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# Serpentine cruise - ultramafic hosted hydrothermal deposits on the Mid-Atlantic Ridge: First submersible studies on Ashadze 1 and 2, Logatchev 2 and Krasnov vent fields

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## Summary of operations and cruise objectives

During the French-Russian Serpentine cruise (Feb. 25 - Apr. 5, 2007) on board the R/V *Pourquoi Pas?*, we used ROV *VICTOR 6000* to conduct multidisciplinary explorations and sampling on ultramafic hosted hydrothermal fields between 13°-17°N on the Mid-Atlantic Ridge (MAR). The Serpentine cruise was part of a 4-year cooperation program between France and Russia. Targets were the Ashadze 1 and 2 (12°58'N), Logatchev 1 (14°45'N) and 2 (14°43'N) and Krasnov (16°38'N) hydrothermal fields (Fig. 1). These hydrothermal fields were localized after several Russian cruises of the R/V *Professor Logatchev*. The major objective of the Serpentine cruise was to study the geological, geochemical, biological, and microbial processes in hydrothermal fields associated with mantle derived serpentinites along the MAR. Four targets, Ashadze 1 and 2 and Logatchev 1 and 2, are on serpentinized peridotites and interspersed gabbroic basement rocks. In contrast, Krasnov is on a basaltic basement. In addition to the sampling operations, a significant portion of the dives was dedicated to obtaining real-time, fine-scale multibeam bathymetric maps. These maps, post-processed on board for subsequent use for sampling operations, have a resolution of a few tens of centimeters. This type of map was for the first time obtained on a ridge at 4000-m water depth. Near seafloor high resolution magnetic maps (3-component magnetometer), CTD and turbidity measurements, water sampling and in situ manganese analyses were also performed during the bathymetric surveys. A high resolution black and white camera (OTUS) was also used to produce mosaic images of the active hydrothermal fields. ROV observations and sampling were complemented by a night program of dredging, water sampling, CTD, and geophysical surveys. The data obtained at 3 altitudes (50, 20, and 8 m) above the seafloor allow us to produce bathymetric maps, physical and chemical anomalies maps, as well as magnetic and biological maps at different scales. The results of the explorations lead to the first submersible observations of three new, high-temperature, active hydrothermal sites at Ashadze 1, Ashadze 2, and Logatchev 2 (Fouquet et al., 2007) and of one inactive hydrothermal site (Logatchev 5). The importance of the inactive Krasnov site as the largest currently known accumulation of seafloor massive sulfides in the oceans was also confirmed.

## Previous work

All three hydrothermal fields and massive sulfide deposits studied during the Serpentine mission were initially discovered by Russian marine geologists (PMGE and VNIIOkeangeologia) on cruises with R/V *Professor Logatchev* over the last 15 years.

**Ashadze.** Ashadze hydrothermal field was discovered in 2003 and later extended in 2005 (Beltenev et al., 2003, 2005, 2007). This field was known to consist of three closely spaced hydrothermal sites (Ashadze 1, 2 and 3, respectively) located at about 13°N, 44°50'W (Fig. 2). Initial studies at 13°N on the MAR revealed large anomalies of turbidity and dissolved manganese in the water column (Sudarikov et al., 2001) and the occurrence of pyrite, barite and iron hydroxides in the sand fraction of the sediments (Beltenev et al., 2003). In 2003 dredging from R/V *Professor Logatchev* at the most promising selected site yielded 120 kg of massive sulfides associated with serpentinites. The presence of hydrothermal deposits and biota at this site, named Ashadze 1, were later confirmed by TV profiling. Distinct turbidity anomalies were subsequently recorded at Ashadze 3 but not at Ashadze 2. The Ashadze 2 site was discovered by monitoring anomalies in the electric potential (EP) recorded by the deep-towed RIFT system during the 2003 cruise. The dimensions of the Ashadze 1 site were estimated to be 450 x 350 m. This site includes two main sulfide deposits with adjacent metalliferous sediments highly enriched in Fe, Cu and Zn. Sulfide deposits are mainly represented by chimney fragments. TV-profiling at the Ashadze 2 site revealed the presence of three ore bodies. The largest of these was about 200 x 100 m. The Ashadze 2 site was estimated to be two times larger than the Ashadze 1 site. Fragments of massive sulfide composed entirely of massive chalcopyrite oxidized to varying degrees as well as iron-manganese crusts, hydrothermally altered gabbroids, and

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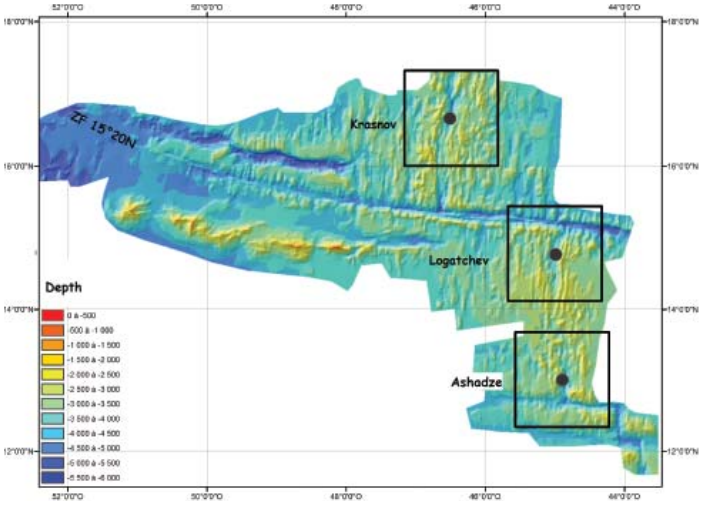



**Figure 1:** Working areas during the Serpentine cruise.

serpentinized peridotites were dredged at this site.

**Logatchev.** The Logatchev hydrothermal field was discovered at 14°45'N in 1994 and also was known to consist of several separate sites: Logatchev 1 (main and largest site) and 2 (Fig. 3). The Logatchev 1 hydrothermal field at 14°45 N was discovered in 1994 by using deep-towed RIFT system (with measurement of EP) and subsequent TV profiling and sampling (Batuev et al., 1994). However, high $CH_4$ and Mn concentrations in deep seawater in this region were detected earlier (Klinkhammer et al., 1985; Charlou and Donval, 1993). Sulfide-like deposits were found and photographed at 14°54'N near the foot of the eastern wall of the rift valley (Eberhart et al., 1988). The first samples of hydrothermal sulfides not far from Logatchev were dredged from the rift valley walls 20 km from the ridge axis in 1990-1991 by Russian geologists. In the following years, after 1994, the Logatchev hydrothermal field was revisited many times by Russian (Krasnov, et al., 1995; Bogdanov et al. 1997; Gebruk et al., 1997, 2000; Mozgova et al., 1999; Cherkashov et al., 2000; Sudarikov et al., 2000) (e.g., *MIR* diving expeditions in 1995 and 1998), French (MICROSMOKE, 1995; Poroshina et al., 1998), German (Kuhn et al., 2004; Schmidt et al., 2007; e.g., see article by Borowski et al., this volume), American (MAR-97, 1997; DIVERSE, 2001), and Chinese (Zhou et al., 2007) expeditions. Prior to the Serpentine cruise the Logatchev 2 field was never visited by a submersible or ROV and was considered inactive.

**Krasnov.** The Krasnov field is an inactive hydrothermal field at l6°38.4'N, 46°28.5'W that was identified and sampled in 2004 (samples of massive sulfides were recovered and video records of the deposits made; Beltenev et al., 2004). Hydrothermal signals had already been recorded from near-bottom waters and bottom sediments at l6°38'N during a cruise of R/V *Professor Logatchev* in 1999. Later, in 2006 the field was extended and new sulfide deposits were recovered. This field is located at a depth of 3700-3750 m, 600 m above the inner floor of the eastern slope of the rift valley (Fig. 4). It lies in a depression connecting the axial volcanic high with the rift slope. Basalts form the host rocks of the sulfide deposits. Two sulfide mounds and several sites of metalliferous sediments were sampled and recorded by video profiling within the hydrothermal field. The largest sulfide mound is located in the southern part of the field and has dimensions of 500 x 300 m. A giant outcrop of massive sulfides 70-100 m high along the scarp zone in the central part of the main mound was detected by video profiling. Another smaller sulfide mound displaying similar structures was also discovered 100 m to the north from the first one.

## Cruise results: Regional setting of the vent fields

At Ashadze, the top of the wall, at 2300-m depth, corresponds to the termination of a large fossil corrugated surface. The axial valley at this latitude is strongly asymmetric, with higher relief to the west. This asymmetry is reversed immediately to the south, where the axial magnetic anomaly appears offset by a few kilometers to the west (Cannat et al., 2007). The active and extinct Ashadze vents are roughly aligned to the north of an irregular, south-facing slope, which we interpret as the surface expression of this minor axial discontinuity (Cannat et al., 2007). We find similarities between this general context and the setting of the two active Logatchev vent fields: Logatchev 1 on the east axial valley wall near 14°45'N, and the smaller Logatchev 2 in a seemingly off-axis position near 14°43'N. Both fields lie to the north of a small offset axial discontinuity, and in an inward position relative to fossil corrugated surfaces. Based on seafloor morphology, dive observations, and rock sampling, we developed a model whereby ultramafic-hosted hydrothermal venting in the 13-15°N region of the MAR involves both large active normal faults, and an inside corner-type position relative to a small ridge offset. The geologic control of the Krasnov site is simpler. The sulfide deposit is located at the top of the eastern rift wall, where a large volcano, rising from the rift valley floor to the top of the rift valley walls, coalesces with the rift wall.

## High resolution mapping and local geological setting

Near seafloor high-resolution bathymetric maps were obtained using a new multibeam bathymetric system (RESON 7125 echo sounder) mounted on ROV *Victor*. The resolution of these maps is 5% of the altitude above the seafloor. Detailed maps obtained on board and direct observations with the ROV allow us to precisely determine the local geological and tectonic settings for each hydrothermal field. Maps at 50 m above the seafloor were done to investigate the relationships between the vent fields and their tectonic/volcanic environments. Higher resolution mapping, 20 m above the seafloor, was done at the scale of the vent fields. These maps, which have resolutions of

a few tens of centimetres, are unique tools to understand the local geological control on the vents. Our observations also emphasize the role of slope failure, and spreading-parallel or oblique structural lineaments on the fine scale topography of MAR axial valley walls and the control of the hydrothermal discharge (Ondreas et al., 2007).

**Ashadze.** The Ashadze 1 hydrothermal field is located on the western slope of the MAR rift valley and differs from all previously discovered MAR high temperature hydrothermal fields that are located on the eastern rift slopes or in the central (axial) part of the rift valley. This area was the main goal of the cruise. One major result of the Serpentine cruise is the discovery of two active black smoker fields (Ashadze 1 and Ashadze 2) located at different levels on the western wall of the axial valley: Ashadze 1 at 4100 m depth, and Ashadze 2 at 3300 m (Fig. 2). The Ashadze 1 site is the deepest active black smoker field so far known in the oceans (Fig. 5). The high-resolution bathymetric maps show a clear relationship between landsliding processes, transversal faults, and the location of the Ashadze 1 site. We also sampled extinct sulfide chimneys near the base of the axial valley wall at 4530-m depth (Ashadze 4). In contrast to the other Ashadze sites, this deepest site is basalt hosted. The Ashadze 1 and 2 sites, 5-km apart, are respectively 4 km and 9 km off-axis. Active vents at Ashadze 1 are distributed over an area about 150-m long, along an EW-trending south-facing scarp. High resolution mapping (450 x 450 m area) reveals the fine structure of sulfide mounds, as well as complex fissure arrays near the vents. Away from the vents, topography appears dominated by slope failure, with prominent landslides. Black smokers at Ashadze 2 (3260 m) lie in a narrow (about 70 m), N-S trending graben-like trough (Ondréas et al., 2007) bounded to the east by a faulted gabbroic body. To the west, it is limited by a narrow N-S trending ridge, 20 to 50 m-high, that bears numerous extinct hydrothermal chimneys.

The host rocks of the deposits at Ashadze 1, 2, and 3 are serpentinized peridotites with interspersed gabbroic bodies which are very common in the rift valley slopes in this segment of the MAR. Two sampling dives were carried out to study the composition of fluids, the animal communities, the bacteria, and the minerals associated with the hydrothermal vents. Another original characteristic is the unexpected observation of gas bubbles in the smokers of Ashadze 1. These bubbles are the evidence of ongoing subsurface boiling processes, and indicate that the temperature at shallow depth must be over 400°C. On the Ashadze 2 site a large group of smokers occurs, in a crater-shaped depression, about 25 m in diameter at the bottom of the graben structure. This constructional structure may indicate the sometimes-explosive nature of the hydrothermal fluid emissions.

**Logatchev.** These sites are located on the eastern wall of the

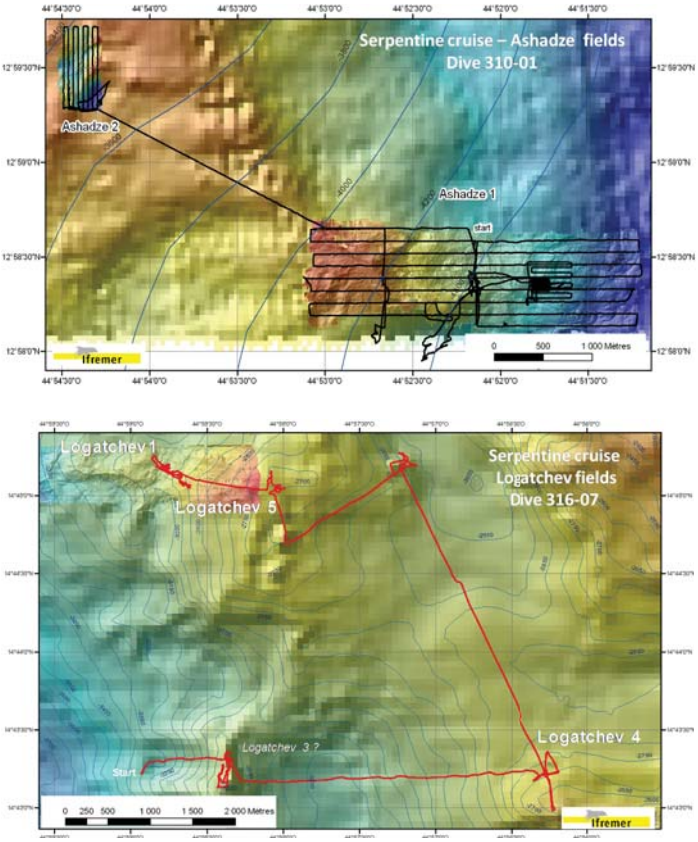



**Figure 2:** (upper) High resolution mapping operations done during dive 310-01 at Ashadze 1 and 2.

**Figure 3:** (lower) Exploration and high resolution map at Logatchev 1 done during dive 316-07.

rift valley. Logatchev 1 and 2 sites, 5 km apart, are located 8 km and 12 km off-axis. We only mapped Logatchev 1 with the ROV (Fig. 3) . It comprises many vents in a NW-trending elongated area about 400 m-long (e.g., see article by Borowski et al., this volume). High resolution mapping at 20-m altitude (550 x 750 m) reveals the circular shape of the main sulfide mounds, as well as complex arrays of scarps and fissures, oriented predominantly E-W, and NE-SW (Ondreas et al., 2007). Numerous lens-shaped slump features are also revealed near the vents.

One important goal was the exploration for new sites in the Logatchev area. During a 13-km exploration dive (Fig. 3), we unsuccessfully looked for the Logatchev 3 site at the top of the rift valley wall. However, the Logatchev 2 site, thought to be inactive, was localized and found to be active and located on serpentinized mantle rocks. The venting fluids (temperature 320°C) are unusual for their low salinity, which is the first observation of the production of a condensed vapor phase for a mantle-based hydrothermal system. In addition, its position 12 km off-axis, moves from 8 (Logatchev 1) to 12 km the possibility to have off-axis black smokers along the MAR. At the end of the exploration, a new low temperature (dominantly birnessite)

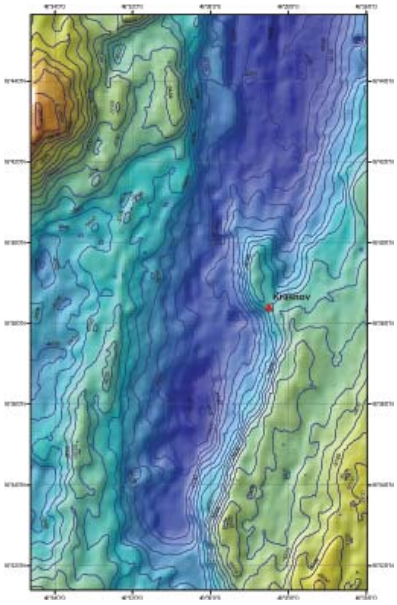



**Figure 4:** Location of Krasnov field at the intersection between a central volcano and the eastern rift valley wall.

inactive hydrothermal field (Logatchev 5) was discovered at the summit of the Logatchev ridge, located 1 km east of Logatchev 1. The second objective at Logatchev 1 was black smoker fluid sampling for time-series studies and additional biological observations and sampling.

**Krasnov.** This site, mapped from the surface during the *Professor Logatchev* cruises (Fig. 4), was observed for the first time by ROV during the Serpentine dives. Submersible observations as well as the high-resolution map established at an altitude of 50 m, revealed several spectacular characteristics of this deposit. First, it is probably the largest accumulation of massive sulfides known to date. The second remarkable characteristic is the collapse of half of the sulfide mound towards the axial valley. This phenomenon creates a large deposit of sulfide talus in the west and a spectacular 100-m high semi-circular section of the mound, showing the heart of the massive sulfide mound at the east. The site was found to be inactive. The samples collected by the ROV and by dredging show a dominance of iron sulfides, and the scarcity of minerals rich in zinc and copper. The samples also revealed the brecciated character of the mineralization and the almost-complete replacement of a basaltic breccia by a mixture of pyrite and silica. This type of mineralization is very similar to the samples collected by drilling in the heart of the TAG sulfide mound at 26°N on the MAR.

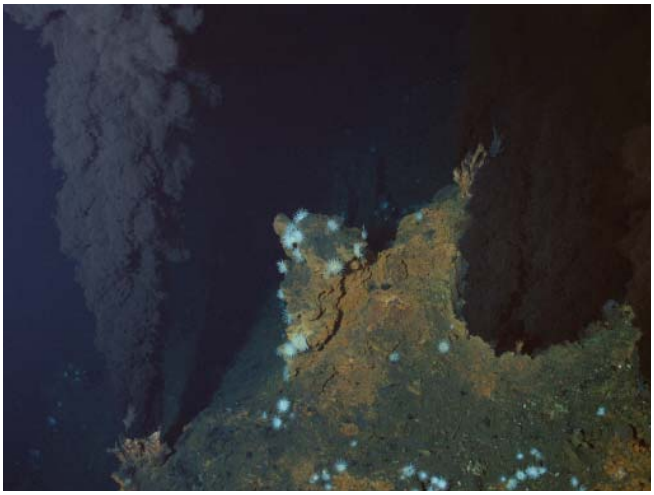
## Hydrothermal precipitates

Basaltic hosted deposits are dominated by pyrite and silica at Krasnov (Fe: 39%, Si: 11%, Cu: 2.2%, Zn: 0.14%) and by sphalerite and pyrite at Ashadze 4 (Fe: 24%, Si: 1.5%, Cu: 0.15%, Zn: 32%). Ultramafic deposits are characterized by high copper concentration dominated by chalcopyrite and isocubanite. Ashadze 1 (Fe: 33%, Si: 1.3%, Cu: 14%, Zn: 14%) and Logatchev 2 (Fe: 20%, Si: 3%, Cu: 14%, Zn: 23%) are enriched in sphalerite. New samples at Logatchev 1 confirm that copper is largely dominant at this site (Fe: 29%, Si: 3%, Cu: 28%, Zn: 4%) (Fouquet et al., 2007). The Ashadze 2 field is unusual; the small active crater can be interpreted as a hydrothermal volcano built up with a mixture of carbonates and secondary copper sulfides and copper chlorides. Massive sulfide chimneys are associated with the active smokers at the center of the crater. Many inactive carbonate/sulfide mounds are also aligned along a N-S depression. Two types of hydrothermal deposits are observed: massive copper-rich sulfides associated with the black smokers and carbonate/sulfide chimneys. Average composition of hydrothermal deposits for Ashadze 2 is Fe: 26%, Si: 11%, Cu: 11%, Zn: 5%, Ca: 8%. The dominant carbonate is aragonite, Mg-calcite is rare, and talc is common (Fouquet et al., 2007).

## Hydrothermal fluids

As previously observed at all ultramafic sites on the slow-spreading MAR between 12°N and the Azores Triple Junction, the active serpentinization process, observed down to 4080-m depth at Ashadze 1, generates hydrogen and abiogenic hydrocarbons during the hydration of olivine and pyroxene minerals through catalytic reactions (Fischer-Tropsch type reactions). Fluids, enriched in $H_2$ and hydrocarbons, confirm the specificity of ultramafic environments as previously found at Rainbow (36°14'N), Lost City (30°N), and Logatchev 1 (14°45'N) (Charlou et al., 2002; Douville et al., 2002). Very strong anomalies in temperature, nephelometry, $CH_4$ (from 1 to 120 ml/l), and helium were found in the seawater column above the Ashadze and Logatchev high-temperature fields. The fluids at these sites exhibit different temperatures (370°C at Ashadze 1, 359°C at Logatchev 1, and 320°C at Logatchev 2) and different chemical characteristics: pH (3.9 at Ashadze 1, 4.3 at Logatchev 1, and 4.4 at Logatchev 2) and chloride (535 mM at Logatchev 1, 150 mM at Logatchev 2, and 620 mM at Ashadze 1), signifying that phase separation is occurring and controlling the fluid chemistry (Charlou et al., 2007). All fluids are issued from ultramafics and controlled by seawater-peridotite interaction. They show low silica (5 to 10 mM), low $H_2S$ (<0.5 mM) and are extraordinary enriched in hydrogen gas (up to 70 per cent of total gas). Gas bubbles were observed coming out from Ashadze 1 vents, and pulses of clear fluid

**Figure 5:** Ashadze 1 black smokers at 4100-m water depth. Temperatures up to 370°C were measured on this site.



were observed venting from Logatchev 2. All fluids issued from the new sites contain very high concentrations of $H_2$, $CO_2$, and $CH_4$. Preliminary calculations show that one vent at Ashadze 1 produces 1 million cubic meters of natural $H_2$ per year (Charlou et al., 2002, 2007).

## Biology

**Ashadze.** The Ashadze 1 site communities (Fig. 6) are surprising for several reasons. The first surprise is the absence or very low abundance of known species that host symbionts (e.g., *Rimicaris exoculata*). In contrast, two species, known to date from other sites as peripheral, form dense populations (anemones and chaetopterid polychaetes). On the chimney wall, two species of alvinocaridid shrimp are present, by decreasing order of abundance: *Mirocaris fortunata* and *Rimicaris exoculata*. This latter species, found as swarms of several thousands of individuals at other MAR sites, was only observed as isolated individuals. The other shrimp species grazes bacterial mats. The gastropod *Shinkailepas briandi* forms small clusters of about 10 individuals, and some platyhelminths are also found in the oxidized and active zones of the chimneys. In the oxidized zones, the most visible population is composed of actinarian anemones of the species *Maractis rimicarivora*, previously described from other deep Atlantic sites (TAG and Snake Pit). This species, as indicated by its name, is most likely carnivorous or omnivorous. Conspicuous bacterial mats are also common in the oxidized zones. At the surface of oxidized chimneys we can also observe a high abundance of tubes of a chaetopterid polychaete. These tubes form large accumulations at the base of the chimneys and are used as substrata for other species and for bacterial mats. Similar chaetopterids were observed at other active sites on the MAR (Rainbow, TAG) but never in such high densities. A diverse associated fauna was observed, specifically abundant populations of the amphinomid polychaete *Archinome* sp., scaleworms (Polynoidae) such as *Iphionella* sp. and *Levensteiniella iris*. Two species of *Phymorhynchus* (gastropod) are also present and are considered as predators of other mollusks or necrophagous. Pycnogonids were also collected at the base of the chimneys. The carnivorous/necrophagous level is also represented by the crab *Segonzacia mesatlantica* and by the zoarcid fish *Pachycara thermophilum*. Some galatheids are also present.

**Logatchev.** At Logatchev 1, in comparison to observations made during previous cruises, biological observations indicate a variation of the proportion of some species and the continuation of intense biological activity on the Irina 2 area. However, the vesicomyid clams, emblematic of this area, have disappeared. The finding of extensive dead mussel fields on Logatchev 2 is surprising. The shells are intact, recent, and seem to indicate a catastrophic event that rapidly destroyed the environment favourable to the growth of mussels. A few live mussels and large populations of shrimp were however observed on the active chimney.

**Krasnov.** From a biological point of view, few fauna were observed; only a few bacterial mats covering several tens of square meters were observed at the bottom of the cliff splitting the sulfide mound.

## Cruise website

More information is available at:
http://www.ifremer.fr/serpentine.

## Acknowledgement

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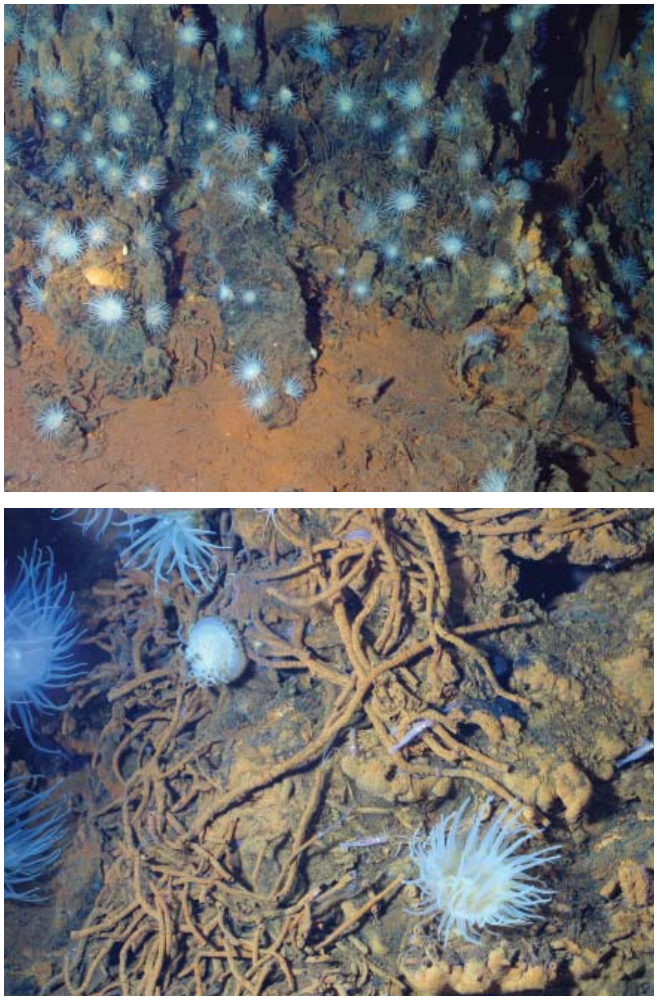
**Figure 6: a** (upper) and **b** (lower). Ashadze 1 populations of *Maractis rimicarivora* and chaetopterid polychaetes.



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# Canada

*Mairi Best, NEPTUNE Canada*

NEPTUNE Canada is installing a regional cabled ocean observatory across the northern Juan de Fuca Plate in the northeastern Pacific. When the initial suite of instruments is installed in 2009, this system will provide the continuous power and bandwidth to collect integrated data on biological, chemical, physical, and geological processes across an entire tectonic plate from the shelf to the deep sea (17 - 2700 m water depth).

NEPTUNE Canada's real-time interactive monitoring capability at Endeavour Ridge will benefit both ongoing and new experiments. Continuous data gathered before, during and after events like earthquakes and intrusions will be recorded across a coordinated suite of instruments both at the hydrothermal vents on the seafloor and within moorings extending 250 m up into the 2200-m water column. A network of seismometers here and at other sites will provide high resolution information on tectonic processes across the Juan de Fuca plate.

For more information, see: www.neptunecanada.ca.

mudstones indicates a Pliocene -Pleistocene age based on the calcareous nannofossils (Analyst: A.G.S. Fernando).

Concurrent with the field mapping, rock sampling was also conducted for geochemical analyses. In addition, geochronological analyses will be targeted in the present work to address the lack of well-constrained ages for the various features observed in Mindoro Island. This ongoing research endeavor is one of the projects under the natural sciences cluster of the Philippines-Taiwan Science and Technology Cooperation Program on Geosciences. Collaborations within this cooperation program are through the Department of Science and Technology of the Philippines and the National Science Council of Taiwan.

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# Russia

*Sergei Silantyev*

Most of the principal investigations in 2008 related to ridge-crest processes have been carried out in the following Russian research centers: Russian Academy of Sciences - Vernadsky Institute of Geochemistry and Analytical Chemistry (Moscow), Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry (IGEM, Moscow), Institute of Geology (GIN, Moscow), Shirshov Institute of Oceanology (Moscow), and Winogradsky Institute of Microbiology (Moscow); and Ministry of Natural Resources of the Russian Federation - VNIIOkeangeologia (St. Petersburg) and Polar Marine Geological Expedition (PMGE, St. Petersburg-Lomonosov).

Among the most important results of investigations of ridge processes carried out by Russian scientists in 2008, we would like to highlight the following:

## VNIIOkeangeologia and PMGE

The 31st cruise of R/V "*Professor Logatchev*" was conducted at the MAR axial zone between 19°-21°N in December 2007 - May 2008. The results of the explorations in this cruise lead to the discovery of a new large ore deposit ("Zenith-Victory") of hydrothermal affinity at 20°07.75'N, 45°37.35'W. This new hydrothermal field is located on the east slope of the rift valley. Host rocks are basaltic, and no hydro-chemical signal of hydrothermal activity has been detected in this area. The estimated ore reserves of Zenith-Victory amount to no less than 10 million tonnes and are characterized by Cu and Cu-Zn mineralization. Also during this cruise, it was established that the hydrothermal ore deposit "Pui des Folles", discovered in 1996 by an IFREMER expedition (France) at the seamount with the same name (20°30.50'N, 45°38.50'W), occupied considerably more area than proposed earlier. Four new inactive hydrothermal vents were discovered by the "*Professor Logatchev*" expedition in this area.

Other VNIIOkeangeologia activities included the 4th International Conference "Minerals of the Ocean" in May 2008 in St. Petersburg. More than 50 scientists from Russia, China, Germany, and USA attended this meeting (see: www.vniio.ru).

## GIN

Investigations of the northern Knipovich Ridge and North Barents Sea (including western continental slope of the Arctic ocean) have been continued in 2008 in the framework of project "Late Mesozoic - Cenozoic tectonic -magmatic history of the Barents Sea shelf and slope as a clue to paleogeodynamic reconstructions in the Arctic Ocean" as well as "International Polar Year" (for details, see: www.ginras.ru). Seismic profiling and multi-beam (SeaBat 8150) surveying as well as dredging of bedrock have been conducted in the region located at 78-82°N, 30-55°E during the 1st Leg of the 25th cruise of R/V "*Akademik Nikolai Strakhov*" (chief scientist A.V. Zayonchek). It was established that Orel Trench (Eagle Trench), located just to the east of Spitsbergen, is a contemporary rift characterized by anomalously high heat flow (500 mW/m$^2$). Investigations of the intersection of Knipovich and Mohns Ridges have been carried out during the 2nd Leg of this cruise in the framework of the program "Main problems of Oceanology: physics, geology, biology, ecology of the World Ocean" (Project: "Regularities of the construction and origin of oceanic crust in key areas of the Atlantic: tectonics, magmatism, formation Fe-Mn substances", supervisor of studies - academician Ju. M. Pusharovsky). The

main result obtained during this 2nd Leg is evidence for migration of the intersection toward SE. Thick Fe-Mn crusts (3-6 cm) are common peculiarities of basalts dredged here. This expedition of R/V "*Akademik Nikolai Strakhov*" was carried out under close cooperation with NPD, Norway.

## IGEM

The ages of 150 grains of zircon from 8 gabbro samples dredged at 4 sites in the axial zone of the MAR at 5°30'6" - 5°32'4"N during the 10th cruise of R/V "*Akademik Ioffe*" (2001-2002) and 22nd cruise of R/V "*Professor Logatchev*" (2003) have been studied using SIMS technique on SHRIMP-II by regular procedure (i.e., Ludwig, 2000, Berkeley Geochronology Center Special Publication 2, 22 pp.). Zircon grains from deformed and altered leucogabbronorites with brown hornblende and non-deformed fresh troctolite were examined. Two groups of zircon grains, different in color, morphology and inner structure, occur in the rocks. Transparent, colorless, prismatic and short-prismatic zircon grains with corroded surface prevail in gabbronorites. Such zircon grains are interpreted to have a magmatic origin and are related to a gabbronorite crystallization event. Pink-semitransparent rounded grains were found among fine (<150 μm) fraction only. Sub-idiomorphic crystals with coarse zoning and thin disparate newly formed rims occur in troctolite. These zircon grains are considered xenogenic. Calculated $^{238}U/^{206}Pb$ zircon ages varied from 2.39±0.19 to 0.76±0.04 Ma. An occurrence of zircon grains of different ages in the same rock samples is evidence for the existence of the heterogeneous lithospheric mantle underlying the MAR. The reasons for the presence of ancient zircon in modern gabbroids from spreading centers remain an open question. A possible explanation is that these zircons were captured from the "cemetery of slabs" by mantle plume, the head of which melted at shallow levels in heterogeneous oceanic lithosphere.

A thorough Sr-Nd isotopic study of fresh pillow-lavas with remnants of quenched glass, dredged from the axial rift zone of the MAR between 5°-7°N (Sierra Leone area), has been carried out. This study revealed small-scale isotope heterogeneity in the basalts and their glasses. The $^{87}Sr/^{86}Sr$ ratios of basalt and glasses in some of the samples do not coincide - in the glasses the Sr-isotope ratio may be higher or lower than that of the basalt by 0.01-0.02%. The $^{143}Nd/^{144}Nd$ ratios of the constituents are practically indistinguishable within analytical error. There is no essential correlation between the isotopic characteristics of the samples and their geochemical features (trace element geochemistry). Sea water was also shown to have no influence on Sr and Nd isotope composition in the studied pillow-lavas. The Sr-isotope heterogeneity is believed to be evidence for small-scale heterogeneity of the basaltic melts, which did not homogenize due to the fast ascent and eruption. The most plausible explanation for such heterogeneity is contamination of basaltic melt by older plutonic rocks of the lower oceanic crust, especially gabbros, on its path to the surface of the ocean floor.

The first data on temperature homogenization of fluid inclusions, fluid salinity and helium isotope ratios were obtained in a course of chimney samples collected during the 2007 Serpentine cruise on the French R/V "*Pourquoi Pas?*" with ROV "*Victor*" at the MAR Logatchev hydrothermal field (14°45'N) and Ashadze hydrothermal field (12°58'N). Results showed that fluids with salinity ranging both higher and lower than seawater at high temperature (≥320° C) deposited sulfide minerals. Fluids depleted in mantle-derived He prevail in fluids trapped by sulphides. The most important findings are that the formation temperature, fluid salinity, and R/Ra ratios ranged more significantly than these figures measured directly for venting fluids.

## Vernadsky

The 2007 Serpentine cruise was led by scientists from France and Russia. Participation of Russian scientists in this expedition has been provided by scientific cooperation between Federal Agency of Sciences and Innovations and IFREMER, France (for more on this collaboration, see the article by Fouquet et al., this volume). Another important result from sample collection during this cruise is evidence of the presence of two distinct types of residual peridotites in the MAR segment just to the south of 15°20'N FZ - characterized by very high depletion degree (Logatchev hydrothermal field area) and moderate and low degree of depletion (Ashadze hydrothermal field area). In addition, the first data on U-Pb and Lu-Hf system behavior in Zr from trondhjemites and host gabbro sampled at Ashadze hydrothermal field area during the Serpentine cruise were obtained in close cooperation with GEMOC Key National Center of Macquarie University, Australia. Sixty grains of Zr have been analyzed by LA-ICP-MS. Almost all Zr grains judging by isotope dating have very young age of ~ 1 Ma. Only one grain proved very old of ~ 2.5 - 3 Ga.

A large study with comparative analyses of geochemical peculiarities of MORB glasses sampled during the last two decades with Russian expeditions (16th cruise of "*Akademik Boris Petrov*" and 19th and 20th cruises of "*Professor Logatchev*") at the MAR axial zone between 29°-34°N and 12°-18°N has been published in 2008 (Petrology, 2008, 16, 1, 36-62). This work was conducted by close cooperation with University of Tasmania, Australia. Data presented in this work indicate that MORB melts occurring at 29°-34°N were derived by the melting of a mantle source (DMM) with a homogeneous distribution of volatile components and arrived at the surface without significant fractionation. On the other hand MAR segments between 12°-18°N combine contrasting geodynamic environments of magmatism, which predetermined the development of a large plume region with the widespread mixing of the melting products of geochemically distinct mantle sources.

The results of a study of a representative collection of samples recovered by deep-sea drilling from the oceanic basement 10 miles west of the rift valley axis in the crest zone of the MAR at 15°44'N (ODP sites 1275B and 1275D) also were published in 2008 (Petrology, 2008, 16, 4, 353–375). This MAR region was selected as a first-priority site on the basis of an application, whose preparation has been contributed by participation of scientists from the Vernadsky Institute. The following sequence of magmatic and metamorphic events resulting in the formation of a typical oceanic core complex of slow-spreading ridges was presented in this work: (1) formation of a strongly fractionated tholeiitic magmatic melt parental to the gabbroids in a large magma chamber located in a shallow mantle and operating for a long time under steady-state conditions; (2) transfer of the parental magmatic melt of the gabbroids to the base of the oceanic crust, its interaction with the host mantle peridotites, and formation of troctolites and plagioclase peridotites; (3) intrusion of enriched trondhjemite melts as veins and dikes in the early formed plutonic complex, contact recrystallization of the gabbro, and development in the peridotite–gabbro complex of enriched geochemical signatures owing to the influence of the trondhjemite injections; (4) emplacement of dolerite dikes (transformed to diabases); (5) metamorphism of upper epidote-amphibolite facies with the participation of marine fluids; and (6) rapid exhumation of the plutonic complex to the seafloor accompanied by greenschist facies metamorphism. The samples studied in this work were granted to Russian scientists by their American colleagues from WHOI according to a Vernadsky - WHOI collaboration in the study of MAR bedrocks drilled at ODP Leg 209.

In addition, a synthesis of results of field studies in Iceland in 2001 and 2003 (performed within Wolfgang Paul Award and Max-Planck Society grant to A. Sobolev) has been carried out in 2008. New data on average compositions (Ni excess and Mn deficit as indicators) of olivine phenocrysts for olivine-rich lavas as well as bulk rock $^{187}Os/^{188}Os$ ratios from Iceland basalt show that these tracers are linked for Icelandic Quaternary lavas, strengthening the recycling model. An estimate of the osmium isotopic composition of both the recycled crust and the mantle peridotite implies that Icelandic Quaternary lavas are derived in part from an ancient crustal component with ages between 1.1 and 1.8 billion years and from a peridotite end-member close to present day oceanic mantle (Sobolev et al., Science, 2008, 321, 536).

### Winogradsky Institute of Microbiology

The following results were obtained in 2008 during a study of organic matter sampled in the Serpentine expedition: (1) An enrichment performing anaerobic methane oxidation at 70-90° C was obtained; (2) An enrichment performing methanogenesis from acetate at 85° C was obtained from the sample from Ashadze hydrothermal field; (3) Four strains of anaerobic hydrogenogenic carboxydotrophic representatives of *Thermococcus* spp. have been isolated from the samples from Logatchev hydrothermal field. 16S rRNA gene analysis revealed that they are very close to *Thermococcus barophilus* earlier isolated from MAR hydrothermal vent samples (Marteinsson et al., Int. J. Syst. Bacteriol. 1999, 49, 351-9); (4) New species *Deferribacter ferriautotrophicus* has been isolated from a chimney sample from Ashadze hydrothermal field. The scientific team that conducted this investigation includes Russian scientists (T. Sokolova, E. Bonch-Osmolovskaya, G. Slobodkina, A. Slobodkin) as well as a French scientist (J. Querellou, IFREMER). These data will be presented at "Extremophiles 2008", in Cape Town, South Africa, 7-11 September 2008.

### Meetings planned for 2009

(1) Russian Ridge Workshop "Hydrothermal Systems in Mid-Ocean Ridges: Interaction between Magmatic and Hydrothermal Processes" - St. Petersburg, Russia, June 2009.
(2) International Conference "Oceanic Minerals" - joint with 38th Annual Conference of the Underwater Mining Institute (UMI) - Gelendzhik, Russia, September 2009.

## UK

*Tim Henstock*

Two major research cruises to the ridge crest were conducted with RRS *James Cook* and ROV *Isis* in 2008. In January - February, cruise JC21 with lead PI Chris MacLeod used ROV *Isis* and a rock drill to sample the Hess Deep at the East Pacific Rise. Preliminary results from this cruise will be presented at the 2008 AGU Fall Meeting. In May - June, cruise JC24 with lead PI Roger Searle surveyed with TOBI side scan sonar and used ROV *Isis* to sample the Mid-Atlantic Ridge at 45°N (see article by Searle et al., this volume). This cruise was an international collaboration involving scientists from Portugal, UK,