When drilling from a ship or floating platform, the borehole remains open to the sea/lake floor, so mud and cuttings do not return to the drill rig. In this set-up drilling must be performed with water in place of drilling mud allowing cuttings spilling out on sea or lake bottom around the well. However, if pressure control and mud return is required, an outer second pipe, a so-called riser, is put in place so the mud and cuttings can be pumped back to the deck.

Coring is performed with a hollow core bit that leaves a central column of rock. This core slides into a pipe barrel while drilling progresses. In the oilfield rotary coring technique, after coring the length of the core barrel, the whole assembly has to be pulled back out of the hole (pipe trip out) to get the core to the surface. In many scientific drilling projects, by contrast, continuous coring by wireline coring technique is utilized to avoid time-consuming round trips. The core barrel is retrieved through the drill string by sinking a wireline catching device that connects to the retrievable inner coring assembly with the drilled-out rock column inside. Once latched into the coring assembly's head, the core barrel is winched up to surface and replaced by an empty core barrel for the next round.

The actual formation-cutting method varies depending on the type of rock or sediment present along depth. Typically, thin-kerf diamond core bits with high-rotation speed are used for hard rock drilling, roller cone abrasion bits are used for softer sedimentary rock, and non-rotating sharp edged hollow metal pistons of several meters length are hydraulically shot (forced) into soft sea/lake-floor sediments to collect cores and thus advance the borehole.

Instable borehole conditions as well as saline or over-pressured formations often require that casing or liner pipes have to be installed. To hold casing in place and avoid formation fluid migration to surface, the casing must be cemented in place after being run in hole. Usually, wells are drilled following a telescopic configuration, starting with largest hole diameter at surface and ending up in the smallest diameter at bottom hole. Exceptions are so-called monobore configurations with static diameter from surface to end depth. Health, safety and environmental regulations or critical downhole conditions often require additional procedures to ensure safe drilling operations and to minimize environmental impact. This includes borehole stability control through mud density variation, biodegradable drilling fluid additives and blowout-preventers (BOP) devices.

Wireline coring

Exploration or diamond core drilling is used in the mining industry to probe rock formations in search of mineral resources. A thin-kerfed diamond core bit is rotated by slim drilling rods at high speeds. The core barrel is retrieved via wireline to the surface. The technique has been widely adapted in scientific drilling because of the capability of continuous coring without having to pull the drill pipe out of the hole. In addition, the slim diameters utilized allow minimizing the rock volume drilled and hence reducing costs. At the same time, the disadvantages of this method are the small core diameters and limitations to achieve enhanced drilling and coring depths.

Standard Diamond Coring Sizes

Type	Hole Size	Core OD
PQ	123 mm	83/85 mm
HQ	96 mm	61/63.5 mm
NQ	76 mm	48 mm

Tab. 4.2.1: Standard Diamond Coring sizes for hard-rock coring operations, OD= outer diameter

Fig. 4.2.2: Truck-mounted wireline coring rig at Snake River Plain (Project HOTSPOT)

In several shallow to medium deep ICDP projects, diamond wireline coring has been utilized very successfully. For example, in the Snake River Plain HOTSPOT project in Idaho, USA, three almost 2000 m deep wells were drilled with this technique. A wireline coring rig (Fig. 4.2.2) was used that can deploy 1000 m of PQ, 1500 m HQ or 2500 NQ drill string.

Following the telescopic well architecture, drilling starts with the larger size diameter from surface and continues as long as possible until the formation in the open hole has to be stabilized with permanent or provisional liners or casings. The next smaller size drill pipe has to be used to continue coring and needed to line or case the hole with the corresponding casing size.

Combined techniques

Wireline diamond coring has also been utilized with oilfield drilling rigs deploying a hybrid coring system. ICDPs Chicxulub Drilling Project started with cementing an 8 m deep conductor casing. A section of Tertiary limestones (392 m depth) was penetrated without coring by standard rotary drilling (312 mm diameter), cased (245 mm) and cemented (Fig. 4.2.3). The following two sections were continuously cored with a HQ string to about 1000 m depth until the pipe got stuck. The subsequent NQ section was deepened to 1510 m and left open.

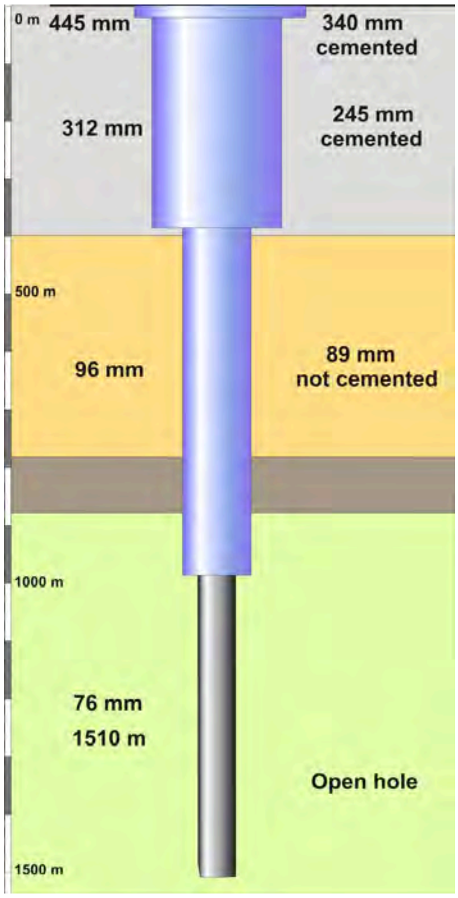

Fig. 4.2.3: Sketch of ICDP Chicxulub well with hole size on the left and casing diameter of the right

Lake sediment drilling

Undisturbed, lacustrine sediment cores serve as important archives for high-resolution studies in environmentally sensitive areas. One of the major issues in sampling those archives is the lack of suitable and cost-effective sampling tools. A very successful approach has been achieved through the redesign of available wireline drilling technology. The Global Lake Drilling unit GLAD800 and its successor, the Deep Lake Drilling System (DLDS) were owned by ICDP and operated by a service contractor. The major components are:

- a wireline drilling rig (Atlas Copco T3W DH)
- four-motor rotary top-head drive
- a container-size modular and versatile barge (24.4 x 7.3 m, Damen system)
- anchor winches or dynamic positioning systems, mud tank, crane and other auxiliary equipment

Fig. 4.2.4: DLDS on Dead Sea

The diamond wireline drilling technique utilizes various special coring tools and can reach depths up to 1400 m depth (CHD 134 string) in 400 m water depth. The DLDS is a complex and modern drilling unit, which requires a crew of experienced, well-trained technicians and engineers for drilling and marine operations on a 24/7 basis (Fig. 4.2.4).

The GLAD800 was deployed with ICDP funding in Lakes Titicaca, Bosumtwi, Peten Itza and as an arctic version on the frozen Lake Elgygytgyn. When severe weather hampered GLAD800 operations significantly during Lake Qinghai and Laguna Potrok Aike operations, a new barge system was designed and built as Deep Lake Drilling System DLDS by DOSECC. The new DLDS was subsequently deployed thereafter in deep-drilling ICDP projects on Lake Van, the Dead Sea and Lake Towuti. The rig was also used in the offshore Chicxulub Crater Drilling Project.

During the Lake Ohrid drilling expedition of ICDP in Macedonia using the DLDS, 480 m coring depth was reached twice within less than 17 days of drilling time, with core recovery rates of over 90% per site. There is hence no doubt that this is a very capable barge drilling system. Nevertheless, it is also limited to wave heights < 1 m and wind speeds of less than 4 Beaufort. Furthermore, mobilization and demobilization are cost-intensive as it comes in 14 20-ft-long shipping containers. Furthermore, staging the barge into water requires a 100-t-crane and a rigid quayside or slipway. Site location, available local infrastructure and logistics constraints can further complicate deployment of lake drilling systemy. Safety and hazard considerations for and around the entire operation must be specified in detail as part of the science and operations plan along the planning phase of the project management strategy.

Soft sediment coring

Loose and soft sandy to clay-rich sediments are not easy to probe continuously. First, all coring devices may lose the lowermost core section from the so-called core-catcher during each coring run. Therefore, to ensure complete core coverage it is necessary to deploy these systems at two or three parallel holes per site, which allows a data processing called 'splicing' (aka: depth-matching of geological horizons across boreholes, see Chapter Core Handling). Second, there is no coring device that is capable of recovering the uppermost water-rich and very unconsolidated sediments at the same recovery percentage as deeper consolidated sections. Accordingly, different coring tools for different lithologies are needed.