Platforms for Shallow Water Drilling

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Additional platforms for shallow water drilling that complement the strengths and capabilities of the JOIDES Resolution are required to address fundamental questions about continental margin development and evolution. One of the major objectives of margin studies is to assess the morphologic and stratigraphic response of the continental margins and sedimentary basins to a number of environmental forcing functions over a variety of scales. More complete core recovery and downhole logging across the entire continental margin from shallow to deep is required for understanding the links between fundamental physical processes and the formation of the preserved stratigraphic record.

Rapid advances in technology have greatly improved the accuracy and precision with which we can navigate and seismically image the sea floor and subbottom horizons (i.e., scales of meters to kilometers). However, coring technology available to the research community has not kept pace with these geophysical advances, especially in shallow water environments. Hole stability in, and core recovery of, unconsolidated sediments remains poor, which greatly limits our ground truthing/ correlating capability. In fact, hole stability problems caused by the thick unconsolidated sands encountered on the New Jersey continental shelf during ODP Leg 174A highlights the need for additional platforms to operate in shallow water environments (< 75 m) that can penetrate, sample, and log deeper into the sedimentary succession. This need was echoed at the COMPOST meetings (COMmittee on POST 98 Drilling) that concluded that the scientific community needs access to the technology necessary to increase the penetration capability and core recovery of ODP's drilling platform(s). New coring and downhole logging technology developed for industry offers exciting prospects for continuously coring and logging unconsolidated sediments in diverse environments (e.g., continental shelf and slope).

In addition, climatic studies will benefit from additional shallow water drilling platforms because most open ocean sediment cores cannot be used to resolve short period climate change, and records from most corals and varved sediment sequences are not long enough to resolve millennial scale changes. However, every ocean basin is rimmed by continental margins with exceptionally high rates of sediment accumulation (10 100's cm/1000 yrs). At these locations, high resolution paleoclimate studies complement the records of corals, bivalves, and varved sediments. Continental margins as a whole have been grossly underrepresented in studies of paleoclimate, because the high terrigenous flux has been viewed as a liability rather than an asset. With shallow water drilling platforms and chemical analysis using sensitive instruments, it is possible to recover high resolution series of paleoclimate proxy data. In particular, shallow water drilling will prove essential to correlate marine and terrestrial results.

MarineCAM, a shallow water drilling workshop held at Lamont Doherty Earth Observatory on May 1 and 2, 1997, was convened by Gregory Mountain (LDEO). The workshop was funded by the JOI/USSAC and Office of Naval Research (ONR). The main objective of the meeting was to examine state of the art industry drilling and logging technology for shallow water environments (<500m) in order to determine if these tools could accommodate the needs of the scientific community. A total of 28 scientists and 6 representatives from 4 offshore engineering companies attended (Alpine Geophysical, Fugro McClelland Marine Geosciences, Inc., Rosscore, and Warren George, Inc.). Three general approaches were presented for shallow water sediment sampling and logging: (1) vibracoring, (2) push/percussive/rotary coring, and (3) in situ geotechnical monitoring without coring (Table 1). In this article, we provide a brief summary of these three sampling and logging approaches and outline the associated costs with the different technologies.

Vibracoring is accomplished by using a cable to lower a core pipe to the seabed and vibrating it into the sediment with a submerged motor. The pipe and motor assembly is vertically stabilized in one of several ways, and must be deployed and retrieved for each core. Vibracores can be acquired in virtually any near shore setting except where high energy surf precludes safe operation. The deep water limit is determined by ship stability and by the type of vibrating motor: pneumatic and hydraulic systems are practical to about 75 m water depth, while electric systems can continue to 750 and perhaps to 1500 m. Depth of penetration and degree of core disturbance are controlled in part by the frequency and amplitude of the applied vibrations. Vibracore penetration and quality can be severely limited by thick sand and more importantly, stiff silts and clays. Nevertheless, penetration of difficult horizons can be accomplished by offset vibracoring and washing down or “jetting” without sampling through the horizon with continued core recovery beneath it. The practical penetration for all types of existing vibracores are in the range of 1020 m subbottom.

Push/percussive/rotary coring spans a large range of operating settings and costs. The basic approach applies a constant load or percussive impulse from above the sea surface that drives a core pipe into the sediment. With increasing induration of the sedimentary succession, operations switch to a top drive motor that rotates a drill bit and cuts into the formation. As water depth and desired depth of penetration increase, progressively more robust systems can be used to reach 1000’s of meters below seafloor (mbsf) in 100’s m of water. The low end of push/percussive/rotary coring begins with a lightweight system typically operated from an anchored platform, which is limited to water depths of less than 30 m because of its weather sensitivity. Depending on the substrate, samples can be recovered to 30 m subseafloor. A modular, portable barge system can be assembled onsite; its operating depth is limited by weather sensitivity, and the size/buoyancy of the barge governs the depth of seafloor penetration. Typical estimates for the modular barge system are up to 30 m water depth and 100 m subbottom penetration. Increased sea worthiness and mobility make ships more versatile platforms than floating barges. Mid-sized, anchored vessels with coring through a center well can recover samples to 650 mbsf in water depths up to 300 m. A dynamically positioned ship increases the operating water depths to 700 m, again with penetration to 650 mbsf. A jack-up platform can be used instead of a ship to lower legs to the seafloor, raise the platform out of the water, and isolate the drill rig from wave motion. These platforms begin with small, towed barges that are recommended for 620 m water depths; they can hang enough pipe to core to 500 1000 mbsf. Larger, self-propelled jack-up barges can work to 100 m water depth and core to 1000 mbsf. Oil field jack-ups complete this group of platforms, operating in water depths up to 100 m with penetration capabilities of well over 1000 m.

The Terrabore system is a variation of the above coring technique currently under development by a consortium of Norwegian companies. It is adapted from mining technology and is under review by Antostrat for possible use in over consolidated glacial tills along the Antarctic continental margin. It uses rotary coring only, is planned for deployment from mid-sized ships of opportunity either over the side or through a center well, and is intended for operating in 500 m of water with penetration of 50100 mbsf. Thus far, however, and in contrast to the available technologies described previously, Terrabore has limited heave compensation, a function that is vitally important to maximizing core recovery/ quality. In further contrast to existing systems, Terrabore at present has no capacity to acquire in situ measurements via wireline logs.

The third approach collects a suite of in situ measurements of sediment properties but fails to recover any samples. These tools record any of several geotechnical engineering properties typically used to determine bearing load capacity before placing structures directly on the seafloor. Because of the cm-scale resolution, high reliability, and downhole continuity of these data, workshop participants agreed this information could be a valuable asset to push/percussive/rotary coring. The tools discussed were cone penetrometers, vane shear devices, pressure meters, and packers. Measurements can be performed in undisturbed sediment 3 m or less ahead of the bottom hole assembly while either continuously pushing the device into the seabed, or in a “measure advance measure” mode. Data are stored downhole and downloaded to a topside computer when the tool is retrieved. Typical properties extracted from these measurements include pore pressure, permeability, shear strength, present stress field, and proxies for sediment density and composition. These devices can be used to 3000 m water depths or more. Their subbottom window of applicability is determined by sediment induration; typical applications to 70 mbsf were described. Each can be deployed from the same platform that acquires push/percussive/rotary cores, i.e., a floating barge, ship, or jack-up. Whatever the platform, however, a seafloor “reaction mass” is needed to stabilize the bottom assembly and as much as possible isolate it from platform motion at sea level.

The relatively affordable costs and the large variety of appropriate platforms ensure that vibracoring is within reach of expected scientific budgets. Furthermore, pre-site characterization needed for 1020 m penetrations is far more modest than for deeper sampling operations.

The jump in cost and operational complexity between vibracoring and push coring poses a significant challenge to meeting a variety of scientific goals. The only route to >20 mbsf samples discussed at the workshop is to hire specialized companies. Daily costs begin at $15K and continue upward to more than $100K (Table 1). Contractors estimated that mobilization costs for these platforms deployed to either the east or west coast of the US would range from $250K to $2M. Obviously, every effort will be needed to reduce these costs by either sharing mobilization with other interests, waiting for a ‘platform of opportunity’ that is transiting through a given study area, or defining scientific programs that are in areas close to where these platforms are already deployed.

ODP could provide managerial benefit to coring at margins. For example, the recently formed Scientific Drilling in Shallow Water Systems Program Planning Group could help to: a) formulate precise scientific objectives; b) maintain a schedule of platforms of opportunity; c) recommend site surveys for pre-coring site evaluation; and, d) ensure proper sample distribution and archiving at one of the ODP core repositories. Participants left the workshop with renewed confidence that the time had come for coordinated coring at margins. The potential rewards in this virtually untapped geologic archive are very large, but so are the costs for reaching those goals.

MarineCAM Options

downhole device	**typical platform**	**WD, m**	**mbsf**	
pneumatic vibracorer	mid-size ship of opportunity	0-70	10[1,2]	
electric vibracorer	mid-size ship of opportunity	0-1500	10[1]	
lt-wt electric vibracorer	small ship of opportunity	0-5000	10[1]	Ros
lt-wt push/percuss/rot corer	small portable barge	5-30	30[1]	Ros
push/percuss/rotary corer	portable barge[5?]	0-20	100	v. v buo
"	self-elevating barge	5-100	?1000+	up/
"	oil field jack-up	100-200	?1000+	
"	anch'd mid-sized ship w/ pool[5]	5-100	650[3]	e.g.
"	DP ship[5]	100+	650[3]	e.g.
"	oil field semi-submersible[5?]	100+	?1000+	
Terrabor rotary corer	mid-size ship w/ pool or over-the-side	500	50-100	und hea
geotech measurement	anch'd mid-sized ship w/ pool[5]	5-100	70[1]	no
"	DP ship w/ pool[5]	100+	70[1]	e.g.

1 limited by stiff clays + thick sands
2 "could be increased to 50 mbsf or more" - *K.Moran*
3 Fugro's Failing 2000 rig + Bucentaur deployable to 650 mbsl (not mbsf)
4 ?Failing systems + Bucentaur can take only push/piston cores (no hard rock diamond core barrel)
5 need seafloor reaction mass
6 $K/day vibra-coring includes mob/demob, ~3-6 cores/day
7 wireline based on 100 mbsf, 30 days on site:
a $K/day not incl mob from east coast US / $K east coast US ops / $K west coast US ops

[b] $K/day not incl mob from Gulf of Mexico / $K east coast US ops / $K west coast US ops

[c] west coast US ops only if ship available from SE Asia or China

Rotary *in situ* Wireline Tools

tool	application	comn
cone penetrometer *(CPT, PCPT, seismic)*	cont stratig, proxy density, proxy sed type, shear strength, dynamic pore press, pore press decay, stress hist, velocity, optical (under devel)	can be done from wir autonomous seafloor *(e.g. Seascout, TSP*
vane shear	undrained shear strength, sensitivity, stress-strain	
pressuremeter	shear modulus, stress-strain, lateral stress, shear strength	
packer	permeability, hydraulic fracturing, flow test	
temperature probe	geothermal gradient, bottom water thermal history	
logging-while-drilling	proxy density, -porosity, -grain size, stratigraphy	uncertain fit with pip unless vel >> 2 km/s generally available