FEATURE STORY

By Dr.Anatoly M.Sagalevitch,
Head of Deep Manned Submersibles Laboratory of P.P.Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia

Kevin Hardy, Vice-President,
DeepSea Power & Light
San Diego, CA, USA
Vice-President, Marine Technology Society, Columbia, MD, USA

New Discoveries in Lake Baikal by the MIR Submersibles

Introduction

Construction of the MIR-1 and MIR-2 submersibles was completed in October 1987. The first deep dives of the vehicles were conducted in the Atlantic Ocean on December 12 and 13, 1987, MIR-1 to 6,170m and MIR-2 to 6,120m. On December 17 the acceptance protocol for the MIRs was signed and the vehicles prepared for their first scientific expedition.

During the 22 years following, the MIRs have performed over 1,000 scientific and technical dives. The MIRs have dove on 22 hydrothermal fields located on the bottom of the Atlantic, Pacific, Indian, and Arctic oceans. The MIRs surveyed new hydrothermal vents sites, discovering wide deposits of metallic sulfide ores, and hundreds of species of animals adapted to a food chain based on chemosynthesis, a biological conversion of inorganic molecules into organic matter in a process devoid of sunlight.

The MIRs have provided stable light and camera platforms for the making of well known deep ocean films, including James Cameron's Titanic, Bismarck, Ghost of the Abyss, IMAX Titanica, Al Giddings' Treasure of the Deep, BBC's Blue Planet and others. The first TV-broadcast from great depth – Titanic (3,800m) – was done from the MIRs in 2005 by James Cameron. A great number of dives were made to the nuclear submarine wrecks Komsomolets and Kursk. The dives on Komsomolets included installation of titanium containment caps to encapsulate part of the bow to prevent the exit of radionuclides. In August 2007, the MIRs made a historic and daring first dive to the bottom of the Arctic Ocean at the exact geographical North Pole. The twin submersibles operated under thick ice, diving to a depth of 4,300m, then returned to surface, finding the keyhole to the surface of a temporary small patch of open water created by a Russian ice breaker.

During 2008 and 2009, the MIRs performed scientific investigations in the deepest lake on the earth – Russia's Lake Baikal. One fifth of the world's fresh water, more than all of the North American Great Lakes combined, is held within its shores. With new means of observation, came new discoveries on the bottom of the lake.

MIR submersible on Lake Baikal

Organizing the Expedition

Baikal is the deepest and biggest lake in the World – 640 km long and up to 80 km wide. Maximum depth of the lake is 1,640 m, reached by the MIR-1 submersible in August 2009.

The water of the lake is very clean, with a very low degree of the mineralization. Baikal is fed by 336 rivers, with a single river, the Angara, flowing from it. In combination with low temperature and great depth, these conditions are conducive to the proliferation of unique endemic organisms. Over 2000 species of endemic animals live in Lake Baikal. The lake was declared a UNESCO World Heritage site in 1996.

Baikal contains 23 thousand cubic meters of fresh water – 20% of the world's natural deposit. The lake is 35 million years old. Over this time, a very thick layer of sediments – 7.5 km – has accumulated on the bottom. Such thick sediments provide favorable conditions for the creation and capture of oil and natural gas. The water in the lake is quite cold: from 300m to the bottom the temperature is stable - between 3.0 to 3.5°C. This means that in the thick sediments at 350 meters and deeper are favorable thermobaric conditions to create stable gas hydrates. Such conditions exist on an astonishing 70% of Lake Baikal's submerged lake bed.

The expedition on Lake Baikal with the MIR submersibles was started in June 2008, and continued through that summer. The MIRs were stored in a warm hangar in Irkutsk during the winter of 2008. Dive operations began again in June 2009. The expedition was finished in September 2009. The transportation of the MIRs from Kaliningrad (Baltic Sea) to Baikal (Ulan-Ude) was performed by the world's largest transport aircraft, Ruslan.

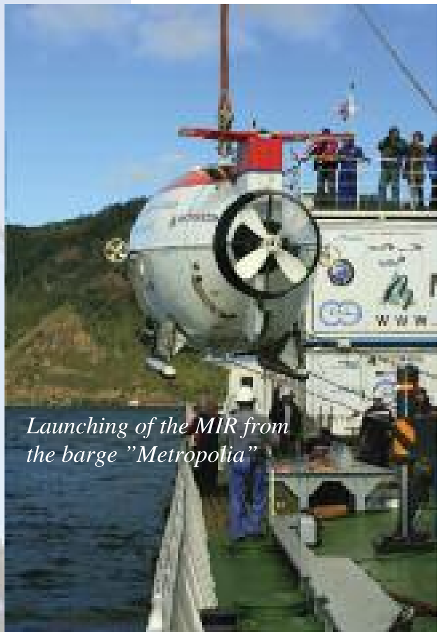
During the two summers, 122 dives of the MIR submersibles were made. The primary focus was on complex scientific research, with some additional time allocated to searching for sunken targets described in ancient archives.

The expedition was organized by P.P. Shirshov Institute of Oceanology, the Russian Academy of Sciences (RAS), and the Russian business organization, Metropol. The Institute of Limnology, Siberian branch of RAS, Burjatian Institute of Natural Use and other organizations also took part in the scientific research.

The 2008/2009 expedition wasn't the first to use submersibles in Lake Baikal. In 1977, Pisces VII and Pisces XI submersibles were used to conduct scientific research. In 1990-1991, a second international project was performed with the Pisces vehicles. That expedition included a large team of American scientists from the National Geographic Society, Harbor Branch Oceanographic Institution, Woods Hole Oceanographic Institution and other organizations.

A large volume of scientific data was obtained during the Pisces expeditions, and many interesting discoveries were made. On the basis of this research, it was concluded that Lake Baikal was formed by a tectonic crack in the Earth's crust in the middle of the continent. The coasts of the lake are spreading at the speed of 2 cm/year similar to the spreading rate of the mid-Atlantic Ridge. The research confirmed the hypothesis that the land is splitting, and Lake Baikal is an emerging ocean which will join the Pacific Ocean in millions of years.

The objectives of 2008-09 exploration with the MIRs was first to refine the detail of earlier data, and second to search new sites with suspected hydrothermal activity, or gas and oil dis-

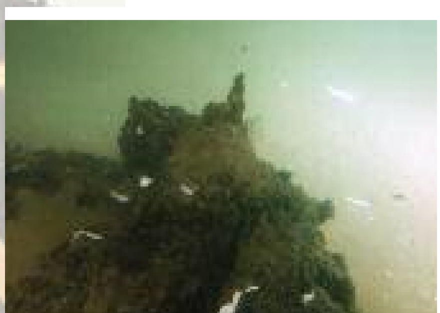


Launching of the MIR from the barge "Metropolia"

charge. Before the expedition two technical problems had to be solved:

- to find and equip the support vessel or platform for carrying and launching of the MIRs; and
- to provide proper buoyancy of the MIRs accommodating the loss of buoyancy due to the lake's less dense fresh water compared to ocean salt water, which the submersibles were originally designed and ballasted for.

The first problem was solved by the use of a river coal barge. The barge had no propulsion system, so it was moved by tug-boat. The stability of the barge with the MIRs and the crane on board was calculated, and proper ballasting was achieved by strategic placement of large iron ingots on board. A 100-ton lifting capacity auto-crane was installed on the deck. Special cabins were mounted on the deck. Some were used as the laboratories and machine shops, and some for berthing for sub crew, scientists and sailors. Two diesel-generators were mounted on the barge to provide electrical power. This huge job was completed in just two months. The converted barge was renamed Metropolia, and the special platform was ready for operations.



Bitumen hill on the bottom with oil leakage

The MIRs are 180 kg too heavy in the less dense fresh water of Lake Baikal, having been designed and ballasted for denser salt water oceans. Buoyancy was adjusted in two ways: 1) the substitution of lighter equipment and removal of some heavy parts; and 2) the installation of additional syntactic foam. On the first dive the MIRs confirmed proper buoyancy control, and were ready for the dives.

Research

MIR operations on Lake Baikal followed the same methods as in the ocean. One auto crane performed the launch and retrieval of both vehicles from Metropolia. The MIRs were attended on the surface by the motorboats Koresh and Zodiak. Underwater communication with the MIRs could be performed by either the motorboats or Metropolia depending upon sea state conditions. Navigation of the MIRs utilized an LBL system when operations covered several days on one site and required high accuracy. Otherwise, an USBL system was used for general operations. During operations using the LBL, all sampling, measurements, video images, and so forth, were fixed with high accuracy in geographical coordinates on the navigational computer. This provides exact mapping of the sites explored by the MIRs.

Gas seeping through the sediment

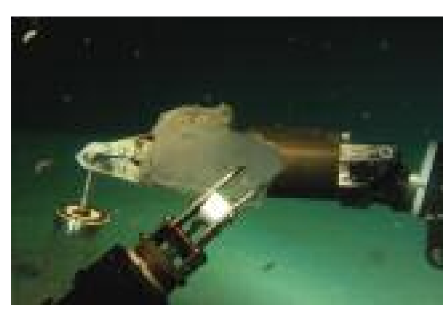
The scientific research included study of the geological structure of the lake, biodiversity in the water column and on the lake bed, hydrophysical processes, chemical composition of geological samples, and other limnologic studies.

Visual observations from the MIRs provided new data about tectonic faults on the Western and Eastern slopes of the lake. They have similar constructions, looking like vertical fault breaches, alternated with horizontal terraces, covered by the sediments. These constructions are very similar to the slopes in rift valleys of the ocean. The deepest area in the middle of the lake is practically flat and covered by a thick sediment layer (7-8 km in some areas).

Hard gas hill on the bottom

The most important discoveries were the oil and gas discharges from the bottom, and large deposits of hard gas hydrates, some looking like ice hills covered by a thin layer of fine sediment.

The seeping of the oil and gas are discovered in the middle part of the lake – at the Gorevoy Utjos site. At a depth 900 meters the MIRs found a large, shallow depression in the flat bottom relief. In the center of this depression, the MIRs came upon a rise 10 meters high and 50 meters in diameter. On the top of this rise were small conical hills 1.5-2 meters high. The surface of these small hills were light-brown in color. Deeper layers were dark-brown looking like bitumen or pitch. On the top of these hills were naturally made vertical pipes, like vertical looking droppers. Small separate drops of oil seep from each pipe every 20-30 seconds and float upward. Several hundred meters from the "droppers", liquid oil, shaped like balls 1-1.5 cm in diameter, were observed on the flat bottom. It is believed this is oil seeping through the porous sediments. Oil balls appear on the surface of the bottom without any regular period and immediately float up. Many of them join in water column and appear on the surface of the lake as large spots of oil. The analyses of the pieces of the bitumen or pitch recovered by the MIRs showed that the organic matter is a paraffin oil consisting of 80-85% of carbon, 10-12% of hydrogen and about 2% mineral. In the same area, small gas discharge formations were discovered. Gas appeared



Piece of hard gas hydrate in the manipulator of the MIR


Dr. Sagalevitch with Vladimir Putin after the dive

from small, sharp, accumulative formations with the dimensions 20x15x20 cm. The piece of one formation was recovered. During ascent, at a depth 360 m, an initial discharge of gas from the sample was observed. As the MIR rose, a cloud of gas bubbles was released. The analyses of the sample showed that the hard structure had disappeared and only liquid matter – oil and water – was left. On the basis of this experiment, it was concluded that the small sharp formations were built by hard gas hydrates.

On the Bitumen hill and the small "droppers", a very high density of animals was observed –more than 100 animals on 1 m^2 as counted by human eye. It was established that most of the observed species belong to well known animals of the deep water zone of Baikal, but the density of the biomass in the areas with oil and gas discharges is much higher than in the usual zones of deep Baikal. The foodweb here likely begins with methanooxydizing bacterias, and does not rely on organic matter produced at the surface.

A remarkably rich discovery of hard gas hydrate deposits was made in July 2009. In the middle of Lake Baikal on the Saint Petersburg site a chain of the hills of 6-8 meters high and 40-50 meters in diameter was found, formed by hard gas hydrates. These hills are covered by a thin layer of sediment and at first glance look like the usual hills on the bottom of the lake. But the attempt to take a sample showed that the composition of the hill was very strong. The pilot used the strength of manipulator (up to 100 kg), and the mass of the vehicle to break a piece of the hill from the monolith. A specially constructed, hermetically sealed container was used to return the sample of the gas hydrate to the surface research laboratory.

Russian Prime Minister Vladimir V. Putin visited Lake Baikal during the operations with the MIRs. He participated in one dive on the MIR-1 on August 1, 2009. He spent 5 hours submerged as a member of the sub crew, diving to 1,400m, showing a natural ability to control the vehicle, and operating the manipulator to take several samples of the bottom rocks. At the end of the dive, Prime Minister Putin gave high marks to the MIR technology and professionalism of her pilots.

Conclusion

The use of the MIR submersibles for the scientific investigation of Lake Baikal confirmed that manned submersibles are irreplaceable instruments for detailed oceanographic research. Side by side with the exploration of hydrothermal vents in the ocean, the discovery of large deposits of gas hydrates in a fresh water lake is of tremendous importance to our modern age. Gas hydrates found earlier in fresh water were but small inclusions in the sediments. These monoliths on the bottom of the Lake Baikal are the first found on such a massive scale.

It's undisputable that the gas hydrates are the fuel of the future. One cubic meter of gas hydrates releases 162 cubic meters of methane gas when the thermobaric balance is disturbed. Gas hydrates are a very convenient means for storage and transportation, because they take much less space than methane gas. The future use of this unique carbon fuel requires the development of new sampling, collection, storage, and distribution technology. The MIR submersibles have already helped with our understanding of how to proceed.