MID-ATLANTIC RIDGE
36° 10'N – 37° 50'N:
RAINBOW TO LUCKY STRIKE

An Integrated Studies Site Proposal for the Ridge 2000 Program

This proposal was considered along with several other MAR ISS proposals at the start of the U.S. National Science Foundation Ridge 2000 Program. It was written by a group of proponents and reflects their vision. This ISS proposal was not endorsed for one of the 3 initial R2K ISS, however work by InterRidge researchers (including some US investigators, but dominantly French) did proceed at a modest rate and has increased since 2005. The summary contained here of R2K objectives that might be pursued in the MoMAR region provides a useful overview, and the synthesis of work (up to the year 2000) may be useful to some researchers beginning to consider work in the area.

MID-ATLANTIC RIDGE 36° 10'N – 37° 50'N: RAINBOW TO LUCKY STRIKE

An Integrated Studies Site Proposal

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INTRODUCTION

The challenge of selection of an integrated study site on a slow-spreading ridge is to find an area that is limited enough in extent to allow coupled studies from mantle to water column to be pursued in a single region, while at the same time having enough variability to encompass a significant range of accretionary variables. Established hydrothermal vents and associated biological activity are also essential in order to plan and carry out the integrated studies and to include all the disciplines involved.

The mid-Atlantic ridge extending south from the Lucky Strike segment to the AMAR segment (Figure 1) fulfills these objectives for the central mid-Atlantic Ridge:

** Hydrothermal vents of diverse styles are well located and extensively investigated. The region contains three well-known hydrothermal sites- Lucky Strike, Saldanha and Rainbow. Lucky Strike vents occur in the center of a segment associated with a central seamount and a very young lava flow. Rainbow and Saldanha vents occur on ultramafic rocks within a ridge offset. These sites are extensive and long-lived, with substantial signals in the overlying water column.

** Life is abundant and complex at the hydrothermal sites. The Lucky Strike and Rainbow sites belong to distinct biogeographical provinces, and occur on diverse host rocks, permitting diverse scales and types of biological problems to be investigated.

** There is a large range of segment styles. The Lucky Strike segment is long (70km) and rectangular with a large mantle Bouguer anomaly and a large central seamount. It is a prime candidate for magmatism primarily by injection at the segment center. Immediately to the south is the shortest well-formed segment in the central north Atlantic, the North Famous segment. This segment has the smallest mantle Bouguer anomaly in the North Atlantic, and has no evidence of hydrothermal activity. The FAMOUS segment is the type example of an hour glass shape, and in contrast to the Lucky Strike segment has a series of small volcanoes along its entire length, suggesting far more distributed volcanism than is the case at Lucky Strike. The most southerly segment in the proposed area is the AMAR segment, which appears to have undergone far more extensive recent tectonic extension than the FAMOUS segment immediately to the north.

** There has been extensive background work, and the area will be the focus of the InterRidge MOMAR (Monitoring the Mid-Atlantic Ridge). Therefore a monitoring presence and frequent visits are more feasible than at other Atlantic sites.

** There is a distinctive petrological signal in the region that permits innovative tests of segmentation models. The region occurs within a chemical gradient south of the Azores hot spot, and the Lucky Strike segment has a pronounced geochemical enrichment

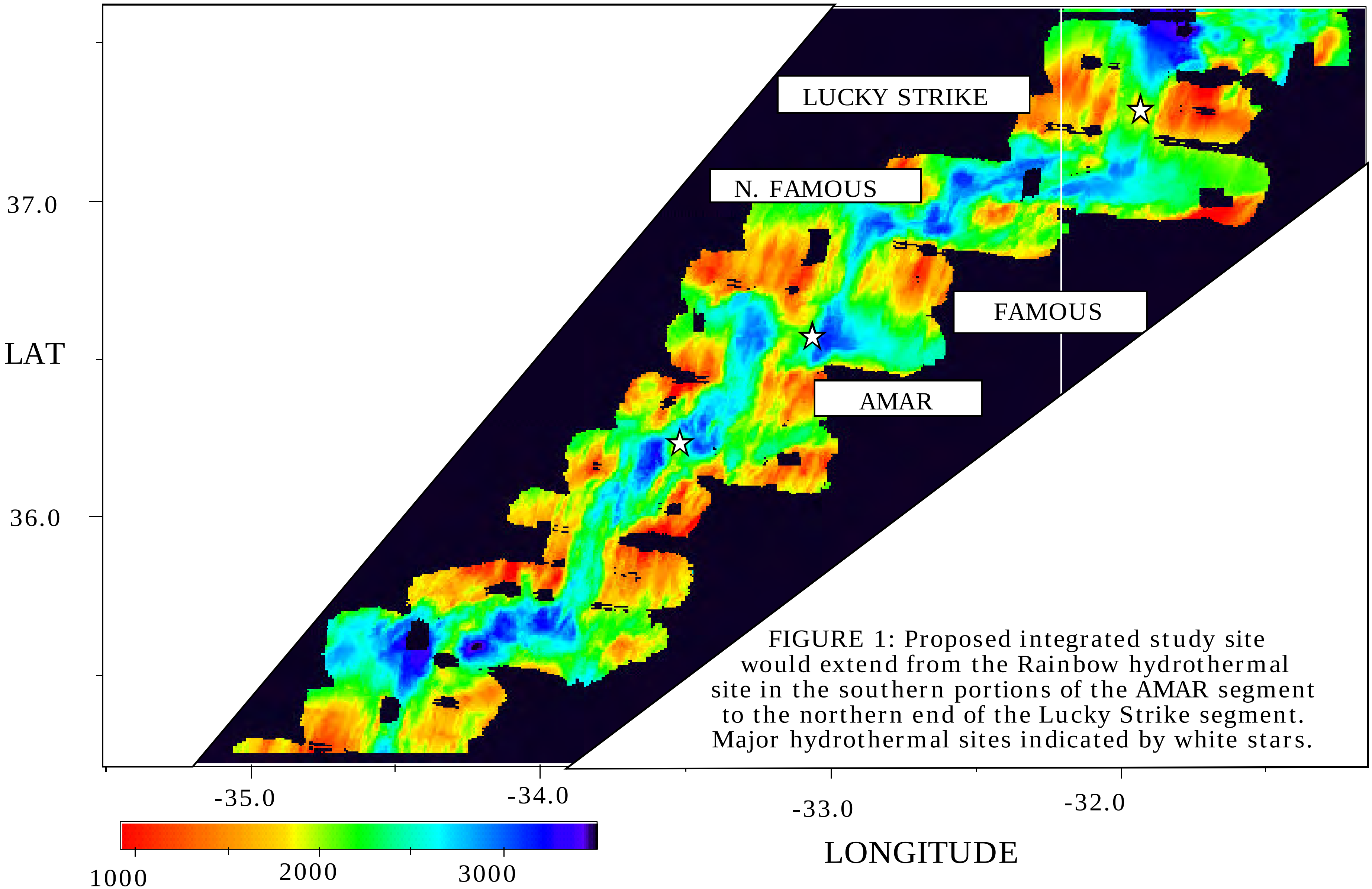

FIGURE 1: Proposed integrated study site would extend from the Rainbow hydrothermal site in the southern portions of the AMAR segment to the northern end of the Lucky Strike segment. Major hydrothermal sites indicated by white stars.

spike at its center. These two features provide a geochemical structure than can be used to test models of melt flow and ridge segmentation.

These general considerations can be made more specific by considering what factors an integrated studies site should encompass to be able to fulfill the diverse objectives outlined in the planning document. An integrated studies site should:

(1) Fulfill site selection criteria in the planning document;

(2) Provide a setting where the seven scientific questions in the planning workshop report can be addressed at a reasonable level of effort;

(3) Be an area where DEOS and drilling programs can be effectively integrated and international cooperation is likely.

FULFILLS SITE SELECTION CRITERIA

Encompasses a representative variety of micro and macro-fauna

Biomass at the Lucky Strike vent community is dominated by mussels (*Bathymodiolus azoricus*; Van Dover et al. 1996, Langmuir et al. 1997, Comtet and Desbruyeres 1998). Associated fauna is characterized by small, highly mobile crustaceans (amphipods, ostracods, copepods; Van Dover and Trask 2000), in contrast to that of East Pacific Rise mussel beds, wherein sessile invertebrates such as tubicolous polychaetes and limpets share dominance with amphipods (Van Dover, submitted). Biomass is also substantially lower within Lucky Strike mussel beds compared to East Pacific Rise mussel beds (Van Dover, pers observ), which may be at least in part a consequence of lower sulfide concentrations at Lucky Strike (Von Damm 1998). The Lucky Strike vent fauna, together with that of Menez Gwen, belong to a biogeographic province that is distinct from that of deeper vent fields to the south (TAG, Snake Pit, Broken Spur, Rainbow, Logatchev; Van Dover et al. 1996, Langmuir et al. 1997).

Encompasses a representative variety of hydrothermal venting styles, fluid and particulate compositions

In the Lucky Strike segment many new active vents and large areas of low temperature diffuse flow have been identified surrounding a central lava lake (Langmuir et al. 1997; Fouquet et al., 1994a, b, c; Charlou et al., 2000). Studies of the vent fluids have demonstrated the importance of phase separation and the enriched and altered nature of the substrate in controlling their chemical compositions, and have indicated there may be two distinct sources of fluids (Von Damm et al., 1998; Charlou et al., 2000). There is also extensive diffuse flow (Cooper et al, 1997), and large numbers of fossil chimneys that are no longer active.

Rainbow is one of the most active hydrothermal sites in the Atlantic, with at least ten clusters of high temperature vents emitting fluids particularly enriched in methane and H_2 (Fouquet et al. 1997; Donval et al. 1997). Therefore this region encompasses in a small region the entire MAR spectrum of venting styles and fluid compositions.

Encompasses a representative variety of rock types and compositions

Rock types in this region are variable both chemically and lithologically. The chemical variability in this region extends from modestly LREE depleted $(La/Yb)_n$ = 0.6 to strongly LREE enriched for a few compositions at the center of the Lucky Strike segment (Langmuir et al, 1997). Samples also encompass a large range in MgO content, so that differentiation processes are well expressed in the erupted lavas. The FAMOUS and AMAR segments are know to encompass a very large range of chemical compositions, with significant changes across the width of the rift valley (Bryan and Moore, 1977; White et al, 1977; Le Roex et al. 199x; Frey et al. 1996).

Non-transform offsets in this region are known to have extensive outcrops of ultramafic rocks (Fouquet et al. 1997), but as with most other parts of the MAR there has not yet been systematic study of the rift valley walls and inside corner highs in this region, and therefore full documentation of the lithological variability is not yet well known. However, even limited sampling has recovered peridotites and gabbros from non-transform offsets and from the transform faults in this region (Schreiber and Fox 1977), and from drilling on 3Ma crust at the latitude of the FAMOUS segment during DSDP leg 37. Therefore it is evident that rocks from lower crustal and mantle levels are well exposed.

Displays a significant hydrothermal signature in the water column

Several surveys of the water column in the Lucky Strike-RAINBOW area have detected hydrothermal plumes on the basis of temperature, nephelometer, and transmissometer anomalies, and/or high methane of Mn concentrations. The known sites in the area are listed in Table 1.

Table 1. Hydrothermal Plumes Detected between Lucky Strike and Rainbow*

37°17'N	Lucky Strike Seamount site	Plume at 1450 m associated with known LS Plume at 1750-1800 m to north of the axial seamount
37°03'N	NTO at south end of Lucky Strike	Nephelometer depth of 1750-1800 m; high particulate Fe; methane anomaly at 1800 m
36°57'N	NTO at north end of N. FAMOUS	Small methane anomalies at 2250 m and 2600 m
36°38'N	Southern limit of FAMOUS	Methane anomalies at 1947 m and 2237 ml; max. nephelometer signal at 2400 m; high Mn; low temperature diffuse flow (Saldanha site)
36°15'N	Rainbow	Methane, nephelometry observed over 50km

* Data from German et al. (1996); German et al (1998); Chin et al. (1998); Bougault et al (1998); Charlou et al. (2000); Gracia at el. (2000); Parson et al. (2000).

These occurrences show that the tectonic settings of hydrothermal activity in this region range from the summit of a seamount in the center of a magmatically robust segment (Lucky Strike) to sites that are either adjacent to (southern FAMOUS site) or within (S. Lucky Strike, north FAMOUS, Rainbow) the non-transform discontinuities that offset the segments. In addition, description of rock types exposed in some of these areas show that hydrothermal sites are hosted in both mafic and ultramafic rocks.

Encompasses a representative range of ridge offsets

The ridge offsets in the study area show diverse morphological characteristics. The AMAR segment, where the Rainbow site is located, is bounded on the south and north by non-transform offsets. Transform faults are located between the FAMOUS and North FAMOUS segments as well as between the North FAMOUS and the Lucky Strike segments. Between the Lucky Strike and Menez Gwen segments is an unstable feature that appears to have propagated southward as the Menez Gwen segment lengthens. While the individual ridge offsets in the study region are relatively short (<60 km), the integrated offset length from 36°27'N to 38°16'N is over 220 km, making the Lucky-FAMOUS area one of the most oblique sections in the north Atlantic. The area encompasses all major morphological features representative of slow-spreading ridge offsets, including transform valleys, nodal basins, inside-corner highs, and septums between overlapping rift valleys [e.g., *Detrick et al.*, 1995*; Cannat et al.*, 1999; *Escartin et al.*, 2001].

Encompasses a variety of morphological expressions

This study area also encompasses a wide range of morphological expressions characteristic of slow-spreading crust. On the northern part of the study area, the Menez Gwen and Princess Alice segments are associated with an axial topographic high rather than a rift valley. The Lucky Strike segment shows a transitional morphology with a subtle axial rift valley that diminishes towards the segment center, where evidence for recent volcanism was found [*Ondreas et al.*, 1997]. In contrast, the North FAMOUS, FAMOUS, and AMAR segments, which lie on the southern part of the study area, show clear axial rift valleys that are typical of the Mid-Atlantic Ridge elsewhere, for example in the Kane to Atlantis area [*Sempere et al*, 1993; *Lin et al.*, 1990]. The AMAR segment appears to have a much greater influence of tectonism than the FAMOUS segment. The diverse morphological expressions of the study area reflect a spectrum of ridge-axis thermal regimes in the study area, making it an idea place to test ridge geodynamics models.

Has Favorable Logistics

This region is logistically favorable, because of the short transit from the Azores to the region. The Lucky Strike hydrothermal site is twenty-four hours from Punta Delgada. This short transit and location near a major mid-Atlantic port makes it feasible to have very short cruises where desirable, to stop at the site while on the way to or from other central Atlantic destinations, and to have planned very rapid response to sea floor events, except in winter. Water depths are less than more southerly areas along the mid-Atlantic Ridge, leading to significant advantages in wire time.

For seismic studies the region lies within the window of 23°N – 38°N that Wilcock et al. (1999) identified as desirable for low enough levels of noise for seismic experiments.

Another important aspect of site logistics is the scale of the site. There is always the urge to expand the scale of a "focussed" site to such an extent that it is no longer focussed. The scale of a site has important logistical consequences. The total number of cruises that can be mounted for an integrated study site will be rather limited. To obtain correlated data sets where seismic structure, high resolution side scan, detailed rock sampling, water column and detailed biological studies can all be collected in the same region places serious limitations on the scale of the area. For example, a detailed water column survey of a single segment can take an entire cruise. Rock sampling on the scale of one sample per square km (a scale which would be sparse for detailed studies of subaerial volcanoes) is necessary to map petrological variations along and across strike. This requires 400 sampling stations for a 50 * 8 km segment. A 100 *15km segment would require 1500 stations! Therefore the role of an integrated study site is not to encompass the entire range of slow-spreading variables, but instead to examine the vertical connections between different data sets in one constrained area.

Another logistical aspect is synergies with other programs that will bring important resources to the problem. The Lucky Strike region has been selected as the MOMAR site (Monitoring the Mid-Atlantic Ridge) by the European Community, and is the site of intensive on-going and planned research and cruises. The combination of US and European field programs, and joint programs in areas such as seismology where many more instruments could be deployed, means that the integrated study site objectives are far more likely to be accomplished in reasonable time frame and with realistic allocation of resources.

Has sufficient background data available

This region is one of the most extensively studied areas of the mid-Atlantic Ridge, and has been the focus of study for thirty years by both European and US investigators. The FAMOUS and AMAR projects took place in this region leading to what were the best studied segments on the mid-Atlantic Ridge. This area was also a focus of the FARA program which involved some twenty US and French cruises in the 1990's. Several European programs have taken place in the last five years, and several more are planned for the near future. Drilling occurred off axis in this region on Legs 37, 49 and 82 of the drilling program. Data available include multibeam bathymetry out to an age of 10Ma, gravity, magnetics, water column sampling, vent sampling, petrological sampling, regional and detailed biological studies, deep-towed bathymetry, side-scan and water column sampling, larval water column dispersal, sediment sampling, deep sea drilling and seismic structure.

Examples of these studies are high-resolution, near bottom geophysics [e.g., Macdonald et al., 1975; Luyendyk and Macdonald, 1977; Heirtzler and van Andel, 1977; Macdonald and Luyendyk, 1977; German et al., 1996; Scheirer et al., in press]; sea surface geophysics [e.g., Whitmarsh et al., 1976; Vogt, 1976; Phillips and Fleming, 1977; Detrick et al., 1995; Cannat et al., 1999; Escartin et al., 2001]; hydrothermalism [Williams et al., 1977; Hoffert et al., 1978; Wilson et al., 1996; Langmuir et al., 1977; Bougault et al., 1998; Von Damm et al 1998], water column studies [Chin et al. 1998; German et al. 1998; Bougault et al. 1998]. geological mapping and sampling [Gràcia et al., 2000]; seismics [Whitmarsh, 1973; Poehls, 1974; Fowler, 1974; 1976; Francis et al., 1977]; geochemistry and petrology [White and Bryan, 1977; Frey et al., 1993]; magnetism [van Wagoner and Johnson, 1983; Prevot et al., 1988]; volcanism/tectonism near the ridge axis [Ballard and van Andel, 1977; Ramberg et al., 1977; Ramberg and van Andel, 1977; Choukroune et al., 1978; Crane and Ballard, 1981; Goud and Karson, 1985; Ondreas et al., 1997]. Most of the high-resolution studies have taken place within the axial valley, allowing the characterization of along-axis variations in magmatism and tectonism.

A list of many of the recent cruises and data collected in this region are presented in Table 2. More than 100 references with data from this region are included in the reference list. Multibeam data is available through the RIDGE Multibeam Database (http://coast.ldeo.columbia.edu/) and through the IFREMER web site; petrological data from are available through the RIDGE petrology database, PETDB (http://petdb.ldeo.columbia.edu/testpetdb/); side scan and photographic data are available through Dan Fornari and Susan Humphris. To give some idea of the scope of existing data, PETDB has 2340 sample records for this region from more than 100 references for petrology alone. Rather than list all those samples and references here, the interested reader is referred to PETDB! Additional data will be compiled and made available over the internet if development of this site proceeds.

TABLE 2

Proposed and Upcoming Cruises to the Lucky Strike-Rainbow Region

Lucky STAR	active and passive seismic study across the Lucky Strike area, submitted Jan 2001, Javier Escartin, PI.
ATOS	PI Sarradin, ROV Victor, Rainbow & Lucky Strike Summer 2001
IRIS	Pi Y. Fouquet, ROV Victor, Rainbow, hydrothermal in peridotite, Summer, 2001

Recently Completed Cruises to this Region

FARA-SIGMA	Multi-beam bathymetry/gravity , Atalante, 1990
HEAT	Tobi and side-scan sonar, Discovery, 1994.
FAZAR	Basalt and water column sampling, R/V Atlantis II, 1992
AII129-6	First Alvin dives on Lucky Strike, Mid-Atlantic, Atlantis, Alvin 1993
DIVA 1:	(Lucky Strike Segment) Hydrothermal site submersible sampling, petrology, hydrothermal chemistry, Nadir, Nautile 1994
DIVA 2:	(Lucky Strike Segment) Hydrothermal site submersible sampling, biology Nadir, Nautile 1994
FLORES	Diving on the Rainbow site, Nadir, Nautile, 1996
LUSTRE:	Lucky Strike, MAR Argo, Jason and AMS-120 surveys of central seamount
CRISTA I:	Menez Gwen and Lucky Strike vent sites Collect fish and crustaceans, test new mooring equipment, baited longlines and fishing nets. Arquipélago 1997
CRISTA II:	Menez Gwen and Lucky Strike vent sites Arquipélago Nov. 1997
LUCKY—	Diving and hydrothermal sampling of Lucky Strike Atlantis, Alvin, 1997
FLAME:	Fluxes at AMAR Exp.: Rainbow, LuckyStrike, Famous, 36°-37°N Discovery, 1997
FLAME-2	Hydrography and sampling of AMAR segment and Rainbow site. Poseidon, PICO (Picking Instruments and Cleaning Operation) on the Azores Triple Junction Area (Menez Gwen, Lucky Strike, Famous and Rainbow Nadir, Nautile 1998
SALDANHA	South Famous, Menez Gwen and Rainbow, Mid-Atlantic Ridge Diffuse & discrete venting, biology, sampling Nadir, Nautile 1998
MODE2	TAG mound and area, and the Rainbow site, Yokosuka, Shinkai 6500 1998
SUDACORES	Geophysics (gravitymagnetics/bathymetry/dredging), Atalante, 1998
MADRIGALS	Mid-Atlantic Deeptowed Resistivity and Induction Geophysics at Lucky Strike, Charles Darwin 1999

PROVIDES A SETTING WHERE FUNDAMENTAL SCIENTIFIC QUESTIONS CAN BE ADDRESSED AT A PRACTICAL LEVEL OF EFFORT

The scientific goals of Integrated Studies have been well enunciated in the RIDGE 2000 planning document and the report of the Integrated Studies Planning Workshop. Therefore we will not elaborate on those questions here, but instead indicate how the seven fundamental questions developed in the in integrated studies document can be investigated efficiently in the Lucky Strike to Rainbow region.

(1) How and to what extent does hydrothermal flux influence the physical, chemical and biological characteristics of the overlying ocean?

This requires known hydrothermal vents of varying types, and clear manifestation in the water column. Lucky Strike and Rainbow are two of the largest sites in the Atlantic, and Rainbow has the largest documented plume in the water column. Biological dispersal in the water column is already being successfully investigated, as has the role of hydrothermal plumes on physical properties of the ocean. Therefore the physical, chemical and biological impact of hydrothermal vents is clearly a major and appropriate focus for this region.

(2) What is the nature and space/time extent of the biosphere from deep in the subsurface to the overlying water column?

The abundant life around the vents and in the overlying water column is well documented. Having a limited region enables drilling to investigate a host of multi-disciplinary problems, including the deep biosphere. Having a site close to port makes time series measurements more practical.

(3) What are the forces and linkages that determine the structure and extent of the hydrothermal biosphere?

This question is particularly difficult to investigate at an integrated site, because its formulation implies investigation of a range of variables. However, this region has sites with very diverse characteristics in a limited area. Lucky Strike is hosted on volcanics with evidence of a recent eruption and occurs at a segment center. Rainbow is hosted by ultramafics, occurring at a ridge offset with no volcanic activity. Both Lucky Strike and Rainbow have vigorous hydrothermal activity. Saldanha is a site with much more limited hydrothermal manifestation. These regions have diverse biological manifestations as well. Therefore forces and linkages clearly vary, and the biology varies as well, making this area ideal for investigating this question.

(4) How does biological activity affect vent chemistry and hydrothermal circulation?

This question requires diverse vents, diverse biology and time series measurements. Lucky Strike has vents that emit fluids of diverse chemical composition providing a single area where linkages between vent chemistry and biology can be investigated. Fluids at Saldanha and Rainbow are even more distinct, providing a large dynamic range to explore.

(5) How does hydrothermal circulation impact melt composition, crustal structure and composition, and ridge morphology? And (7) What are the relationships among mantle flow, mantle composition, crustal geology, ridge morphology and segmentation?

These questions require comparison of segments with different styles of hydrothermal activity, including those with little or no active venting, and segments with different morphological characteristics It also implies the determination of hydrothermal circulation, which requires drilling and long term monitoring. Coordinated studies must be undertaken such that crustal structure determined by seismic methods and detailed mapping occur for the same segments. Questions of mantle flow and structure require seismic tomography.

The combination of diversity and coordinated studies at a scale that is logistically feasible is exceptionally well met by the Lucky Strike to Rainbow region. There is a large range in ridge morphology, there are hydrothermally active and inactive segments, and the scale of the region is such that coordinated studies can be undertaken. The region lies within the latitudinal band appropriate for seismic tomography identified by Wilcock (1998).

(6) How are melt and fluid transport organized within the mantle and crust?

Addressing this questions requires a combination of seismic structure of entire segments, seismic tomography, geological mapping of the seafloor, detailed petrological sampling, and, one hopes, documentation of eruptive activity. There is also unlikely to be a single answer to this question, as some segments, such as Lucky Strike, show evidence of magmatism concentrated at the segment center, while others, such as FAMOUS, have evidence for small volcanic episodes distributed along most of the length of the segment. Therefore both types of segments need to be investigated.

Addressing this question adequately also requires a consideration of scale. Detailed mapping and sampling of a segment requires extensive ship time. A segment 100km long and 10km wide simply cannot be mapped and sampled in detail. On the other hand, a segment such as North FAMOUS, which has all the geological and tectonic attributes of an MAR segment but is only 17km in length, can have a complete documentation that is simply not feasible with the largest segments. This region strikes an excellent balance between dynamic range of variability and logistical feasibility—the mantle Bouguer anomaly and segment length contrast between Lucky Strike and North FAMOUS is large, yet the sizes of the segments are small enough to be investigated thoroughly.

ALLOW FOR ACTIVE LIAISON WITH OTHER PROGRAMS AND INFRASTRUCTURE

The limited scale and beneficial logistics of this region enable optimal integration with other programs.

As the subject of intensive investigations the region is well suited to future drilling proposals. Drilling would be more efficient in this region because of the shallower water depth relative to most other portions of the MAR. Successful drilling took place in this region on legs 37, 49 and 82.

This region is the site of the InterRIDGE program, Monitoring the Mid-Atlantic Ridge (MOMAR), which plans to set up deep sea instrumentation and an observatory in this area over the next decade (see the InterRidge planning document). Additional meetings to enable implementation of the MOMAR program are taking place in Europe over the next six months.

Because the Lucky Strike site lies in Portuguese waters, the European Community has a particular interest in portions of this region, as indicated by the large number of cruises that have focussed on this area in the last five years. Because the accomplishment of the diverse objectives of integrated studies requires a substantial effort over a long period of time, the possibility that the full potential will be achieved is enhanced by international cooperation, and the leverage provided by visits from many ships from diverse nations. Time-series measurements, deployment and recovery of instrument, repairing malfunctioning equipment, event monitoring—all these and other activities central to integrated studies require frequently repeated presence. Having an international group working in one area that is only 24 hours from port substantially enhances the possibility that the scientific objectives can be achieved.

Deployment of a buoy as part of the DEOS program would also be favored by the positive aspects of this site. Sites to be serviced by buoys must be limited in extent, and focus on a small region is consistent with instrumentation and monitoring of processes from the mantle through to the water column. The short distance to port also facilitates maintenance and repair of the buoy.

WHY IS LUCKY STRIKE TO RAINBOW A SLOW SPREADING SITE RATHER THAN A HOT SPOT SITE?

Some may criticize this site location because of its proximity to the Azores hot spot. However, ridge segments show normal variations in this region. The FAMOUS segment, with its isolated volcanoes, appears to be in a less robust magmatic state than the segment south of Kane with its well developed axial ridge; segments with clearly focussed magmatism at the segment center, such as the Lucky Strike segment, are found at many places along the MAR, and the AMAR segment appears to be in an extensional phase compared with the hour- glass FAMOUS segment. That is, the range in segment styles and the questions that can be addressed are fully characteristic of a slow-spreading ridge.

Indeed, the mild hot spot influence in this region provides a number of advantages for an integrated study site:

(1) The site is close to port (conveniently provided by the hot spot), providing a host of logistical advantages;

(2) There are significant variations in apparent magmatic budget over relatively short distances.

(3) There are gradients in the chemical compositions of basalts that allow formulation of unique tests for segmentation models.

Furthermore, the influence of the Azores hot spot, and the Oceanographer chemical anomaly (which may also be a hot spot influence), extends over most of the central North Atlantic. Bougault and others suggested that the chemical boundary for the Azores hot spot was the Hayes fracture zone. Highly enriched basalts, influenced by the Oceanographer anomaly, occur immediately south of the Oceanographer fracture zone (35°N) and therefore this region is certainly also hot spot influenced. And the mean depth of the ridge and $^{87}Sr/^{86}Sr$ ratio decrease steadily from the Azores all the way to the Kane fracture zone. Therefore "hot spot influence", depending on how it is defined, encompasses the entire central North Atlantic.

Full investigation of ridge/hot spot interactions requires a far larger scale of investigation than a focussed integrated study site, because hot spot influence can extend over characteristic distances of thousands of kilometers. Therefore this proposal is not for a “hot-spot ridge interactions” study because the problems associated with hot spots are much larger in scale. Instead, we note the advantages of having ridge segments with normal structural expression and modest hot spot influence as an ideal laboratory for investigating how ridges behave.

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