British Geological Survey remotely operated sea bed rockdrills and vibrocorers: new advances to meet the needs of the scientific community.

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Abstract *The British Geological Survey (BGS) have developed a number of coring and drilling systems for use in science projects in the UK and internationally. These include 3m, 4m and 6m vibrocoring systems; a 5m combined rockdrill and vibrocorer system (RD1); an oriented drill designed specifically to recover samples for use in palaeomagnetic studies; and a 55m rockdrill (RockDrill2).*

The BGS has recently completed a series of modifications to increase the flexibility and performance of its vibrocoring and rock-drilling capability to meet the ever increasing needs of the scientific community. The latest generation vibrocorers can be operated without an umbilical power cable. The new system not only allows vibrocoring in greater water depths, but can also be used on a wider range of vessels including those with limited deck space. The BGS RockDrill2 can core up to 55m sub-seabed by focussing on reducing the overall weight therefore extending operational water depth to 4000m.

Keywords *Vibrocorer; Rockdrill; Subsea Sample*

INTRODUCTION

The British Geological Survey (BGS) built their first remotely operated rock drill in the late 1960s. *CONSUB* (Fig. 1) was a remotely operated vehicle (ROV) capable of retrieving short cores from the seabed. It was decommissioned in the early 1970s to be replaced by the midi-drill. The midi-drill (1975-1983) was capable of acquiring cores up to 1m long and was constrained to shallower water depths. As scientific exploration moved into deeper water a new version of the rock drill (RD1) was designed and built in-house (Fig. 2). RD1 is a combined rockdrill and vibrocoring system offering the flexibility of two sampling systems in one rig to the scientific and commercial communities. RD1 is capable of retrieving cores up to 5m long in "hard rock" via traditional rotary coring techniques and cores up to 6m long in "soft sediment" environments in vibrocorer mode. The maximum operational water depth for the RD1 system is 2000m. The RD1 system has been operational since 1982 and is still in use today. The Oriented Drill was specifically designed to recover samples for use in palaeomagnetic studies and was initially developed for use on the Natural Environment Research Council (NERC) funded *BRIDGE* Programme (British Mid-Ocean Ridge Programme; 1996-1998) on the Mid-Atlantic Ridge. The maximum core length is 0.8m and the maximum operational water depth of the drill is 5500m. Orientation is achieved by scribing the core along its length with a single reference line and then using the two drill-mounted compasses to assign a heading to this reference mark. This mark can then be related to a world reference thereby facilitating detailed palaeomagnetic analysis.

The BGS have designed, built and operated vibrocorers since the 1970s and are the BGS's oldest form of powered coring device with a long and successful track record of recovering high-quality samples worldwide from Greenland to the Scottish fjords. The system can be configured for 3m, 4m or 6m maximum core lengths and can operate in maximum water depths of 2000m via the BGS umbilical winch or 6000m water depth using the new battery-operated system (Fig. 3).

The Rockdrill2 is the most recent BGS remotely operated sampling system and is capable of coring up to 55m below sea floor in water depths up to 4000m (Fig. 4). The system is operated via its own launch and recovery system and can be outfitted with additional sensors.

This paper will discuss in more detail the battery-operated vibrocoring and the RockDrill2 systems.

Fig. 1. One of the early ROVs, *CONSUB* (late 1960s to early 1970s) which was built by the British Aircraft Corporation, represents the first attempt by the British Geological Survey at seabed robotic rock coring.

Fig. 2. The British Geological Survey 5m Rockdrill (RD1) first developed in 1982 and is still used to recover cores today.

BATTERY VIBROCORER

The latest development of the much used BGS vibrocorer is an autonomous system compatible with our 3m, 4m and 6m vibrocoring systems that can be used in water depths up to 6000m (Fig. 3). Use of a battery system can be deployed using the vessel's own A-frame and winch increasing flexibility and the range of vessels the system can be installed upon such as those with restricted deck space. The autonomous battery system comprises a 6kWh battery pack to run the coring system and subsea hydraulics. The standard vibrocoring system is operated via a standard 3 phase 440V umbilical system. The battery-operated system has been developed as an inverted system whereby the 300V DC battery supplied power is inverted to give the necessary 440V AC supply.

Control is provided by a microprocessor with a real-time clock that carried out a number of functions via a pre-set program set up before deployment. Data from the sensors are recorded with a time-stamp, giving diagnostic information that can be downloaded once the system is returned to the deck.

Further developments to this system are in progress including the addition of extra sensors (for example Niskin bottles and a conductivity, temperature and depth sensor), an acoustic telemetry communication system, and an increase in the operational water depth to more than 6000m (the hadal zone). The ultimate aim for the BGS is to make the battery-operated system compatible with the RD1 system allowing rock cores to be acquired from full oceanic water depths.

The autonomous system was used for the first time in June 2014 and then again in 2015 on-board the *R\V Belgica* (Fig. 3) to acquire samples from 20 sites in the Dangeard and Explorer canyon heads, off the southwest of England in 430m water depth. The system will be used again in May/June 2016 in the Bay of Biscay.

Fig. 3. The British Geological Survey 3m configuration of the battery operated vibrocorer on its side on-board the *R/V Belgica*.

ROCKDRILL2

RockDrill2 is a multi-barrel wireline subsea remote drill capable of coring up to 55m below sea floor in water depths up to 4000m. The rockdrill is operated via its own launch and recovery system (Fig. 4) and can be outfitted with additional sensors. The system weighs 6 tonnes in air and is 3m in width at its maximum and 5m in height. The RockDrill2 is deployed via its own launch and recovery system that forms its own 20 foot container for ease of shipping around the world.

Samples are taken in 1.7 meter sections using an internal core barrel that is recovered through the main drill string into the unit's drill centre. In addition to retrieving cores, the hole can be logged using a range of downhole logging tools. The BGS have an Optical, Acoustic and spectral Gamma (OAG) memory logging tool, dual-induction logging tool and magnetic susceptibility logging tool. A gas capping system has been developed by the BGS for use in gas hydrate entrained sediments for assessing the volume of gas hydrate. The unit also comes with a soft sediment landing system for deployment in areas of soft seabed sediments.

The most recent developments are a borehole plug that can be installed in the cored hole, Niskin bottles and a tracer injection system.

The borehole plug isolates the borehole from the surrounding sea floor and sea water allowing subsequent borehole water sampling to be carried out by ROV. The next stage will be the installation of sensors within the plug system for the collection of data on a long term monitoring basis.

Two Niskin bottles can currently be installed on the RockDrill2 frame as close to the seabed as possible in order to acquire water samples immediately before coring commences and immediately after coring is completed. The tracer injection system will allow monitoring of contamination of porewater by drilling fluid. Both the Niskin bottles and tracer injection system have been developed primarily for microbiological research.

The RockDrill2 has been used to sample hydrate-entrained sediments in the Sea of Japan. The maximum coring depth achieved was 32m below sea floor and the system can operate for more than 50 hours on a single deployment. The RockDrill2 will be deployed on two offshore campaigns during 2015. The first is a sampling campaign offshore Oban, Scotland and the second is in conjunction with the Bremen University MeBo sea floor rockdrill as part of the International Ocean Discovery Program (IODP) Expedition 357 to core serpentinites at Atlantis Massif, central Atlantic. Additional developments have been made to RockDrill2 for this expedition including an extension to the mast allowing standard length logging tools to be deployed downhole.

Fig. 4. The British Geological Survey 55m remotely operated seabed rock drill (RockDrill2) being deployed in the Sea of Japan.

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