurface Material (Welhan, 1983; Edmond, 1985, Jannasch, 1985)

Species	Sea Water	Vent Effluent *
Ag (μM)	0.02	38
Al (μM)	0.01	5
Ba (μM)	0.14	7
Ca (μM)	10.2	15.6
CH ₄ (mM)	0.001	1.6
Cl (mM)	541	489
Co (nM)	0.03	213
Cu (μM)	0.007	35
Fe (μM)	0.001	1664
H ₂ (mM)	0.001	50
H ₂ S (μM)	0	7.3
K (mM)	9.79	28
Mg (mM)	52.7	0
Mn (μM)	0.001	960
Na (mM)	464	432
Pb (nM)	0.01	308
Si (mM)	0.16	18
SO ₄ (mM)	27.9	0
Zn (μM)	0.01	106
pH	8.1	3.4

*Vent effluent determined from 21° N East Pacific Rise (2610m) vent site

Perhaps two of the most important parameters associated with an sub seafloor re-circulation system are temperature and pressure. Both can be inferred through chemical analysis. Pressure is of particular interest to us as we are interested in evaluating systems where circulation is not directly coupled to ocean flows or ocean hydrostatic pressures. Thus hydrostatic pressures which deviate from that indicated by water column height indicate interesting potential environments.

Sub-sea floor pressure can be constrained by evaluating effluent chemistry. As seawater enters the oceanic crust it is in a single liquid phase. If at any time during its circulation it crosses the two phase curve below the critical point for seawater (407°C and 298 bars) it will undergo a phase transformation and produce a low salinity vapor derived fluid and a concentrated liquid. If these flows remain segregated the vapor derived fluid will contain greatly reduced levels of salts and metals. In

addition, most gases will be segregated to the vapor phase. Analysis of these effluents can provide a mechanism of determining if the circulation is deep or shallow. Shallow circulation systems are more likely to cross the critical point while deeper circulation's are not. Regions which are decoupled from the ocean will by definition have pressures well above that attributable to water column height and will thus be unlikely to cross the critical point.

Another important parameter is dissolved gases. These are important in that they indicate that direct magma degassing is contributing to the effluent. Extremely high concentrations of gases such as CO₂ and ratios of ³He/heat provide evidence for this process (Lilley, et al., 1991).

In addition to these physical parameters detailed information concerning the chemistry of the sub-sea floor environment can also be deduced from effluent analysis. Table 2 summarizes the current theories on controlling mechanisms of selected species associated with passage through vent systems.

Table 2. Known Controls on Chemical Composition of Vent Effluents as Determined by Their Passage Through Subsurface Material (Von Damm, 1995)

Element	Source	Mechanism
Cl	Seawater	Phase separation
Si	Rock	Equilibration with quartz at high temperature and pressure
Na	Seawater	Removal in albitization reaction
K	Rock	Equilibrium with K containing aluminosilicates
Mg	Seawater	Removal into Mg-OH-Si minerals
Ca	Rock	Released in albitization reactions, removed into anhydrite, removed into epidote or other Ca-AL-Si phases
S	Rock and Seawater	Removal of SO ₄ into anhydrite and metal sulfides
H+	Seawater	Released by -OH mineral formation and oxidation of sulfides
Fe	Rock	Removed primarily in metal sulfides
Mn	Rock	Incorporated into aluminosilicates and sulfide minerals
Sr	Rock	Released in albitization reactions, removed into anhydrite, removed into epidote or other Sr-AL-Si phases
Cu	Rock	Removal in metal sulfides
Zn	Rock	Removal in metal sulfides

Biology

There are two approaches to understanding the biology of deep sub seafloor environment 1) collection of samples followed by cultivation in the laboratory 2) in situ characterization of environmental parameters and population dynamics. Both methods can provide information on the metabolic pathways utilized by organisms in a given environment. Unfortunately both methods also limit the potential results to only those anticipated prior to definition of the experimental evaluations. For the case of anaerobic chemosynthesis a limited number of potential metabolic process are indicated (Jannasch, 1995). They are anaerobic sulfide oxidation, methanogenesis, denitrification, and fermentation. The proposed reactions are provided in Table 3.

Table 3. Anaerobic Chemosynthesis

Reaction	Free Energy (J/Mol)
Anaerobic Sulfide Oxidation (Wachterhauser, 1988) $\text{Fe} + \text{H}_2\text{S} + \text{CO}_2 \rightarrow \text{FeS}_2 + \text{H}_2\text{O} + \text{HCOOH}$	-11.7
Methanogenesis (Jones, 1983) $\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$ $2\text{CO}_2 + \text{H}_2 \rightarrow [\text{CH}_2\text{O}] + \text{CH}_4 + 3\text{H}_2\text{O}$	-139 -34
Fermentation (Jannasch, 1992) example $\text{C}_3\text{H}_6\text{O}_2 + 2\text{H}_2\text{O} \rightarrow \text{CH}_3\text{COOH} + \text{CO}_2 + 3\text{H}_2$	
Denitrification (Volkl, 1993) $\text{CO}_2 + 8\text{H}_2 + 2\text{NO}_3^- \rightarrow [\text{CH}_2\text{O}] + \text{N}_2 + 7\text{H}_2\text{O}$	

Denitrification and fermentation are based on the availability of organic material. It has been postulated that these materials could be available in the sub-sea floor through processes such as Fisher-Tropsch synthesis of cooling volcanic gases and water rock interactions (Zolotov, 2000).

MEDUSA

The Medusa sea floor monitoring system has been developed by Dr. Adam Schultz of the University of Cambridge to measure the temperature and velocity of hydrothermal effluent flowing out of sea floor hydrothermal systems, primarily at mid-ocean ridges. Medusa is also designed to capture a set of discrete samples of the fluid, either under the control of an operator connected to the instrument through a digital link, or under data logger timer control. Medusa is

designed to work with deep diving manned submersibles, and to be directly emplaced on the sea floor through the actions of the submersible. The system is designed to operate at ocean depths as great as 6,000 m and for periods in excess of one year. Figure 1 provides an image of the Medusa.

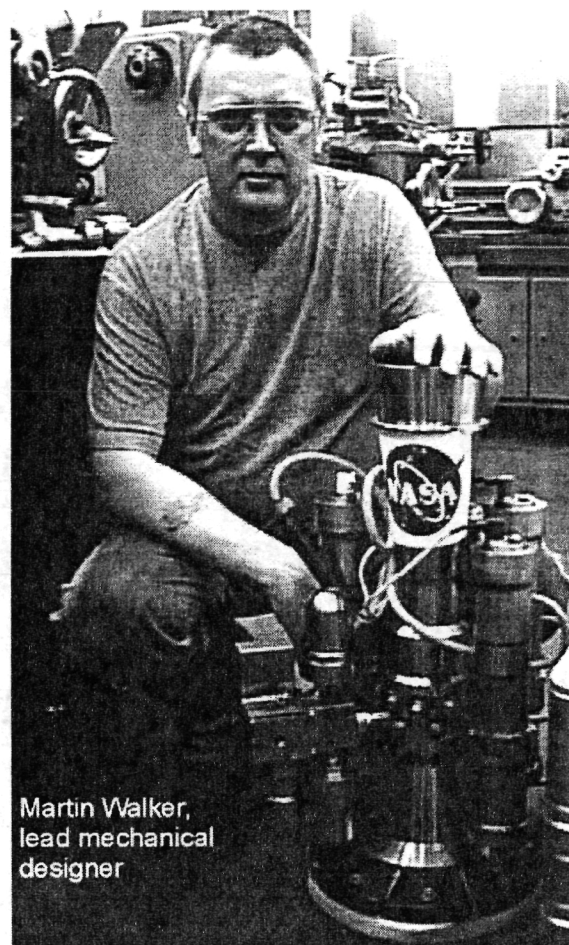


Figure 1. Scale image of Medusa.

Medusa is currently being developed with the support of NASA as a deep sea floor monitoring system capable of serving as a platform for future development of in situ measurement systems. The system uses a modular sensor head integrated into a venturi flow collector. When in operation the venturi is affixed to the sea floor bottom. Any hydrological transfer of fluid from or into the sea floor are thus concentrated at the sensor head. Velocity is determined by a hot wire anemometer. Temperature is measured through a combination of thermocouples and thermistors. Since the sensor head is designed as a modular unit the system can easily be upgraded to include specific ion probes and eventually optical sensors.

Medusa consists of two parts. The first major component is a sensor head. The second is an instrumentation pressure case.

The sensor head is connected to the pressure case by a single 18 conductor undersea cable, and signals related to the velocity and temperature of the effluent are transmitted from the sensor head to the datalogger electronics inside the pressure case. Signals commanding the effluent sample bottles to capture a fluid sample are sent from the pressure case to the sensor head. The pressure case electronics are, in turn, connected to the manned submersible by a second undersea cable which transmits digital information using RS-232 standards. This connection is used to control the functions of the Medusa system via a laptop computer installed inside the submersible. The temperature and velocity of the effluent, as well as other system and environmental parameters, are transmitted from the pressure case electronics to the laptop through this cable. The digital communications connector on the pressure case bulkhead is designed to survive immersion open-faced (i.e. unconnected to any mating connector) at pressures as great as 680 bar, and the entire Medusa system may be left on the sea floor, autonomously, for periods as long as one year. During such operations, the data are logged internally on a 120 MB disk.

The Sensor Head

The sensor head is a pure titanium construction configured as a venturi tube. The choice of pure titanium for the sensor head is a result of stringent temperature requirements; resistance to corrosion, and the need to maintain a chemically inert environment for purposes of chemical sampling. The use of a venturi tube configuration boosts the velocity of the fluid within the central section of the sensor head, thus increasing substantially the sensitivity of the instrument to low effluent velocities. By using a venturi configuration, the velocity boost is achieved while maintaining a minimum pressure drop on the hydrothermal system.

The venturi tube is 610.3 mm long and assembled from several components parts using titanium welding techniques.

A gasketing system consisting of high temperature resistant material with an inner 2.5 to 5 cm seal of disposable open cell foam is affixed to the outer periphery of the bottom of a flange on the inlet cone. The gasket system inhibits the lateral advection of seawater into the venturi tube, and prevents contamination of the effluent through mixing with seawater.

The Sensor Element

The sensor element consists of a removable titanium insert, or "coupon" upon which is fitted a flow sensor. Twin temperature sensors are also mounted in the coupon (described below). The coupon is inserted into

the venturi tube such that the flow sensor element is on the center line of the venturi tube.

Temperature Sensors

One type K and one type T thermocouple are positioned inside a single titanium sheath. The thermocouples are ungrounded. The unit uses two different types of thermocouples as a means of increasing the accuracy of the temperature measurements. Each thermocouple type has a different calibration curve, and thus each temperature measurement benefits from the solution of two equations for a single unknown. This allows an estimation of inaccuracy to be made for each temperature measurement. The thermocouples have a characteristic response time of approximately 5 seconds.

A thermistor is located at the cold junction of the thermocouples immediately outside the venturi tube, and this temperature is monitored as well.

Effluent Sample Bottles

Four 170 ml (nominal) capacity non gas tight titanium sample bottles are affixed to the outer periphery of the venturi tube. Upon either operator or timer command, an automated sampling syringe mechanism is activated. A small inlet is automatically inserted into the interior of the venturi tube. This is used to draw in a sample of the hydrothermal effluent. When the bottle is filled, the inlet is withdrawn and the bottle is sealed against ingress of additional fluid.

In addition to these non gas tight sample bottles two gas tight sample bottles are also provided. These bottles are evacuated and use ocean depth pressure to fill when a motorized valve is actuated.

Pressure Case

The pressure case is built of 6AL4V titanium alloy, with a designed pressure rating (collapse pressure) of 1,336 bar. The dimensions of the case are 533.40 mm O. D., 127 mm I.D. One end cap has no connectors, the second has bulkhead fittings designed to accommodate the necessary connector for cabling to the sensor head and a second connector for cabling to the submersible.

Electronics

The electronics necessary to operate the sensor head and to communicate to the submersible are housed within the pressure case. The case also contains a battery section which may be filled with as many as 12 DD sized lithium (3.7 V nominal) cells, or alternatively, 27 D sized (1.5 V nominal) alkaline cells. By using lithium cells, it is possible to power the system on the sea floor for very long periods of time. Use of alkaline cells is sufficient for

carrying out spot measurements during a normal submersible dive.

The main elements of the electronics section are

1. A four layer PC board positioned at the top of the internal electronics frame which contains signal conditioning circuitry for the velocity and temperature sensors.
2. A two layer PC board in the second level of the internal electronics frame that is a daughterboard to the internal datalogger, and which controls the water bottle actuators and also is responsible for serial communications and emergency interrupt/reboot signals.
3. The datalogger and 2.5" IDE 120 MB disk drive in the second level beneath the daughterboard.
4. A two layer PC board behind the datalogger on the second level containing counters and phase discriminators used by the velocity detector.
5. A battery section found on levels three and four.

The datalogger is based on the Motorola MC68332 processor, a low power datalogging variant of the MC68020 microprocessor. The basic system clock speed is 16 MHz, which is software-selectable. The datalogger includes 2 MB of pseudostatic RAM memory used as a disk buffer, and .5 MB of static ram. A 2.5" IDE interface disk drive rated to -200C provides 120 MB of disk storage. Communications between the datalogger and the operator are through a special opto-isolated RS232 serial link. Communications parameters and procedures are found later in this manual. The instrument comes complete with an executable control program for Medusa operations.

Medusa Instrument Weights and Power Consumption

Weights in Air in kg (Measured) and Water (Calculated)

ITEM	Wt (kg)	
	Air	Water
Pressure case	7.7	5.0
Cable looms & cold junction	2.7	2.7
PVC end cap protectors	5	0
Sensor element	5	0
<u>Sensor head including 2 bottles</u>	<u>17.7</u>	<u>16.4</u>
TOTAL	29.1	24.1

Note, the calculations of weight on volume calculations of 4338 cc for sensor head, 6755 cc for pressure case, and 2 x 280 cc for water bottles. These figures are approximate, and differ from the weights for Medusa Version 3/1.0 which are substantially LESS than those shown above.

Power Consumption

The Medusa power budget depends largely on sample rate. At higher rates the ADC is driven harder, and more power is consumed. The power consumption is also significantly higher for spot measurement (non-sea floor) mode, as the opto isolated RS232 serial link uses a significant amount of power. At faster sampling speeds, the RS232 uses more power because it operates nearly continuously. At lower sampling rates, there is a significant power savings since the RS232 is not used as frequently. For non-sea floor mode, typical power consumption is:

Sample Rate Voltage Current

1000 ms 12 V ~80 mA
5000 ms 12 V ~12 mA
10000 ms 12 V ~11 mA

CONCLUSION

The Medusa instrument package is designed to be deployed in an array of multiple instruments connected on the sea floor via acoustic modem. The system will ultimately be upgraded with a variety of advanced instrumentation currently under development by NASA. Some of the instrument packages currently under development include deep ocean rated gas chromatograph mass spectrometer (organics), a Tri-Spectroscopy Interferometric Micro-Imaging Sensor (Raman, adsorption, fluorescence), a fluorescent metabolic detection instrument (ATP, NAD[P]H, CaSUP +2 - dipicolinic acid complex, tryptophan and cytochromes), a deep ocean photometer (organics), and a fluorescent imaging microscope/molecular probe (microbial).

It is envisioned that when complete the Medusa system will be capable of conducting scientific investigations of extremely long duration (years) in situ investigations of diked hydrothermal vents and pre-existing bore holes. The general approach is to place a matrix of these units around a diked vent and then leave them there until an eruption occurs. The instruments will be triggered through an integrated seismometer and shall send data back to the surface via acoustic modem once triggered by a seismic event.

We recently conducted two deployments of the prototype Medusa system to the Juan De Fuca Ridge via the Woods Hole Institute of Oceanography's Alvin Submersible launched from the Atlantis research vessel. One unit was installed at the Ocean Drilling Program (ODP) bore hole 1025C, located 47deg 53' 247"N 128deg 38.919'W in a water depth of 2606 m on 9/24/99, and was later recovered by the Alvin at 13 15 (PDT) 9/29/99.

An analysis of the recovered Medusa ship board indicates that the new gas tight effluent sampling system worked well and both sample bottles were filled and held pressure up to the surface. 78 ml of effluent was captured by each sample bottle. In addition, the four conventional non-gas tight Medusa sample systems worked - giving us only the second seafloor chemical sample time series - and the only one from an ODP hole, capable of resolving chemical and biological variability on a diurnal time scale.

Onboard analysis of Ca in the samples reveals strong diurnal variability in fluids within ODP Hole 1025C - ranging from near seawater to 3x seawater levels. Additional analysis of these samples is currently being performed and will be published at a later date.

We also collected over 14 MB of time series data covering flow and temperature of the effluent of the Hole. This data was sampled near continuously with a 2 second integration period over the 9-day deployment.

The 2nd Medusa instrument was deployed at the Endeavor Main Vent Field via the Alvin submersible on a dive managed by Dr. William Seyfried of the University of Minnesota. The unit was placed adjacent to the S&M vent structure. They report it was deployed on a patch of mild diffuse flow issuing from a crack in pillow basalt, and flowing at about 13.5°C at the point of emission on the seafloor. They estimate (on a visual basis) that the flow out the top of the instrument was perhaps 1 cm/s. This instrument will be retrieved through a collaboration with Dr. John Baross, University of Washington, and Dr. Adam Schultz, University of Cambridge, UK, during the summer 2000 dive season. The goal of this deployment was to evaluate the ability of the Medusa system to generate long duration (1 year) data records in a relevant vent environment

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