ICDP INTERNATIONAL CONTINENTAL SCIENTIFIC DRILLING PROGRAM

ICDP Operational Report

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Operational Report

The Nam Co Drilling Project, Tibet (NamCore): A one million year sedimentary record from the Third Pole

Marie-Luise Adolph[1], Junbo Wang[2], Liping Zhu[2], Leon J. Clarke[3], Andrew C. G. Henderson[4], Hendrik Vogel[5], Peter Hofmann[6], Jianting Ju[2], Cindy Kunkel[7], Anders Noren[8], Doug Schnurrenberger[8], Volkhard Spiess[9], Camille Thomas[5], Arne Ulfers[10], Torsten Haberzettl[1]

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The Nam Co Drilling Project, Tibet (NamCore): A one-million-year sedimentary record from the Third Pole

- Operational Report -

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Abstract

The Nam Co Drilling Project (NamCore) aims to retrieve and interpret one of the longest sedimentary records of past climate and environmental changes from the Earth's third Pole - the Tibetan Plateau. As a result of vast glacial systems, permafrost, and large lakes, the Tibetan Plateau contributes to the "Asian Water Tower" and feeds river systems (e.g., Brahmaputra, Yangtze) that supply water to almost 2 billion people downstream. NamCore will shed light on the response of the Asian Monsoon system(s) and the Westerlies to variable climate boundary conditions in the past and thereby provide a better understanding of future climate change scenarios with socio-economic significance. Nam Co, one of the largest and deepest lakes on the Tibetan Plateau, represents an ideal natural archive to record the temporal development of large-scale atmospheric circulation systems due to its location close to the northern boundary of the modern monsoon regime. Comprehensive site survey seismic data suggest a >700-m-thick infill of well-layered, undisturbed sediments in the depocentre of the lake. Scientific drilling operation at Nam Co was realised through matching funds from the ICDP, ITPCAS, DFG, Swiss NSF, China NSFC and UK NERC funding agencies in June to July 2024. Drilling at high altitude (4718 m asl) in remote Tibet required extensive preparation, including the establishment of a camp on the northern shoreline of the lake. The project drilled a total of 1415.45 m, cored 1175.99 m sediments and recovered 950.77 m of sediment cores, with a maximum drill depth of 510.2 m below the lake floor.

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INTERNATIONAL CONTINENTAL SCIENTIFIC DRILLING PROGRAM

Participants in the NamCore Expedition in June-July 2024

(Alphabetical order, **bold PI**)

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Ceriotti	Giulia	University of Lausanne, Switzerland
Clarke	**Leon**	**Manchester Metropolitan University, UK**
Daut	Gerhard	Friedrich Schiller University Jena, Germany
Grelle	Thomas	LIAG Institute for Applied Geophysics, Germany
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Henderson	**Andrew**	**Newcastle University, UK**
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Ju	Jianting	Institute of Tibetan Plateau Research, Chinese Academy of Sciences, China
Kilian	Ethan	University of Lausanne, Switzerland
Kipfer	Rolf	Swiss Federal Institute of Aquatic Science and Technology (Eawag), Switzerland
Klamt	Wilhelmine	University of Greifswald, Germany
Kou	Qiangqiang	Institute of Tibetan Plateau Research, Chinese Academy of Sciences, China
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Li	Minghui	Institute of Tibetan Plateau Research, Chinese Academy of Sciences, China
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Schmitz	Olga	Friedrich Schiller University Jena, Germany
Schnurrenberger	Doug	Continental Scientific Drilling Facility, University of Minnesota, USA
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Vinnepand	Mathias	LIAG Institute for Applied Geophysics, Germany
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Zhaxi	Cidan	Institute of Tibetan Plateau Research, Chinese Academy of Sciences, China
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Participants in the Core Opening and Sampling Parties in 2025

(Alphabetical order, **bold PI**),

CAS = Chinese Academy of Sciences
CSD = Continental Scientific Drilling Facility

Name	First Name	Affiliation	Feb 25	May 25	Sept 25
Adolph	Marie-Luise	University of Greifswald, Germany	x	x	x
Braun	Erwin	University of Greifswald, Germany		x	
Ceriotti	Giulia	University of Lausanne, Switzerland		x	
Clarke	**Leon**	**Manchester Metropolitan University, UK**		x	
Daut	Gerhard	Friedrich Schiller University Jena, Germany		x	
Grivna	Brian	CSD, University of Minnesota, USA	x		
Haberzettl	**Torsten**	**University of Greifswald, Germany**	x	x	x
Henderson	**Andrew**	**Newcastle University, UK**	x	x	
Höhle	Marlene	University of Greifswald, Germany		x	x
Jiang	Baoqi	ITPCAS, China		x	
Ju	Jianting	Institute of Tibetan Plateau Research, CAS, China	x	x	
Kai	Jinlei	Institute of Tibetan Plateau Research, CAS, China		x	
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Kunkel	Cindy	ICDP Operational Support Group, Germany	x	x	
Laakkonen	Aliisa	University of Bern, Switzerland	x	x	
Li	Minghui	Institute of Tibetan Plateau Research, CAS, China	x	x	
Li	Yurong	Institute of Tibetan Plateau Research, CAS, China		x	
Ma	Qingfeng	Institute of Tibetan Plateau Research, CAS, China	x	x	
Müller	Kaja	University of Greifswald, Germany		x	
Otero	Santiago	University of Greifswald, Germany			x
Picard	Maïlys	Umeå University, Sweden		x	
Thomas	Camille	University of Bern, Switzerland	x		
Vogel	**Hendrik**	**University of Bern, Switzerland**	x		
Wang	**Junbo**	**Institute of Tibetan Plateau Research, CAS, China**	x	x	
Wu	Xiangjun	Institute of Tibetan Plateau Research, CAS, China		x	
Yang	Hongyi	Institute of Tibetan Plateau Research, CAS, China		x	
Zhaxi	Cidan	Institute of Tibetan Plateau Research, CAS, China	x	x	x
Zhu	Haoran	Institute of Tibetan Plateau Research, CAS, China		x	
Zhu	**Liping**	**Institute of Tibetan Plateau Research, CAS, China**	x	x	
Zhu	Xinghuan	Institute of Tibetan Plateau Research, CAS, China		x	

Abbreviations

ALN: Alien Corer

CC: Core Catcher

CSD: Continental Scientific Drilling Facility, University of Minnesota, USA

DFG: German Research Foundation

EXN: Extended Nose Corer

GPM: Gallons per Minute

HPC: Hydraulic Piston Corer

IGSN: International Generic Sample Number

ITPCAS: Institute of Tibetan Plateau Research, Chinese Academy of Sciences

m blf: metre below lake floor

mDIS: mobile Drilling Information System

NAMORS: Nam Co Monitoring and Research Station for Multisphere Interactions

PSI: Pound-force per square inch

TP: Tibetan Plateau

1. Introduction

Nam Co (Co = lake) is one of the deepest, largest and best-investigated lakes on the Tibetan Plateau (Fig. 1, Fig. 2). It was targeted for drilling as part of the ICDP "Nam Co Drilling Project" (NamCore), which aims to recover the longest and most continuous sediment record from the Tibetan Plateau. This region is known as the Earth's "Third Pole" due to its extensive high-alpine ice fields storing the third largest amount of ice outside the polar regions. These ice reservoirs and large alpine lakes also contribute to the idea that the Tibetan Plateau is an "Asian Water Tower" as they feed the large Asian river systems, including the Brahmaputra, Yangtze, Yellow River, Indus, and Ganges, which supply freshwater to almost 2 billion people downstream (Yao et al., 2022). Therefore, it is essential to refine future climate change scenarios and the consequences of a changing climate for ecosystems and human societies via improving our knowledge of the timing, duration and intensity of past climatic variability, especially the monsoon systems, and to understand its environmental impact on long geologic timescales, under different boundary conditions. The sediments of Nam Co record the temporal development of large-scale atmospheric circulation systems because of its location in the modern monsoon regime. Comprehensive pre-site survey seismic data (Fig. 3) clearly show an infill of >700 m of well-layered, undisturbed sediments in the central part of the lake, spanning several glacial/interglacial cycles. Moreover, Nam Co's sedimentary record is an exemplary archive to fill the paleoclimate data gap between two ICDP/IODP transects that will allow comparisons of climate evolution/behaviour on a continental scale. Drilling operations at Nam Co were conducted in the summer of 2024. We drilled a total of 1415.45 m at one site, with seven holes, recovering 950.77 m of sediment. The maximum depth was reached in Hole 1_G at 510.2 m below lake floor (blf). This report documents (i) the drilling strategy, which was adjusted repeatedly before and during the drilling, (ii) the site preparation, (iii) technical and (iv) scientific on-site operations, as well as the (v) core opening and sampling parties.

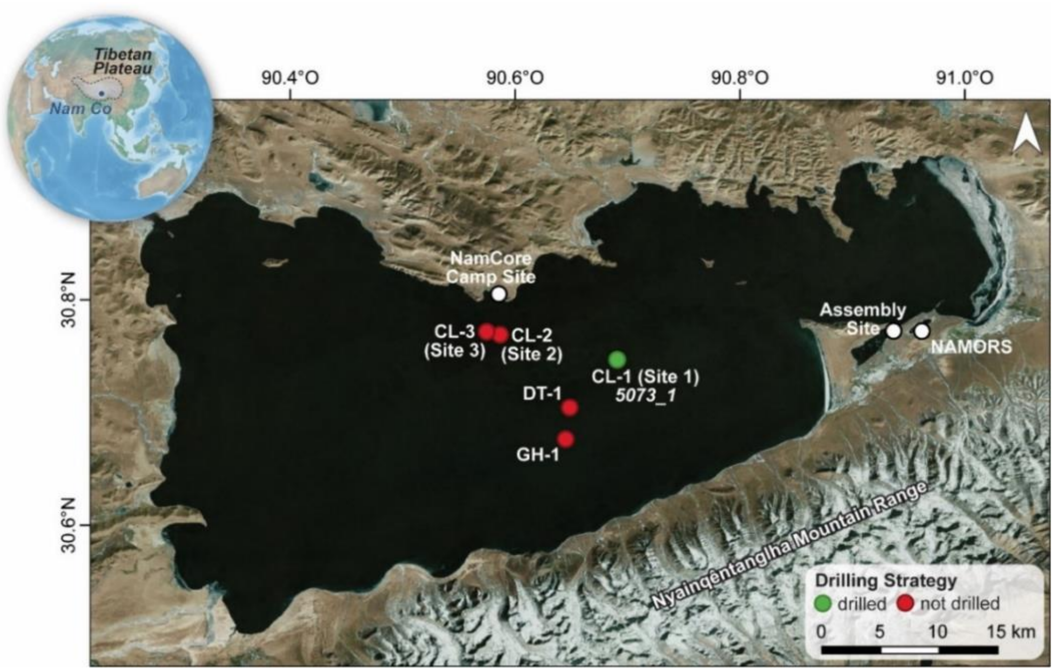


Fig. 1: Location of Nam Co on the Tibetan Plateau (inset). Aerial image of Nam Co, including the originally proposed drilling sites CL-1, CL-2, CL-3 (referred to as Sites 1 to 3), DT-1 and GH-1. Colour of the drill sites refers to whether the Site was drilled or not in June-July 2024 (red = not drilled, green = drilled). Additionally shown are the locations of the NamCore Camp Site on the northern shoreline, as well as the Nam Co Monitoring and Research Station for Multisphere Interactions (NAMORS) and the Assembly Site of the drilling platform at the south-eastern shoreline (white dots). Base map: Bing Maps Satellite Imagery.

2. Site Description

Nam Co has a flat, up to 100 m deep, central basin, and a smaller/shallower (~60 m deep) basin to the NE (Wang et al., 2009) (Fig. 2). The lake covers an area of 2,015 km² (Zhu et al., 2010), with a 10,680 km^2 catchment (Zhou et al., 2013) that contains >60 streams, most of which drain the glaciated Nyainqêntanglha mountain range (>7,000 m a.s.l.) to the south and southwest of the lake (Fig. 3C) (Wang et al., 2009). The Nam Co basin is located in the Paleozoic-Mesozoic 'Lhasa block' between the Yarlung and Bangong sutures to the north and south (Pullen et al., 2008) and is considered to be part of the southern margin of Asia (England and Searle, 1986; Murphy et al., 1997). Collision of the Indian subcontinent with Asia since the Eocene led to the uplift of the Tibetan Plateau (TP) (e.g., Aitchison et al., 2007; Gibbons et al., 2015). The collision exhumed the Gangdese batholith, to which the Nyainqêntanglha range belongs, formed during Cretaceous Andean-type subduction (Kapp et al., 2005). While the pace of construction of the continental TP from 50 Ma onward remains debated (e.g., Ai et al., 2019; Ding et al., 2014; Xu et al., 2018), Nam Co has likely been close to its present elevation since the upper Miocene (12-10 Ma) (Kapp et al., 2005).

Presently, the Nam Co basin belongs to the endorheic catchments of central Tibet (Fig. 3B). The lake is isolated from drainage into the Yarlung Zangbo-Brahmaputra catchment by the uplift of the Nyainqêntanglha mountain range due to normal faulting along the Gulu-Yanbaijin graben (Armijo et al., 1986). The Nam Co basin is thus surrounded by major active faults, the Beng Co right-lateral strike-slip fault to the north, the left-lateral transtensional Damxung-Yanbajin fault system to the southeast and normal faults in the Gulu graben to the east (Armijo et al., 1989). These faults are responsible for some of the largest earthquakes (M7 to 8) in the area during the last century (e.g., the 1952 Damxung earthquake of M8) (Armijo et al., 1989). The most recent example is the destructive 2008 M6.3 earthquake with its epicentre located in the Yanbajin graben (Elliott et al., 2010), 100 km south of Nam Co (Fig. 3C). Other faults with similar kinematics, but with much slower slip rates, cross the Nam Co basin. Clear evidence of faulting is absent (or subdued) in the Nam Co catchment and, despite disruption within the Nam Co sediments, as seen in seismic data, cumulative deformation within the basin is small.

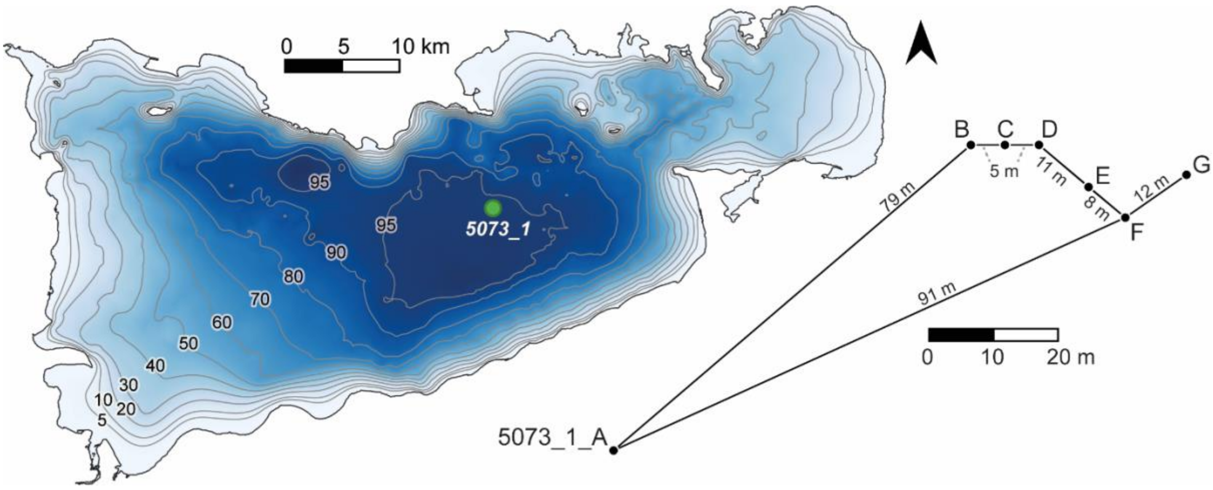


Fig. 2: Left: Bathymetry of Nam Co including the drilling location (green dot). Right: Distance between the holes at 5073_1.

The present climate is semi-arid to sub-humid, with ~420 mm annual precipitation, of which >90 % derives from rainfall during the monsoon season (June-September) (Maussion et al., 2014). The mean annual temperature is 0 °C. Since Nam Co is situated in a closed basin, the water balance is primarily controlled by precipitation, evaporation, meltwater and groundwater input. Intra-annual lake level fluctuations of ~1 m result from the strong seasonality driven by monsoonal precipitation during summer and evaporation throughout the rest of the year. This behaviour, in combination with a recorded lake level increase of ~5 m over the past 30 years (Kropáček et al., 2012; Zhu et al., 2010), emphasises the sensitivity of Nam Co to changes in the precipitation/evaporation balance.

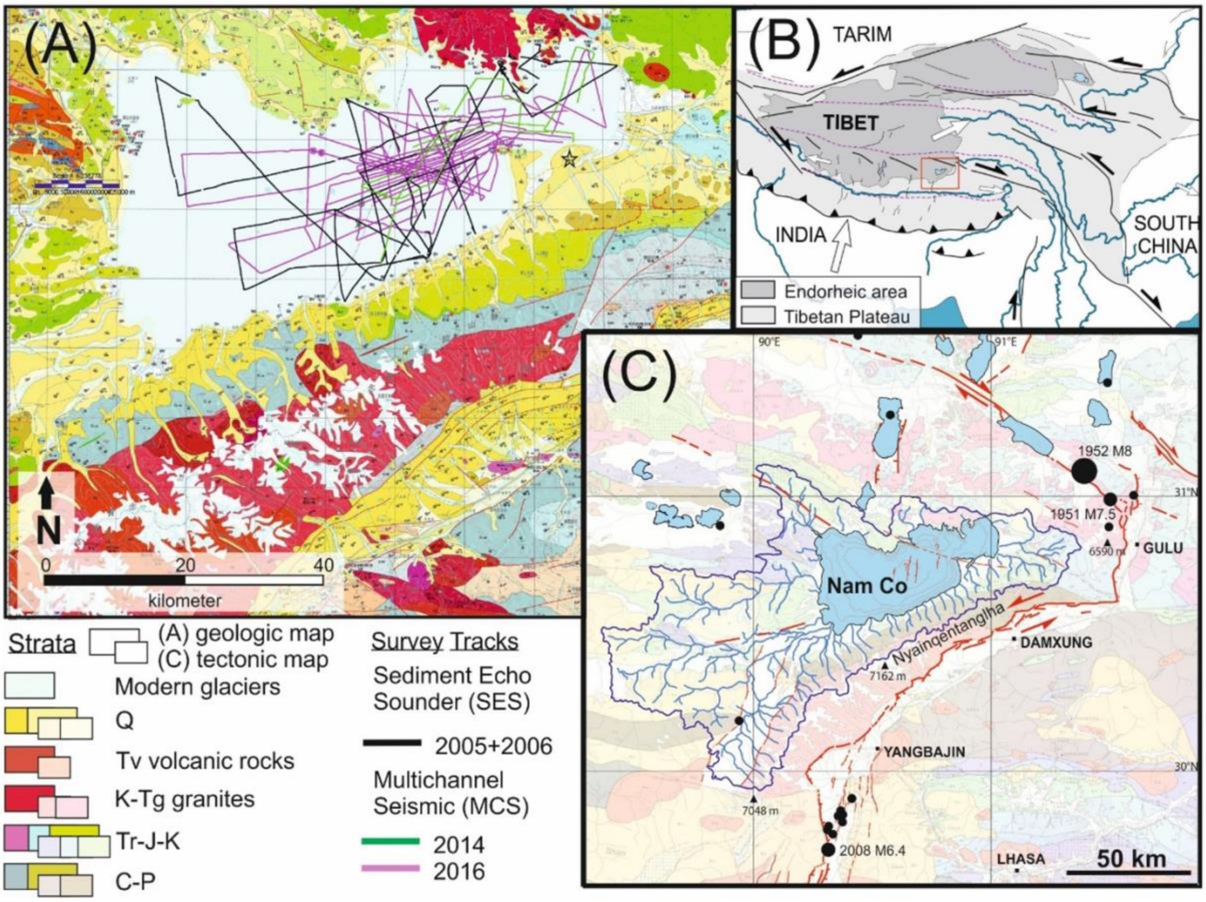


Fig. 3: Geological map of the Nam Co area (Wu et al. 2011, Regional Geological Survey Report of China, modified) and location of site-survey seismic profiles. The black open star indicates the location of Nam Co Research Station. (B) Simplified tectonic map of the Tibetan Plateau (light grey), indicating an internally drained area (dark grey). (C) Local tectonic framework of the southern Lhasa terrane around Nam Co (Armijo et al., 1989, modified). Epicentres of recent earthquakes are marked with black circles. Approximate E-W extension characterises the active tectonics of the region with N-S directed normal faults in Gulu and Yangbajing and oblique NW-SE right-lateral faulting in the north (Beng Co fault) and SW-NE left-lateral faulting near Damxung. Fault directions found in the seismic data from Nam Co are indicated schematically. Additionally, the catchment of Nam Co, including the inflows, is shown.

3. Scientific Objectives

With the recovery of a continuous Quaternary sedimentary record from Nam Co, NamCore aims to address several objectives regarding paleoclimate, the evolution history of lacustrine and terrestrial species endemic to the Tibetan Plateau, (geo-)microbiology, paleomagnetism, tectonics and glacier dynamics. Scientific objectives include:

i. Long-term climate variability on the Tibetan Plateau and its relation to hemispheric and global atmospheric circulation patterns, including the timing and magnitude of Indian monsoon variability and the interplay with the Westerlies;
ii. Glacial history and dynamics of the Tibetan Plateau using lake sediment proxies reflecting glacier advances over glacial-interglacial timescales;
iii. Impact of geological and environmental changes on (micro-)biological processes, evolution and resilience of high-altitude ecosystems during both glacial and interglacial climate conditions;
iv. Deep biosphere at high altitudes by quantifying microbial-community diversity and assessing the rates of elemental cycling and their metabolic pathways in subsurface life;
v. Geomagnetic changes and Earth's paleomagnetic field behaviour beyond the Holocene, capturing rates of change and the dynamic features of secular variation;
vi. Tectonic history and evolution of faulting to explore the timing of basin deformation and validate models of source-to-sink geomorphology.

For details on the objectives, please see Haberzettl et al. (2019).

4. Drilling Strategy

4.1. Drilling Strategy in the original ICDP Proposal

The site selection and drilling strategy for the NamCore drilling is based on four extensive joint Sino-German hydroacoustic surveys carried out in 2005, 2006, 2014 and 2016 (Fig. 3A). Methodological details and preliminary seismic results are explained in detail in Haberzettl et al. (2019) and Schulze (2020).

The drilling strategy in the original ICDP proposal included a transect of three cores (CL-1 to CL-3), a deep site (DT-1) and a nearshore hole (GH-1) (Tab. 1, Fig. 1). Based on the Nam Co sedimentary architecture, the drilling strategy aimed to build an ~500 kyr record by splicing together a composite record that comprises three overlapping "short" composite drill sites, Sites CL-1 to -3, with target depths of ~150 m blf. The Sites CL-1 to CL-3 composite record was planned to be complemented by a 700 m deep hole from the long-term Nam Co depocentre at Site DT-1, where it was intended to recover the entire seismically imaged sediment fill, which was estimated to cover ~1 Ma and at the time assumed to be older than CL-1 to CL-3. To identify periods of stronger or predominant glacial activity, which may elsewhere in the lake only be picked up by proxies, two holes down to 100 m were planned to provide a composite record where lacustrine facies are interlaced with glacially-derived and/or glacially deformed sediments and moraines from the northern flank of the Nyainqêntanglha mountain range at Site GH-1, located near the southern shore (Fig. 1). This approach aimed to capture the entirety of processes relevant for our research program, synthesising both near- and far-shore signals in the sediment record of Nam Co. The order of priority for the drilling operation was CL-1, CL-2, CL-3, DT-1 and GH-1, producing a total targeted core recovery of 2250 m (Tab. 1).

Tab. 1: Drilling strategy in the original ICDP proposal (see Fig. 1 for locations).

Site	Expected Age Range	Max. Depth (m)	No. of Holes	Total Core Length (m)	Days
CL-1	Recent – mid-MIS 5	150 m	Triple	450	18
CL-2	Top MIS 5 – base MIS 11	150 m	Triple	450	18
CL-3	Mid-MIS 8-10 – >MIS 13	150 m	Triple	450	18
DT-1	0 – 1 Ma	700 m	Single	700	28
GH-1	Recent – MIS 5	100 m	Double	200	8
Total				**2250**	**90**

4.2. 1st Modification of the Drilling Strategy (before drilling)

Due to limited funds available for drilling operations, a substantial revision of the drilling strategy was required during the planning of drilling operations. Beyond technical aspects, such as choice of equipment, contractors, personnel and scheduling, a significant reduction in drilling time was needed. Since the original plans led, even in an optimistic setting, to more than one field season (considering weather conditions allowing for drilling), we decided to reduce the total length of cores by maximising the penetration rates while maintaining as many scientific objectives as possible.

4.2.1. Transect (CL-1 to CL-3)

Triple coring was originally proposed to ensure sufficient overlap at core gaps and a 100 % continuous record. The choice of only double coring at the transect sites was estimated to save 450 m and 18 days. Furthermore, a distinct overlap along the coring transect CL-1 to CL-3 was originally planned to deal with spatial variations and to ensure a continuous splice section. We planned to reduce the overlap for CL-2 by 40 m, maintaining 10 m overlaps between CL-1 to CL-2 as well as between CL-2 to CL-3. Shortening CL-1 was not planned since the top sediments at CL-2 are likely more shallow water deposits. The final drilling depth of CL-2 would have then been ~110 m, saving 3 days of drilling time. Accordingly, total savings along the transect were estimated at 530 m (40 % of the originally proposed 1350 m) and 21 days. With this reduction, all objectives regarding the high-resolution and high-quality sampling along the drilling transect were still achievable.

Major Adjustments:

- *Double cores instead of triple cores*
- *Decreased overlap between sites*
- *Total savings: 530 m drilling and 21 days*

4.2.2. Deep Site (DT-1)

As originally proposed, a 700-m-long sediment core would comprise 30 % of the envisaged total recovered core length (Tab. 2), a longer total drilling time, and substantially more drilling and weather-associated risks. Moreover, the seismic data quality at depths > 300 m for DT-1 did not allow for the reconstruction of stratigraphy/ages from seismic facies analysis, since the energy of multiple reflections masks primary reflections. Additionally, a clear bedrock reflection could not be identified at DT-1 but was revealed by special processing at different locations. We decided to shift the deep drilling targets from DT-1 to CL-3 to (i) save time for shifting the platform, (ii) avoid drilling in the lake centre for safety reasons, and (iii) to significantly reduce transfer times. Additionally, the burial depth of sediment at CL-3 would not exceed 300 m, and therefore, diagenesis may be less pronounced compared to DT-1. We assumed that a similar age predicted for 700 m at DT-1 would be possibly drilled at CL-3 at a much shallower depth, just above the presumed bedrock (Fig. 4). The geologic age target of NamCore was therefore found achievable at site CL-3 by only drilling to 0.51 s TWT instead of 0.93 s TWT. The compromise was a more condensed section, which, however, could be drilled with better core quality and by double coring down to this depth. Moreover, the likelihood of reaching the age range of 0.5 to 1 Ma, given the financial constraints of the project, was considered much higher at CL-3, with no negative effect on the scientific objectives. The only possible difference may have resulted from the proximity to the shoreline, and therefore, a difference in terrestrial sediment inputs as well as lower sedimentation rates. On the other hand, seismic data did not indicate major lateral changes in facies and amplitudes, and thus CL-3 was evaluated to provide similar results compared to DT-1. We therefore decided to deepen CL-3 down to ~300 m and eliminate site DT-1 from the drilling strategy.

Major Adjustments:

- *Shift drilling location from DT-1 to CL-3 to recover a longer core at CL-3, covering the same time frame at reduced sediment and water depths*
- *Total savings: 550 m drilling and 22 days*

4.2.3. Nearshore Site (GH-1)

At this site, drilling was likely to face significant technical challenges due to coarser material towards cobble size, based on lithologies encountered during drilling near this location, organised by ITP after the approval of the ICDP proposal. We decided to eliminate Site GH-1 from the drilling strategy or keep it as a low priority, because GH-1 may be the only site to provide direct evidence for glacial impact on the basin and geologic periods with glaciers proximal to the lake. The total savings of this change were estimated at 200 m of single coring and 8 days.

Major Adjustments:

- *Eliminated from the drilling strategy or lower priority*
- *Total savings: 200 m drilling and 8 days*

4.2.4. Summary of the 1st modified drilling strategy

Finally, the revised drilling strategy at Nam Co aimed at retrieving sediment cores from three drill sites (CL-1, CL-2, CL-3, referred to as Sites 1, 2, and 3, Fig. 4, Tab. 2) using an offset drilling approach. The offset drilling approach was chosen to recover a stratigraphy as complete as possible with maximum temporal resolution while minimising necessary drilling depths. All drill sites are located along a transect from the northern shoreline to the lake's depocentre. Hence, for the purpose of reducing shift crew transfer times by boat between the shoreline and the drilling platform (distances range from ~3 to ~12 km), a field camp was set up in a protected bay on the northern shoreline (Fig. 1).

Tab. 2: First revision of drilling strategy. The drilling focus on the transect (CL-1 to CL3) replaced the deep drill core (DT-1) and shifted the priority of the nearshore core (GH-1)

Site	Expected Age	Max. Depth (m)	No. of holes	Total Core Length (m)	Days
CL-1	Recent – mid-MIS 5	150	double core	300	12
CL-2	top MIS 5 – base MIS 11	110	double core	220	9
CL-3	mid-MIS 8-10 – >MIS 13	150	double core	300	12
CL-3	extension to the basement	300	single core	150	6
Total				**970**	**39**
GH-1	Recent – MIS 5	100	double core	200	lower priority
DT-1	0 – 1 Ma	700	single core	700	removed

4.3. 2nd Modification of Drilling Strategy (during drilling)

During the early stages of the drilling campaign, the expected fine-grained sediments at CL-1 turned out to be intercalated with coarse-grained sand layers, which were (i) difficult to core, (ii) required use of rotary coring tools, which yield lower quality core than the preferred hydraulic piston coring tools, and significant additions of bentonite and polymer to the drilling fluid to maintain borehole stability, and (iii) resulted in lower core recovery than desired. In light of these problems, we revisited the seismic stratigraphy. As originally planned, Sites 2 and 3 were much closer to the shoreline, which we expected would hold a greater number, thickness, and coarseness of the problematic sand layers. Given the lithologies encountered at Site 1, we assessed that drilling at Sites 2 and 3 would have resulted in an even more challenging drilling environment with limited depth advance and core recovery. Therefore, we decided to focus only on Site 1 (5073_1) as the seismic stratigraphy promised a continuous high-resolution sediment record of at least 300-450 m (Fig. 4).

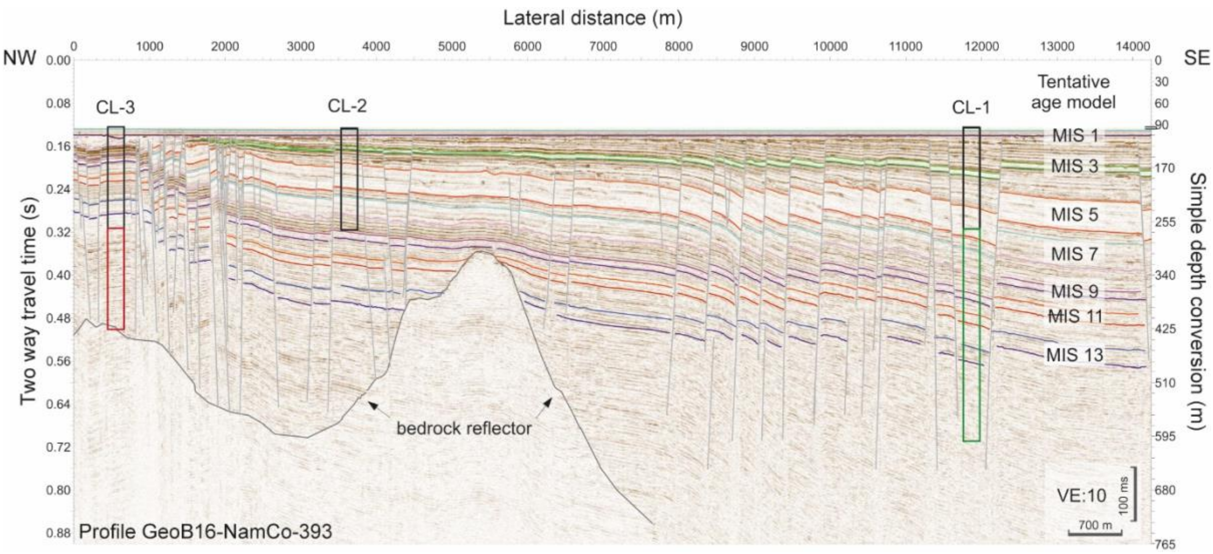


Fig. 4: Seismic reflection profile with original planned drill sites CL-1, -2 and 3 (referred to as Site 1, Site 2 and Site 3). The red rectangle at CL-3 indicates the adjustments during the 1st modification of the drilling strategy, which was envisioned to extend this site to the basement. The green rectangle at CL-1 indicates the 2nd modification during the drilling campaign, which finally only drilled CL-1 down to 510.23 m blf.

5. Drilling Preparation

5.1. Camp Construction

To reduce transfer times to the drilling site, we decided to build a camp at the northern shoreline, instead of staying at Nam Co Monitoring and Research Station for Multisphere Interactions (NAMORS, Fig. 1). After several pre-site surveys, three camp sites were proposed (Fig. 5). On September 12, 2023, all PIs, Anders Noren from the Continental Scientific Drilling Facility (CSD), along with representatives from the drilling company, the modular platform manufacturer, and the camp construction company jointly surveyed these sites, and selected Site A for the camp construction (Fig. 5).

From the beginning of 2024 until May, the Chinese PIs arranged to submit a temporary land use application to the local government and obtained approval. The camp was located in a place without infrastructure except for a ~500 m path from the main sand-gravel road, which was used for tourism, so it was necessary to build an access road, structures, water supply, power supply, network, and other facilities from scratch. In early May 2024, the camp construction contractor began with land levelling and gravel road construction. At the same time, the project installed a pontoon pier into the bay as a landing site for the tug boat and crew transfer boat. More than forty 20 ft containers were purchased to be used as warehouses, a kitchen, dining rooms, meeting rooms, toilets, bathrooms, laboratories, washrooms, and dormitories (Fig. 6). Drinking water was provided by purchasing barrelled pure water and domestic water was provided by building an electric water supply system. Power was supplied by renting 100 kW and 50 kW diesel generators. Sewage was disposed in a temporary septic tank. The setup of a reliable communication network was challenging. Initially, an attempt was made to amplify the mobile phone network signal from a nearby hill and then transmit it to the camp, but the signal was too weak. In the end, a local communications company installed a base station nearby, providing broadband access for the camp's wireless network and telephone signals. In addition, the base camp, the barge, the tug boat and the transportation boat were always connected by a series of interphone systems to ensure all sites can communicate with each other for 24 hours.

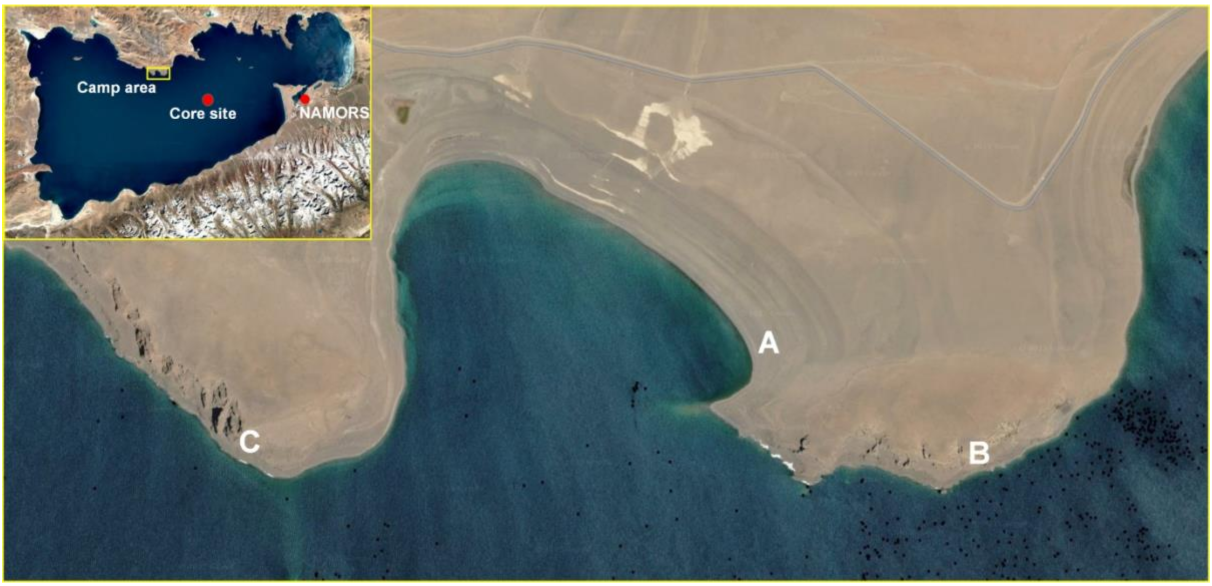


Fig. 5: Sites proposed for the location of the NamCore Camp. Finally, the camp was constructed at Site A

The setup of the field camp included accommodation, a 24/7 canteen, showers, laundry, laboratory, storage space and meeting rooms. Each dormitory was equipped with a set of beds, bedding with an electronically heating blanket, a desk and chair, and a shelf for each person. The kitchen was fully equipped, including refrigerators, steamers, electric water heaters, and liquefied gas stoves, to serve up to 50 people. The dining room could accommodate up to 30 people at the same time. The meeting room could hold meetings for 20 people and was equipped with a video conference system. Part of the meeting room was used to store an automated coffee maker, all kinds of drinks, instant foods and snacks that were accessible all the time. It also served as the dining room during eating time. The men's and women's restrooms were equipped with flush toilets and could be used by 10 people at the same time. The shower rooms (with a simultaneous capacity of 6 people) and washrooms (with a simultaneous capacity of 12 people) provided 24-hour hot water produced by a solar energy heating system.

Fig. 6: Overview of the NamCore camp, including the pier (left) and containers equipped for living (right)

5.2. Construction of the barge, tug boat and transfer boat

The NamCore drilling project contracted Weifang Dragon Machinery Technology Co., Ltd, PRC, for design, construction, and assembly of a modular platform and modular tug boat. During the design process, the PIs, CSD Facility and and project company man worked closely with the vendor to iterate on initial plans, and designs were finalized for the platform load capacity, draft depth, wind and wave resistance, stability, drilling rig and support equipment layouts, and personnel working and sample processing spaces (Fig. 7). The overall length of the platform is 20.3 m, the width is 9.8 m, and the pontoon height is 2.5 m. The platform weight with accessories is 103 t, the load capacity is 50 t, with a deck strength of 6.5 t m^{-2}. The platform is equipped with four anchor winches, each with a 750 kg anchor and 500 m of 22 mm anchor line, a 5 t folding deck crane, an 82 kW hydraulic power station to operate the anchor winches, a 30 kW diesel generator to supply electricity, and two rooms for crew shelter and storage. The tugboat is constructed of two modules attached side by side, with a combined 13.0 m length, a beam of 5.2 m, and a moulded depth of 2.0 m. It is powered by two Weichai 370 hp diesel engines (one in each module), with a towing capacity of 300 t (Fig. 7). The crew transfer boat was ordered from Hubei Bolang FRP Ship Co., Ltd., equipped with two Yamaha two-stroke 200 hp engines, with a maximum passenger capacity of 14 people (Fig. 7). Engine valves were improved to adapt to the low oxygen environment at an altitude of 4700 m, with a speed of up to 50 km h^{-1}. Due to the high altitude, outboard engines were not operating at their maximum capacity and required regular maintenance.

Fig. 7: Technical drawing of the tugboat (top left) and the barge (top right) built for the NamCore project. The tugboat was used to tug the barge to the drill site (centre). Transfer between the campsite and barge at drill site (bottom right) was carried out with the transfer boat (bottom left).

5.3. Mobilisation and Demobilisation

Since heavy trucks cannot reach the NamCore base camp in the north shoreline area, we selected a natural small harbour as the assembly site, which was close to NAMORS for mobilisation (Fig. 1). All barge, tug boat, and drill rig components (Tab. 3) were delivered there. Drilling barge and tug boat assembly by Dragon staff commenced on 14 May and took place in an easily accessible bay protected by waves through an approximately 200-m-long sand spit in the SE part of Nam Co. An excavator was used to dig a shallow beach along the bank by 1 m to prevent all watercraft from running aground and to ensure that the drilling platform, tugboat and other watercraft can reach a certain draft depth. Assembly was facilitated by an 80 t crane that operated from a gravel cliff approximately 2 m higher than the water, allowing for sufficient reach to align barge and tug boat components in the water and to place the drill rig and other equipment on the barge. Each module of the barge was assembled in the water near the bank, and after assembly, the drilling rig was hoisted and fixed on the barge. Assembly was completed on 4 June 2024. Commissioning of the barge and tug boat took place on the next day, including testing of all barge and tug boat components in a nearby shallow water area fixed by two anchors.

Towing the barge from the launch site in the NE of the lake to Site 1 (Fig. 1) started in the morning of 5 June 2024 (Fig. 7). The ~30 km distance was travelled in roughly 7 h. Anchoring commenced in the afternoon, and all four anchors were set by dawn. The barge was anchored in place with an anchor set out from each of the four corners of the barge. Anchors were towed out and lowered to the lake floor by the tugboat at predefined GPS anchor locations approximately 500 m from each corner of the barge. Each anchor was attached to a heavy chain, which was connected to the steel cable on the hydraulic winch. The science team coordinated and managed the anchoring process. Precise water depth measurements were conducted using a handheld sonar and rope measurements during gravity coring. Depth measurements were used to calculate the drill string length to the sediment-water interface. GPS locations were recorded for each hole (Tab. 4). On 7 June 2024, one anchor needed to be repositioned, resulting in a larger distance between hole 5073_1_A to the other holes (Fig. 2).

At the end of drilling operations, demobilisation was carried out in two groups: (i) one group dismantled the camp facilities and loaded the equipment onto multiple trucks, and (ii) the other group worked on the water, including weighing anchors and towing the platform to the dock at NAMORS. From October to November 2024, engineers from Weifang Dragon Machinery Technology Co., Ltd, PRC, and NAMORS personnel disassembled the barge. An 80 ton crane was hired again to hoist the disassembled modules of the barge ashore one by one. The damaged parts were painted, the anchor lines were maintained with grease, and then sealed with plastic bags. Sensitive equipment, such as the engines and generators, underwent maintenance, and all of them were packed in a newly purchased 12-m-long container. The tugboat and crew transfer boats were also hoisted ashore and safely stored onshore near NAMORS.

5.4. Logistical personnel

The project originally contracted three boat operators and marine crews. However, two of the three boat operators had to leave during adaptation due to severe altitude sickness. The project immediately contracted another boat operator to keep operations ongoing. Crew transfer and supply runs were covered, and barge operations were handled by day shift science crews to accommodate the staffing shortage. To ensure the required onshore support services were provided for efficient drilling operations, logistics personnel were employed, including two chefs, two kitchen assistants, a camp manager, a water and electricity technician, a doctor, a local guard and a cleaner. Short-term employees included temporary personnel during barge assembly and disassembly.

6. Technical Operations

6.1. Drilling Equipment

6.1.1. Drill Rig

Drilling services were provided by Sichuan Huafeng Drilling and Engineering Co., Ltd., PRC, with a Boart Longyear LF230 wireline diamond coring rig (Tab. 3). This rig offered the required capabilities to deploy the coring tools, with pullback and torque ratings sufficient to provide a buffer for the expected decrease in engine output at the high elevation at Nam Co. Huafeng were contracted to provide the drilling equipment, drilling consumables and supplies, and staff for drilling operations. A CHD134 drill string provided sufficient rigidity to drill without joint-welded casing through the water column. Soft sediment coring tools designed and manufactured by QD Tech, Inc. (Salt Lake City, USA) and used in numerous scientific lake drilling projects to recover HQ diametre cores (63.5 mm) in rigid polycarbonate liners were used. Modifications of the barge layout and drilling equipment requested by QD Tech advisers during platform setup were carried out by Huafeng and Dragon staff.

Tab. 3: Technical details of the drill rig

Rig Type	**Boart Longyear LF230**
Rig engine	8.3 l Turbocharged, Intercooled Tier 3 Cummins Diesel, tuned for operation at high altitude
Hydraulic pumps	Primary (four main functions: rotation, traverse, main and wireline winch). The secondary pump operates the Mud Pump, Auxiliary pump operates the drill feed control and auxiliary functions.
Main winch capacity	177.9 kN
Wireline winch capacity	17.2 kN
Rod pull length	6 or 9 m (for the barge operation, the telescopic drilling mast was set for the 6 m pull)
Rope	Dyneema rope and swinging boom for handling inner tubes on the tube rack
Chuck-type Rotation Unit	4-speed funk transmission, drilling operations mostly done with 3rd gear at reduced engine speed of 1500 RPM (note rig specifications based on 2100 RPM operation)
Drilling rotation speed	Depending on the hole conditions, generally in the range of 150-280 RPM
Rotation head traverse length	3.35 m
Chuck Axial holding capacity	222-400 N
Max. Rotation torque	117.9 kN
Max. Rotation head pullback	223.6 kN
Rod clamps	Cantilever 2 jaw system
Rod breakout	Single hydraulic ram with a circle wrench
Mud pump	W1122 FMC BEAN triplex pump, hydraulically operated
Mud mixing	2 x 1000 l mixing tanks with high-capacity stirring paddles driven by electric motors (heavy-duty design by Huafeng). Each mixer tank was mounted over a 1000 l drill tank, which gave us the opportunity for continuous drilling, while mixing mud in one tank; the other was used for drilling.
Drill pipe	CHD 134 (manufactured by Jinshi Engineering, China)

6.1.2. Drilling Tools

QD Tech were contracted to provide the lake sediment drilling tools and the training of Huafeng drilling staff in tool assembly and operation. Each of the tools can collect 3 m cores in a plastic liner in a single run. The Hydraulic Piston Corer (HPC) uses pressure generated by the mud pump to instantly advance the 3 m run, yielding the highest-quality cores in the softer sediments. When the lithology becomes too consolidated for the HPC, the Extended Nose Corer (EXN) is used. This tool offers a non-rotating shoe that protrudes ~15 cm below the coring bit, allowing it to collect high-quality cores while rotating the drill string to overcome the friction at greater depths. As depth increases, or in lithified intervals unsuitable for the EXN, the Alien corer (ALN) functions much like a standard rock coring tool. A Non-Coring Assembly (NCA) provides the capability to drill without core recovery. These four tool types use the same bottom hole assembly, drill string, and bits, and therefore can be selected and efficiently deployed for the specific lithologies expected in each coring run, without changing other drilling equipment components. The CHD134 drill string was produced by Jinshi Drilltech Co., Ltd. (Tangshan, PRC). Overall, 240 3-metre-long drill pipes were produced for the NamCore drilling. Since the hired drillers from Huafeng had not previously used the soft sediment coring tools, they were trained from 21-24 April, 2024, by Marshall Pardey of QD Tech, just before the start of project operations. This training also included the Chinese scientists and translators to learn the general drilling process and specific workflows for operating each of the drilling tools.

6.2. Drilling Operations

Drilling commenced on 6 June and concluded on 17 July 2024 (Fig. 8). Huafeng drilling staff were supported through the work of additional personnel. Peter Hoffman was contracted as the drilling supervisor, and CSD Facility (Douglas Schnurrenberger and Ryan O'Grady onsite, and Anders Noren providing remote support) was contracted to provide drilling, core handling/documentation and drilling database expertise.

Drilling operations were conducted in two 12-hour shifts: a day shift from 7:00 AM to 7:00 PM and a night shift from 7:00 PM to 7:00 AM. Each team consisted of (i) a drilling adviser, (ii) 6-7 drillers (including a translator), (iii) a co-chief scientist and (iv) 4–5 scientists. The science team was divided into Team 1 (27 May – 22 June 2024) and Team 2 (15 June – 11 July 2024) to reduce the time spent at high altitude for the international team members. The crew, cores and small equipment were transferred with the transfer boat. Drilling supplies (e.g., bentonite, spare parts), fuel for the drill rig and generators, and equipment (e.g., drill pipe, logging tools, other heavy equipment) were transported with the tugboat. Tugboat supply runs took place almost every day to ensure sufficient bentonite and fuel storage on the barge and were coordinated by dayshift science and drilling leads, with loading and unloading taking place with minimal disturbance of drilling operations.

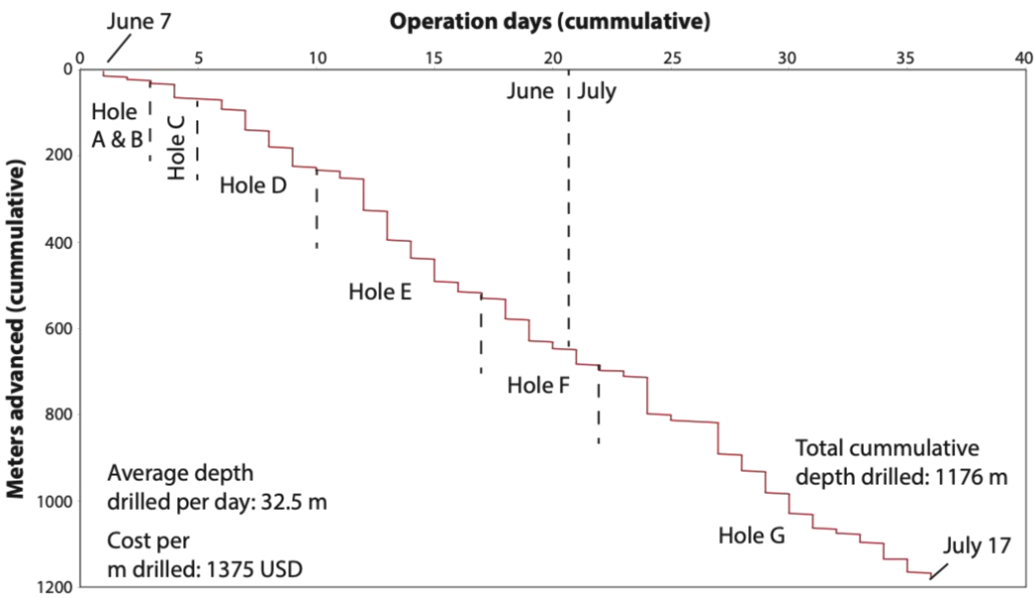


Fig. 8: Summary of progress and costs, including a drill-time log and a depth vs. cost breakdown. 7 June marks the first core on deck.

Drilling operations started on 6 June with tripping pipe during the day shift, with the first core recovered during the night shift on 7 June. Coring at 5073_1_A started at about 0.8 m above the sediment water interface using the HPC (Fig. 2, Fig. 9, Tab. 4). HPC coring was only possible to a depth of ~12 m blf when dm-thick sand layers and consolidated sediments hampered further HPC penetration. Below that sediment depth, the EXN was tested, but core recovery was found to be unsatisfactory. The ALN was found to be the only coring tool that was suitable to advance with the highest possible core recovery at sediment depth below 12 m blf (Fig. 9, Tab. 4). ALN core recovery was high through fine-grained lithologies and even recovered some of the frequent well-sorted sand beds throughout the stratigraphy. ALN core quality was excellent in fine-grained lithologies, although occasional mud injection traces were found after core opening in ALN cores. We used both standard and basket-type core lifters, with the basket-type lifters performing best in difficult formations and sands. After these initial issues with finding the right coring equipment, we refrained from drilling Site 2 and Site 3, which were much closer to the shoreline, and more coarse-grained layers in a shorter interval were suspected, likely resulting in much more challenging drilling conditions and lower core recovery. Therefore, we focused on Site 1, which promised a continuous and deep sediment record. At 5073_1, we drilled seven holes (A to G, Fig. 2) for 1175.99 m total, and recovered 947.14 m of sediment cores. The maximum depth was reached in 5073_1_G at 510.23 m blf (Fig. 9, Tab. 4).

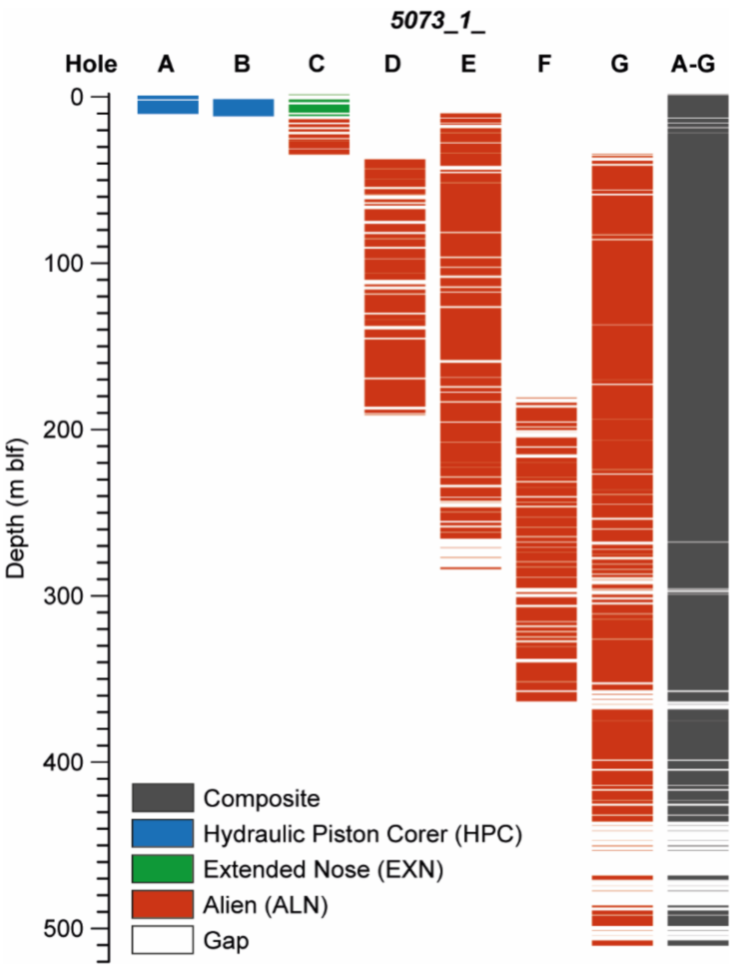


Fig. 9: Drilled holes (1_A-1_G) from the NamCore drilling site (5073_1) (excluding core catchers and noble gas samples). Colours indicate coring tools (blue = Hydraulic Piston Corer, green = Extended Nose, red = Alien). White parts are either (i) not recovered by using an NCA system to penetrate or failed to retrieve cores due to unsuitable lithologies, (ii) core catchers, or (iii) noble gas samples.

Drilling operations relied on sustained bentonite and polymer addition to the drilling fluid to keep the borehole stable throughout drilling operations. Fluorescent, environmentally friendly green pigment (BW181, Green Colorcom Pigment, Hangzhou City, China; particle size: 0.2–0.35 µm) was regularly added to the drilling mud to help trace potential contamination by drilling fluid into the cored sediment. When core recovery was insufficient or drilling quality was deemed suboptimal, the science and drilling teams collaboratively reviewed potential causes for core loss and made real-time adjustments to the drilling protocols. Safety was continuously monitored, and operations were suspended during severe swells or storms. Generally, drill mud pressures and compositions varied depending on lithology and depth in the stratigraphy. At 50 m blf, the hole pressure was typically between 30-50 PSI with mud flow rates of 12-18 GPM. The drill pressure increased on average by 50 PSI for every 50 m of hole depth drilled due to the head pressure. In the deeper holes, the drillers reduced the pump flow to around 10-12 GPM to reduce pressure to avoid core erosion. Swelling clays and collapsing sand strata increased drill pressure and rotation torque, which varied with depth and between holes. Drill mud viscosity was in the range of 26-27 seconds Marsh funnel measurement as a qualitative estimate. For the standard mix per mud tank, one 25 kg bag of bentonite was hydrated and stirred for 12 min, then mixed with Guar Gum organic polymer. When encountering thicker and unstable sand formations, the mud mixture concentration was increased to two or three bags of bentonite, with a Marsh funnel viscosity of 35-40 s, to increase the stabilisation and hole flushing capacity of the drill mud. The mud mixture was reduced back to the standard 1-bag mix once sand formations were passed, and drilling conditions improved. The bentonite supplied by Huafeng drilling mixed well and began yielding good viscosity in 12 min, and there was no noticeable sand residue in the mixing tanks when drained. Generally, drilling operations were smooth (Fig. 8), with adverse weather conditions (heavy winds, large swells, lightning storms) being the primary reason for drilling and crew transfer delays (Tab. 3).

*Tab. 4: Summary information about the drilled holes (including their International Generic Sample Number (IGSN)) during the NamCore drilling campaign, including coordinates of the individual holes, total drilled length, core length, bottom depth, core recovery, indication whether borehole logging was carried out, and used drilling tool(s). *Note that the driller's depth for the sediment-water interface was sometimes slightly negative, which can cause an offset between maximum cored depth and total cored length. CC = Core Catcher*

Expedition _ Site_Hole	IGSN	Longitude (°N) [WGS 84]	Latitude (°E) [WGS84]	Drilled Length (m)	Max. Cored Depth * (m)	Total Cored Length * (m)	Core Recovery incl. CC (m)	Core Recovery excl. CC (m)	Core Recovery (%)	Drill Tool
5073_1_A	ICDP5073EHG0001	90.690444	30.746639	11.02	10.22	10.93	10.03	9.68	91.4	HPC
5073_1_B	ICDP5073EHH0001	90.691028	30.747139	11.68	11.68	10.32	10.42	10.25	100.5	HPC
5073_1_C	ICDP5073EHI0001	90.691083	30.747139	38.91	37.43	42.00	25.82	24.45	61.3	EXN, ALN
5073_1_D	ICDP5073EHJ0001	90.691139	30.747139	193.83	193.83	168.40	131.53	126.61	77.6	ALN
5073_1_E	ICDP5073EHK0001	90.691220	30.747070	282.95	285.95	282.00	238.42	229.54	83.8	ALN
5073_1_F	ICDP5073EHL0001	90.691280	30.747020	363.86	363.86	183.00	152.43	146.35	82.4	ALN
5073_1_G	ICDP5073EHM0001	90.691380	30.747090	510.20	510.20	479.34	387.69	377.20	79.9	ALN
Total				1415.45		1175.99	950.77	924.08	80.8	

7. Scientific Operations

7.1. Core Handling

The science team was present on the barge for each core recovery and recorded all drilling and sampling metadata, including core run number, recovered core length, time on deck, number and length of sections, core loss reasons, drilling protocols, lithological descriptions, and sample data both in the digital CSD Facility drill site database and the on-site hard copy recording sheet, which allows efficient planning, tracking, and adjustment of drilling depths and all other required metadata in the context of soft sediment lithologies that do not provide the tactile feedback that drillers rely on for their standard workflows for each core run. Each hole, core, and section was named using ICDP standard protocols, and samples were labelled accordingly. All cores were recovered in polycarbonate liners with a 71 mm outer diametre, with the caps of different colours on both sides.

The drilling team extracted the core from the 3-m-long drill pipe in its plastic liner and placed it onto a pipe handling rack (Fig. 10A). The bottom end of the core was examined for a preliminary lithological assessment, and top and bottom depths were noted. The core was then transferred to the science table for further processing (Fig. 10). Drilling fluid was drained from the liner, and the core was then cut into 2-4 sections depending on (i) recovery, (ii) location of gas cracks and (iii) sampling for noble gases, with a maximum section length of 1.5 m. Samples were extracted for DNA and methane analyses for selected sections, and the section bottoms were trimmed to prevent movement during transport. Sections were capped, sealed with tape (bottom: red tape, top: black tape), measured, and labelled with the Section Combined ID, e.g., 5073_1_F_048A_1 (Tab. 7) and oriented with arrows pointing upward (Fig. 10C, F). Core catcher sediment was extruded, lengths were measured, the sample was bagged in plastic Ziplock bags, and stored in a cool box. Core sections were stored vertically (bottom-down) until the next shift change and were transported to the onshore camp with the crew transfer boat at shift changes (Fig. 10). Once ashore, sample labels were verified, and core section caps were resealed when gas or material expansion had occurred. Core sections were stored in a truck-based refrigerated container before they were transported to Lhasa (Fig. 10F).

7.2. On-Site Sampling

Sampling was only allowed after a sample request was approved by the PIs and all samples were documented in ICDP’s mobile Drilling Information System (mDIS). Samples were extracted from the ends of sections or cut from sections as whole-round samples.

7.2.1. Offshore Sampling

DNA Sampling and Methane Sampling

The exposed bottom surfaces of the core section (usually section 1) were checked under a portable UV light for traces of the added green pigments before sampling. If pigments were not detected, the bottom of the top section was sampled for DNA and methane analyses. For DNA sampling, sterilised 5 mL syringes (pre-cut) were used to extract 2 cm^3 of fresh sediment, which was then transferred into two 15 mL tubes containing Zymo DNA/RNA Shield preservative. DNA samples were taken every three metres for Holes 1_A to 1_F (Fig. 10B). Samples were temporarily stored in a cool box on the barge, transported onshore at shift change, and subsequently stored at -15 °C. For methane sampling, 1.5 mL of sediment was extracted using a cut syringe and placed into serum vials pre-filled with 6 mL of NaOH.

Methane samples were collected from every core in Holes 1_A to 1_D and every third core in Holes 1_E and 1_F down to 360 m blf. These samples were kept at room temperature.

Noble Gas Sampling

Every ten metres, a 30 cm-long whole-round core section was collected from the bottom of Section 2 of each core down to 355 m. These were measured, labelled, and stored for onshore noble gas extraction using pristine mud sealed into copper tubes.

^{10}Be Sampling

When applicable, ~10 mL ^{10}Be samples were taken approximately every 12 m. These were collected in Ziplock bags, stored in a cool box, and refrigerated onshore.

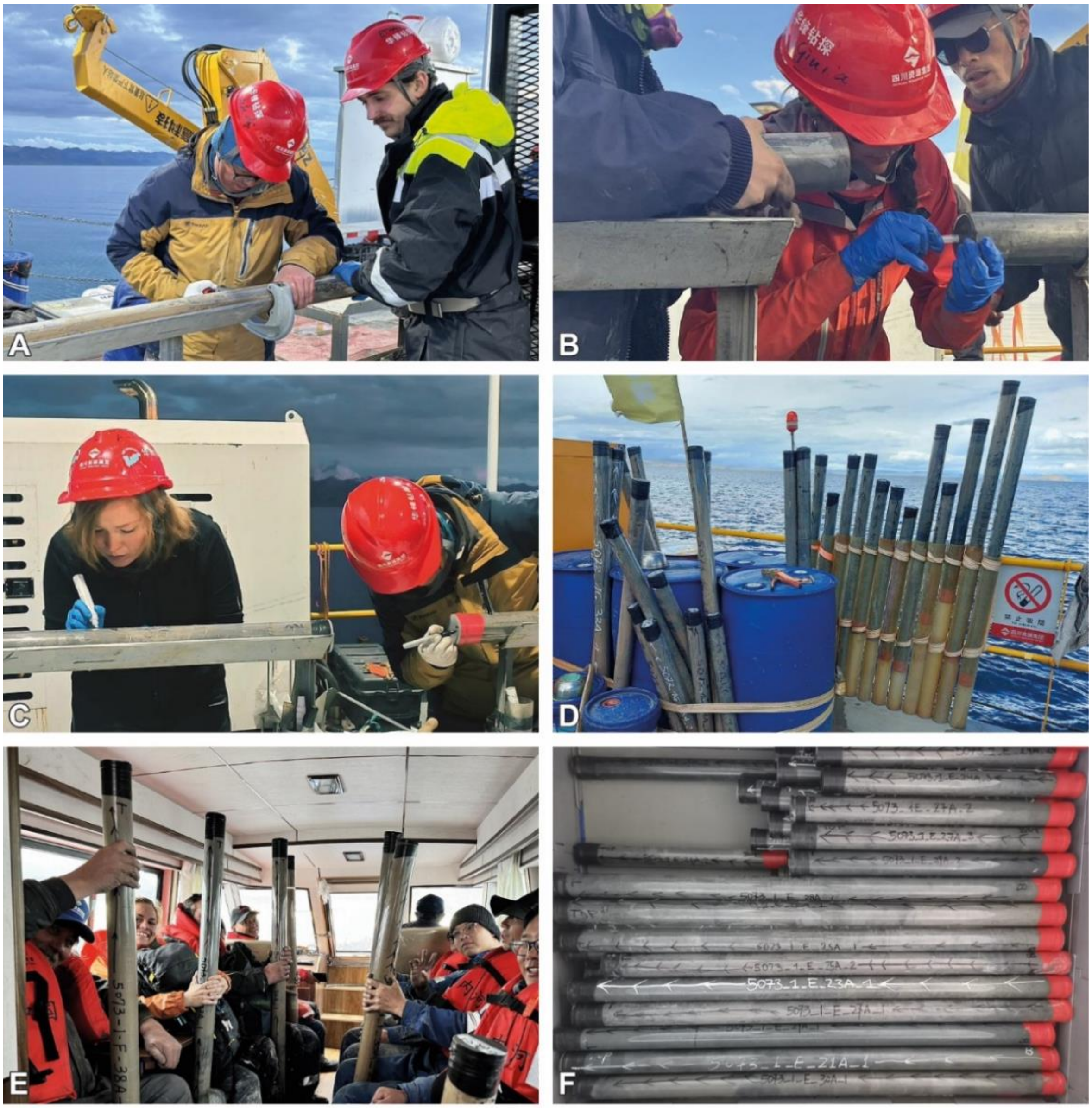


Fig. 10: Core handling and sampling on barge from cutting the sediment cores (A), to methane and DNA sampling (B), sealing and labelling (C), to storage bottom-down (D), transport to the shoreline (E) and storage before transporting the sediment core sections to Lhasa (F).

7.2.2. Onshore Sampling

For the first 10 m of drill core, porewater was sampled in 20 cm intervals using Rhizon samplers (Rhizosphere Research Products, Wageningen, The Netherlands). Sampling was done through a hole drilled into the liner. Below this depth, core catcher subsamples were pressed to extract the porewater.

Core catcher processing was conducted daily in the onshore lab. An aliquot of each sample was taken for smear slide preparation and examined under both natural and polarised light using a microscope. Additionally, Munsell Soil Colours were determined for all core catchers using an x-rite CAPSURE RM200 Soil spectrophotometre. Subsampling of core catchers was carried out for further analyses at the scientists' home laboratories, including samples for sedimentology, stable isotopes and inorganic geochemistry, ostracods, mineralogy, diatoms, palynology, and optically stimulated luminescence.

7.3. Geophysical Downhole Logging

The downhole logging equipment was shipped from the LIAG Institute for Applied Geophysics, Hanover, Germany, and a downhole logging winch from the ICDP-OSG located at GFZ Potsdam, Germany. Geophysical downhole logging was conducted in two teams. The first team carried out the measurements at Hole 1_D within a single logging session (Tab. 5). The second team carried out the measurements during two logging sessions at Hole 1_F. The probes used included:

- ABI: Acoustic borehole imager,
- DIP: Dipmetre (incl. Caliper, Deviation and deviation direction plus the dip of geological strata),
- DLL: Resistivity (in Ωm, both near- and far-field),
- MS: Magnetic susceptibility (10^{-4} SI),
- SGR: Spectrum gamma radiation (gAPI), incl. concentrations of K (%), U, Th (ppm),
- SONIC: Seismic velocity (m s^{-1}),
- TSAL: Salinity (mS cm^{-1}), Temperature (°C) of the borehole fluid

Both teams were equipped with the same wireline probes. Due to time constraints and prioritisation, slight deviations occurred in the compilation of the measurement plan for the geophysical downhole logging. The first team used the TSAL probe every time after the drill pipes had been pulled. The probe was therefore partly operated inside the drill string and in the lower part of the open borehole.

The parametres that can be detected through the drill string are measured first. The drill string was then pulled in sections, and the following parametres were measured in the open borehole. Although this procedure is time-consuming, it is common practice in potentially unstable sediments to avoid borehole collapse. Technical issues appeared for both teams with the winch system, which led to delays in the measurement plan. Other difficulties occurred with the ABI. Either the tool could not be positioned in the open hole due to the narrow diametre of the drill bit, or there were technical problems with the data transfer.

Tab. 5: Wire-line logging overview. Abbreviations: mblf: metres below lake floor; DIP: Dipmetre, DLL: Dual laterolog resistivity, MS: Magnetic susceptibility, SGR: Spectrum Gamma Radiation, SONIC: Sonic log (seismic velocity of P- or S-Wave), TSAL: Temperature and salinity of mud. The last column indicates whether the tool runs in the open hole (=Y) or inside the drill string (=N). In case the tool was partly inside the string and partly in the open hole section during one run, we use Y/N. Depth information results from the total cable length in the hole subtracted by water depth, and the reference point on the barge above lake level. Negative values indicate position above the lake floor (i.e. TSAL was measured from reference point level, through the water column into the sediments).

Hole (Date)	Parametre	From (m blf)	To (m blf)	Open Hole
5073_1_D (14./15.06.2024)	SGR	152	74	N
	SGR	80	-8	N
	Remark: Continuation of drilling operations for another ~40 m			
	SGR	191	146	N
	Remark: Drill string retracted (20 rods à 3 m)			
	TSAL	-95	188	Y/N
	MS	189	132	Y
	DLL	189	134	Y
	SONIC (P-Wave)	188	132	Y
	SONIC (S-Wave)	188	135	Y
	DIP	185	132	Y
	Remark: Drill string retracted (20 rods à 3 m)			
	TSAL	-95	140	Y/N
	MS	142	73	Y
	DLL	147	75	Y
	SONIC (P-Wave)	142	74	Y
	SONIC (S-Wave)	142	75	Y
	DIP	140	72	Y
	Remark: Drill string retracted (9.5 rods à 3 m)			
	TSAL	- 95	80	Y/N
	MS	80	18	Y
	DLL	80	32	Y
	SONIC (P-Wave)	87	24	Y
	SONIC (S-Wave)	81	21	Y
	DIP	81	18	Y
5073_1_F (27.06.2024)	SGR	311	-11	N
	Remark: Drill string retracted (40 rods à 3 m)			
	MS	310	171	Y
	DLL	311	185	Y
	DIP	309	185	Y
	SONIC (S-Wave)	308	187	Y
	SONIC (P-Wave)	308	187	Y
	Remark: Drill string retracted (40 rods à 3 m)			
	SONIC (P-Wave)	207	78	Y
	SONIC (S-Wave)	207	82	Y
	DLL	214	87	Y
	MS	208	83	Y
	DIP	209	80	Y
5073_1_F (01.07.2024)	*Remark: The last logging session was carried out in the open borehole in 1_F*			
	SGR	356	288	Y
	MS	360	289	Y
	DLL	358	293	Y
	DIP	358	291	Y
	SONIC (P-Wave)	359	285	Y
	SONIC (S-Wave)	358	290	Y

7.4. MSCL Core Logging

During and after drilling operations, sediment cores and core catchers were transported in a refrigerated truck to the Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Lhasa Campus. Sediment cores were sorted and measured using a whole-core multi-sensor core logger (MSCL-S, Geotek Ltd., UK) for loop sensor magnetic susceptibility and gamma density in a 1 cm resolution operated by a dedicated three-person team (Fig. 11).

Fig. 11: MSCL core scanning at the Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Lhasa Campus.

8. Core Repository, Core Opening and Sampling Parties

8.1. Core Repository and Permanent Curation

After MSCL-S scans at the Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Lhasa Campus, China, all sediment cores and remaining core catchers were transported in a refrigerated truck to the Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Science City Campus, China, for permanent curation in the ITP repository in refrigerated conditions at +4° C.

8.2. 1st Core Opening Party (February 2025)

During the 1st core opening party from 8-16 February 2025 in Beijing, China, we focused on providing an overview of the entire stratigraphic section using cores from holes 1_A, 1_B, 1_E and 1_G guided by the loop sensor magnetic susceptibility data. Sediment core sections were split lengthwise into working and archive halves. The archive half was used for undrained shear strength measurements using a handheld penetrometre (Eijkelkamp Inc.) on selected archive halves from holes 1_A, 1_B, 1_E, and 1_G, using different tips depending on the sediment softness. The measurement resolution depended on major lithological shifts but was generally < 1 m. The penetrometre was pushed 5 mm perpendicular to the split core face.

The working half core face was cleaned for optical imaging using a high-resolution line-scan camera (MSCL-S with Geoscan-V camera, Geotek Ltd.). The core section description was recorded in the software PSICAT (v. 1.2.6) (https://cse.umn.edu/csd/psicat). The description included (i) lithology, (ii) predominant grain size, (iii) type, thickness, and contact of beds, (iv) sedimentary textures (e.g., mottling), and (v) specific sedimentary features (e.g., sand layers). Lithological changes were confirmed by petrographic smear slide analysis and HCl tests for carbonates. The upper 32 m of the sediment sequence were sampled for radiocarbon dating in ~1 m intervals. Samples for micro-scale X-ray computed tomography (µCT) analysis were taken at regular intervals.

8.3. 2nd Core Opening/1st Sampling Party (May 2025)

We continued opening the sediment core sections from 5-18 May 2025 in Beijing, China, opening all remaining sediment core sections. Identical to the first core opening party, sediment core sections were split, photographed, and described, but additionally spliced to bridge gaps in recovery from individual holes and develop a complete profile for the entire sediment sequence (Fig. 12). The NamCore splice was created using the software Corelyzer (v. 2.3.3) and is based on sedimentary marker layers identified in high-resolution core section images and whole-round magnetic susceptibility. As of this writing, the splice covers the upper ~250 m and will be refined and extended in the future using new datasets, including XRF core scanning results and point-sensor magnetic susceptibility data. Standard splice metadata (splice and affine tables) were recorded in the software Excel and later added to the mDIS database.

Sediment sections in the splice were scanned using a Konica Minolta CM-2600d Spectrophotometre (8 mm spot, D65 at 10 nm steps from 360–740 nm wavelength) in a 1 cm resolution for the upper ~30 m and in a 2 cm resolution down to ~100 m splice depth. The splice was used as a basis for sampling, which took place at the same time. Contrary to standard procedures, samples were taken from the archive half to preserve the working half for scanning techniques (e.g., XRF scanning, point-sensor magnetic susceptibility) after the sampling party. The sampling interval was a multiple of 8 cm down to 33 m splice depth, which was assumed to be the limit for radiocarbon dating. Samples below were taken in a 128 cm interval covering the entire sediment sequence (Tab. 6).

Sedimentary DNA was sampled for Holocene and Late Glacial sediments only. Samples for ^{14}C and ^{10}Be dating were taken at locations with suitable lithologies and features. Additionally, methane samples were re-sampled for TOC analysis at the same sediment depth as during the drilling activities. Selected off-splice sediment core sections were sampled for microfluid experiments. Additional core catcher material was provided for further overview analyses. Altogether, almost 6000 samples were taken between the core recovery and during the sampling parties.

Tab. 6: Sampling strategy for the individual subsamples taken during the Sampling Party in May 2025.

	Sampling Resolution (cm)	
	0-33 m	**33-510 m**
Sedimentology	8	128
Carbonate Geochemistry	8	128
Ostracods	32	
Palynology	8	128
Sulphur Isotopes	32	128
Sedimentary Pigments	32	
Paleoaltrimetry	64	

8.4. 2nd Sampling Party (September 2025)

In between the sampling parties, working halves of sediment core sections for the upper 30 m were scanned for XRF using an ITRAX system. Afterwards, a small group aimed to sample U-channels from sediment core sections down to ~10 m. Originally, it was planned to sample U-channels for the entire 30 m. However, already at 10 m sediments were too consolidated to successfully sample the sediments using U-channels.

Fig. 12: Impression from the Core opening and sampling parties. Opening the sediment cores (A) and first inspection of the cut sediment cores to decide which half to use for cleaning and describing (B). Subsequently, sediment core sections were cleaned (C), then photographed (D), described (E), and smear slides were prepared (F). After splicing the sediment cores (G), the sampling strategy was discussed (H), and sediment samples for various analyses were taken (I). Once sampling was finished, the sediment cores were wrapped in cling film and stored in D-tubes (J). All sediment cores were transported back into the cooling facility (K) and sorted (L) for permanent curation.

9. The NamCore Sediment Cores

Instead of the originally proposed several drill sites, the NamCore project focused on one site, 5073_1, which promised a continuous sedimentation of at least 300-450 m blf. Although the first three holes (1_A to 1_C) were relatively short (Fig. 9), we drilled altogether 1175.99 m and recovered 918.5 m of sediment cores. The first two holes were drilled with an HPC, which turned out to be unsuitable for Nam Co's sediments below 10 m blf. Attempts to recover the sediments with an EXN resulted in a damaged EXN drill bit and unsatisfactory core recovery. Finally, the ALN was suitable to advance with the highest possible core recovery at sediment depths below ~12 m blf (Fig. 9). In the end, the maximum depth was reached in 5073_1_G at 510.23 m (Tab. 4). The core recovery was generally higher in the upper 242 m due to predominantly fine-grained sediments. Between 242-321 m blf, sediments are mostly unconsolidated coarse-grained material, resulting in lower core recovery. Below this depth, the sediments are highly consolidated.

Generally, we observed four different lithologies, i.e. (i) calcareous mud, (ii) calcareous mud with ferric staining, (iii) sand, and (iv) non-calcareous mud:

- 510.23-321.15 m blf: calcareous mud with ferric staining and a few intercalated sand and non-calcareous mud layers,
- 321.15-242.07 m blf: very fine to medium sand, interspersed with a few calcareous and non-calcareous mud intervals,
- 242.07-127.66 m blf: recurrent shifts between calcareous and non-calcareous mud,
- 127.66-0 m blf: silty to sandy calcareous mud (Fig. 4), partly interspersed with sand layers, sand lenses and sometimes dropstones.

Details on sediment cores will be published in the corresponding Scientific Drilling article (Adolph et al., in prep.).

10. The NamCore Operational Data Set

10.1. <u>Data from Drilling Operations</u>

Drilling information was initially stored digitally in the CSD drill site database and on hard copy paper sheets for each core run (Fig. 13). Information was stored offline and backed up regularly. Working in remote Tibet with limited internet access prevented us from uploading information directly into the NamCore mDIS database on-site. After drilling concluded, expedition information, along with notes from drillers, the drilling manager, and the lead scientist, and sample information in standardised spreadsheets, were uploaded to the NamCore mDIS database. All data collected during the core opening and sampling parties were directly entered and curated in mDIS.

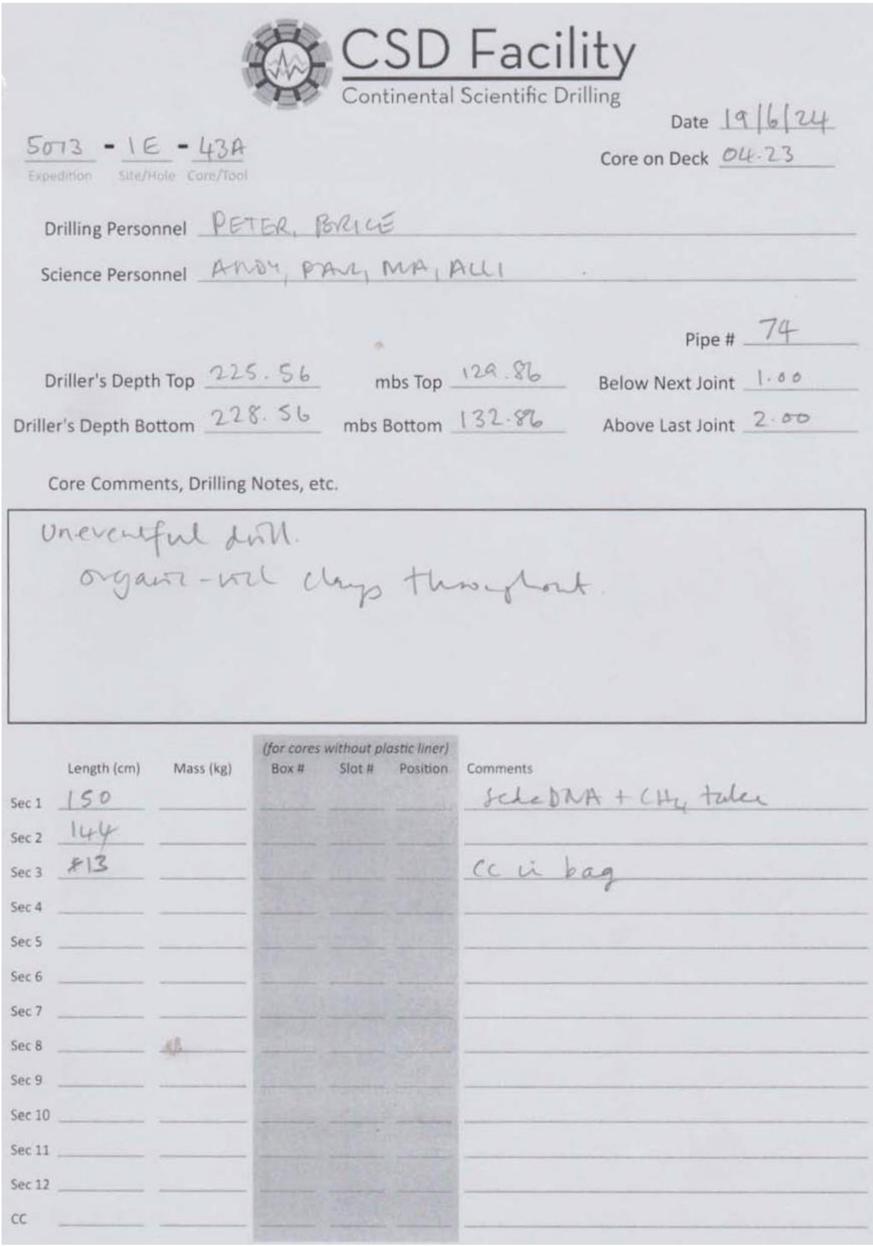
The mDIS (mobile Drilling Information System) is an open-source, web-based, platform-independent software application for the management of geological samples and drilling engineering data and is under continued and advanced development by ICDP. mDIS is operated through a browser and consists of hierarchically structured forms. Noticeably, the system is based not on absolute depth values, as depth can change during a project's lifetime. Several reports show data in tabular, graphic, or digital formats, and labels for samples can be directly printed.

icdp INTERNATIONAL CONTINENTAL SCIENTIFIC DRILLING PROGRAM

The NamCore project follows the ICDP naming convention (Tab. 7), starting with 5073, which is the Expedition Identifier unique for the NamCore project. NamCore drilled only one Site; therefore, the Site is always “1” with seven holes (A-G). We used three different drill tools, which are shortened as H (HPC), E (EXN) and A (ALN). A split core section is designated as either A = archive half, or W = working half. Whole rounds (unsplit sections) are designated as WR = whole round. Samples are always recorded in depth below the top of the section (section depth, cm). Based on the FAIR principles, each hole, core, section, half, and sample has a unique identifier, the International Generic Sample Number (IGSN). More detailed information is available in the Explanatory Remarks (Adolph et al., 202x) as a supplement to this operational report.

Tab. 7: Example of naming conventions within the NamCore project.

5073	_	1	_	A	_	006H	_	3	_	W	:	0-14
Expedition		Site		Hole		Core/Drill Tool		Section		Half		Sample



CSD Facility
Continental Scientific Drilling

Date 19/6/24
5073 - 1E - 43A
Expedition Site/Hole Core/Tool
Core on Deck 04.23

Drilling Personnel PETER, BRICE
Science Personnel ANDY, PAUL, MA, ALLI

Pipe # 74
Driller's Depth Top 225.56 mbs Top 129.86 Below Next Joint 1.00
Driller's Depth Bottom 228.56 mbs Bottom 132.86 Above Last Joint 2.00

Core Comments, Drilling Notes, etc.

Uneventful drill.
organic-rich clays throughout.

	Length (cm)	Mass (kg)	Box #	Slot #	Position	Comments
			(for cores without plastic liner)			
Sec 1	150					sedaDNA + CH4 tube
Sec 2	144					
Sec 3	13					CC in bag
Sec 4						
Sec 5						
Sec 6						
Sec 7						
Sec 8						
Sec 9						
Sec 10						
Sec 11						
Sec 12						
CC						

Fig. 13: Example for hard copy sheets for each core run, here 5073_1E_43A

10.2. Data and Metadata from mDIS

The following tables list the data, metadata and images included in the NamCore Operational data set (Tab. 8). The data will be available on the GFZ Data Service Repository (Adolph et al., 2026, https://doi.org/10.5880/ICDP.5073.001) or during the moratorium period until 15 May 2028, with access restriction on the ICDP NamCore Project website (https://www.icdp-online.org/projects/by-continent/asia/namcore-china/).

Tab. 8: Available data sets from the NamCore drilling project

	Data	Files	Remarks
1	ICDP Identifier	READ ME (.pdf)	
2	All Data as a single xlsx-file	All Data	
3	Sample Requests	All Sample Requests (.csv)	
4	Sites	All Sites	
5	Holes	All Holes	incl. Coordinates (WGS84)
6	SPLICE	Splice (Hole 1S) All Samples on Splice	
7	Cores	Hole 1A Hole 1B Hole 1C Hole 1D Hole 1E Hole 1F Hole 1G	incl. Drillers Depth, Drilled Length, Number of Sections, Core Recovery, Notes from Drilling (Additional Information)
8	Core Sections	Hole 1A Hole 1B Hole 1C Hole 1D Hole 1E Hole 1F Hole 1G	incl. Section Length, Section Depth, Core Catcher (yes/no), Section Split (yes/no), Additional Information (e.g., samples taken during drilling) IGSN, related Splice Combined ID
9	Section Splits	Hole 1A Hole 1B Hole 1C Hole 1D Hole 1E Hole 1F Hole 1G	incl. Split Type, Percentage of Whole Round, Still Existing, Original Combined ID, Sampling Allowed, Curated Length, IGSN, Driller Depth
10	Samples	Hole 1A Hole 1B Hole 1C Hole 1D Hole 1E Hole 1F Hole 1G	incl. Combined ID, IGSN, Sample Request, Material, Sample Top & Bottom, Sample Length, Sample Size, Sample Unit, Percentage of Fraction Split, Purpose, Drillers Depth, Splice Depth if available
11	Core Descriptions	Hole 1A Hole 1B Hole 1C Hole 1D Hole 1E Hole 1F Hole 1G	PSICAT Exports, including Core Image, Lithology, Grain Size, Bedding, Features and Additional Comments
12	Lithological Overview	Hole 1A Hole 1B Hole 1C Hole 1D Hole 1E Hole 1F Hole 1G	PSICAT Exports, including Lithology, Grain Size, Bedding, Features and Additional Comments
13	Shear Strength Measurements	Overview with depth	

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10.3. Image Files

All core images were taken after splitting the sediment cores and cleaning their surface using a Geoscan-V linescan camera mounted to the MSCL-S (Geotek Ltd.) at the Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Science City Campus, Beijing. The scans are "slabbed section" scans from the working half of the sediment cores. Raw images (300 DPI TIFFs) were converted using the LacCoreGeotekConverter (v2.3) to JPEGs in small and medium sizes to optimise the performance of PSICAT and Corelyzer software applications. During conversion, a ruler was added to each image. The data volume is ~630 Mb/100 sections for high-resolution JPEGs and 62 Mb/100 sections for low-resolution JPEGs. The archives contain images sorted by Holes (1_A-1_F) with download size as zip files with max. 1 GB file size (Tab. 9). Additionally, the Corelyzer archive file containing all images from the NamCore project, including splice ties, is available (> 5 GB). To access this data file, please consult the README first.

Tab. 9: Available images in the ICDP NamCore project

	Image Type	Low Resolution (.zip)	High Resolution (.zip - max. 1 GB)
1	Slabbed Sections	Hole 1A Hole 1B Hole 1C Hole 1D Hole 1E Hole 1F Hole 1G	Hole 1A Hole 1B Hole 1C Hole 1D Hole 1E, cores 001-069 Hole 1E, cores 070-094 Hole 1F Hole 1G, cores 001-059 Hole 1G, cores 060-109 Hole 1G, cores 110-163
2	Core Images in Corelyzer		READ ME Core Images in Corelyzer

11. Outreach

11.1. Media Coverage During the Drilling Campaign

From the very beginning of our drilling campaign - including the assembly of the drill barge, the construction of the camp, and throughout the drilling process - several national broadcasting and television outlets such as China Media Group (CMG, which includes China Central Television), Xinhua News Agency, and People's Daily sent reporters to conduct on-site interviews and frequent coverage. Their reports, especially those at the start of the drilling and during key milestones such as reaching 400 m depth and completing the drilling, helped publicise the project across China. Several of these updates can be accessed via https://www.icdp-online.org/projects/by-continent/asia/namcore-china/press-releases

Xinhua News also reported on the project internationally through its English-language channel, allowing audiences outside China to learn about our work. One such report was published online and was also featured on the English website of the State Council of the People's Republic of China (Fig. 14). For more information, please see here: https://english.news.cn/20240713/1fd4871e29cf4cc3acdd06f639324462/c.html

A special live broadcast was organised on 12 July when the drilling approached a depth of 400 m. Hosted on the Xinhua News platform and joined by many media outlets, the broadcast attracted around 20 million viewers and lasted about 1.5 hours. As one of the on-site principal investigators, Junbo Wang participated in the live program, explaining the scientific significance of the project and its societal relevance, including its importance for research on the Tibetan Plateau and the protection of the "Asian Water Tower." Local media, including Xizang TV Station and its new media platforms, also made significant efforts to report on the NamCore drilling project, helping to share this scientific endeavour widely, particularly with the local community.

11.2. Press releases and publication of science-related articles to promote the Nam Co Drilling Project

Following the successful ICDP drilling of the Nam Co, Junbo Wang was invited to publish two articles aimed at enhancing public and governmental understanding of this research field. The first article appeared in *Study Times*, a highly influential and reputable newspaper within governmental and administrative sectors, under the title "What Can Be Unlocked by the Sediment Cores from the Bottom of Nam Co". For more information, please see here: https://paper.studytimes.cn/cntheory/2024-10/23/content_9948659.html.

The second article was published in *Knowledge is Power*, a well-known popular science journal targeted particularly at school-aged students. This shorter piece introduced the Nam Co Drilling Project and explained, in accessible terms, how past lake-level changes can be identified and how lake sediment cores are used to study past climatic variations (Fig. 15).

Additional outreach activity centred on presenting the NamCore Project in December 2024 in issue 98 of *GMIT Geowisenschaftliche Mitteilungen*, the joint news publication of several major German geoscience societies and organisations. The contribution highlighted the project's objectives, recent developments, and its relevance for advancing geoscientific research and collaboration. For more information, please see here: https://e-docs.geo-leo.de/handle/11858/12265.

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Record-breaking lake drilling depth achieved in China's Qinghai-Xizang Plateau

Updated: July 13, 2024 12:37 Xinhua

LHASA, July 13 -- The core drilling project in Nam Co, the world's highest saltwater lake in southwest China's Xizang Autonomous Region, achieved a drilling depth exceeding 400 meters. It is of great significance in the country's lake drilling and paleoclimate study, according to scientists.

At 06:35 p.m. on Friday, the multinational joint scientific expedition team extracted a lake sediment core from a depth of 402.2 meters under the lake bed of Nam Co, surpassing the previous maximum depth of 153.44 meters in lake drilling on the Qinghai-Xizang Plateau.

Nam Co is an enclosed lake that gathers information about rocks, soil, vegetation, rivers and human activities in the catchment, making the lake significant for environmental changes research, according to Wang Junbo, one of the leaders of the scientific expedition team.

Fig. 14: The NamCore project was featured on China Central Television (CCTV), the country's most influential national broadcasting platform, and was also published on official government websites.

News releases from the University of Greifswald, the Max Planck Institute for Geoanthropology and EAWAG served as outreach activities to communicate NamCore's goals and progress to a broad scientific and public audience. By featuring the project on their official institutional platforms, the articles increased visibility beyond the immediate research community and highlighted the project's international collaboration under the ICDP framework. These publications ensured that the significance of the campaign reached stakeholders, for example, such as academic partners, funding bodies or students. More information please see here

- https://www.uni-greifswald.de/forschung/nachrichten-aus-der-forschung/detail/n/hoechste-seebohrung-aller-zeiten-in-tibet-erlaubt-blick-in-eine-million-jahre-erdgeschichte-199539/ or
- https://www.gea.mpg.de/99150/deepest-lake-drilling-on-tibetan-plateau
- https://www.eawag.ch/de/info/portal/aktuelles/news/klimageschichte-aus-dem-see-auf-fast-5000-m-uem/

11.3. Participation in and support of the production of a project video in collaboration with professional media

As one of the lead principal investigators of the NamCore project, Junbo Wang participated extensively in the production of a project video created by *China Today*, an official new-media platform dedicated to presenting China's developments across diverse fields to international audiences in multiple languages. The production team visited NAMORS as well as the ITPCAS laboratory in Science City, where the sediment cores are stored, and sampling activities are conducted. They conducted interviews with the project's principal investigators and team members. Torsten Haberzettl provided a detailed introduction to the project, and several team members contributed by demonstrating various stages of the research workflow. The completed video has been released internationally on multiple platforms in several languages, including Chinese, English, German, and French. For more information, please see here: http://www.chinatoday.com.cn/ctenglish/2018/videos/202508/t20250815_800411500.html

11.4. Participation in Popular Science Activities to Present the NamCore Project to Students and Facilitate Communication with Other Research Institutions

As part of the National Science Popularisation Education Base, the Nam Co Station conducts several public outreach activities each year focused on lake sciences and paleoenvironmental research. Following the successful completion of the Nam Co Drilling Project, Junbo Wang organised and participated in numerous such events at NAMORS, the Natural Science Museum of Xizang, and various other institutions across China, presenting the NamCore and its societal relevance to audiences of different age groups.

In addition, several research teams from various institutions visited the drilling camp and even the drilling barge to gain a deeper understanding of the project. These visitors included delegations from, for example, Xizang University, Qinghai Normal University, Henan University, and the Institute of Earth Environment of the Chinese Academy of Sciences.

In addition to media outreach, the NamCore project provided an excellent opportunity for public science education. During and after the drilling campaign, many residents, especially middle school students, visited NAMORS, where they learned how the drilling facilities operate and gained insight into the importance of studying past climate evolution on the Tibetan Plateau.

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科技前沿

纳木错湖底岩芯可以解锁什么

□王君波

今年7月，我国科学家首次在青藏高原海拔超过4700米的纳木错深水区，于93.3米深处开始钻探，并成功采集到了长度总计为951.12米的湖底岩芯，这是第二次青藏科考2024年重大标志性科考活动之一，也是迄今为止国际大陆科学钻探计划（ICDP）中海拔最高的钻探项目，更是全球古气候研究领域的重大突破，将助力人类通过珍贵的"岩芯胶囊"还原古气候变迁的历史，为应对未来气候变化提供科学依据。

为何在纳木错钻取湖"芯"

青藏高原作为世界屋脊、亚洲水塔和地球第三极，既是我国重要的生态安全屏障和战略资源储备基地，也是全球气候变化的驱动器和地球系统科学研究的天然实验室。它吸引着全球地球科学、生命科学及环境科学等多领域的科学家前来探索。青藏高原的古环境古气候研究尤为关键，它是全球古气候研究的重要一环，与南北极、深海及中国黄土的古气候研究共同构成了地球系统科学研究的国际前沿与热点。

20世纪60年代以来，全球古气候研究以南极冰芯、格陵兰冰芯、深海沉积物及中国黄土堆积为核心介质，取得了显著进展，极大地推动了地球科学的发展。这些研究将地球气候变化的历史追溯至千万年前，还揭示了气候系统演化的周期性及其背后的控制因素，特别是太阳辐射量对轨道尺度气候变化的影响，有效衔接了构造尺度上地貌格局演化与轨道尺度气候变化的联系。这些成果不仅深化了人类对地球自然变迁的理解，更为应对当前及未来气候变化提供了坚实的科学基础。

青藏高原的隆升，作为地球演化史上的重大事件，对亚洲乃至全球气候与生态环境产生了深远影响，尤其是促进了亚洲季风系统的形成。因此，探索古季风在不同时间尺度上的演化规律，以及西风环流与季风间的相互作用机制，成为了古气候研究领域的热点。青藏高原大量内陆湖泊是

重大科学意义

纳木错近千米湖芯的成功获取，标志着历时十年之久的纳木错ICDP钻探项目完成了关键性一步，不仅有利于提升我国科学家牵头的国际团队在国际湖泊钻探领域的影响，也是青藏高原古气候研究领域的一个里程碑式的进展，对青藏高原地球科学研究具有深远影响。

该湖芯的钻探深度达510.2米，结合沉积物地震剖面测量与既有研究，其记录可追溯至60万年前甚至更早，从而将青藏高原湖泊的连续沉积序列研究从十万年尺度提升至百万年尺

特别策划 SPECIAL REPORT

湖泊是地球上最具特色的地标式自然地理景观之一。青藏高原是我国重要的湖泊分布区，这里的湖泊大多在海拔 4000 米以上，面积大于 1 平方千米的湖泊超过 1200 个，总面积超过 5 万平方千米，是我国海拔最高、数量最多、面积最大的湖群区。湖泊在演化过程中，会留下许多地质遗迹或地质档案，对它们开展研究的学科可被称为"古湖泊学"。

少年古湖泊学家养成记

文图/王君波（中国科学院青藏高原研究所）

▶ 西藏自治区邦达错，湖边的古湖岸线记录着湖面下降的历史

在湖水之上"纵览古今"

青藏高原的湖泊以它们那无与伦比的蓝带给大家美的享受，同时，也暗藏着丰富的科学问题。

湖泊是陆地水循环的重要枢纽，它的扩张和收缩与气候变化息息相关，在湖泊涨落过程中，会留下古湖岸线和阶地（沿河流、湖泊和海滨伸展，超出河、湖、海面以上的阶梯状地貌，由侵蚀剥蚀、堆积过程和地壳构造运动合力塑造而成），这些正是古湖泊学家开展研究工作最好的载体。

湖底的沉积物蕴藏着更丰富、

▶ 作者（右一）正在对从湖中提取的岩芯做现场记录

除此之外，我们还要……

观察湖盆基本形态 明确湖泊成因

了解湖泊水文状况

掌握湖泊水质特征

Fig. 15: Popular science articles were published in high-impact newspapers and journals to promote and disseminate information about the NamCore project.

11.5. Outreach activities in social media and on webpages

NamCore was promoted in social media, in particular Instagram, using the Instagram account of the Sedimentary Geochemistry working group of the University of Bern (@sedgeochem), which was actively involved in the drilling. Multiple videos and updates were posted during the drilling campaign, sampling parties and from workshops. More information, please see https://www.instagram.com/sedgeochem/

The sampling parties were extensively covered using Instagram reels via the Instagram account of the Geology Department of the University of Bern (Fig. 16, @geologyunibern). For example, time-lapse videos cover the core opening processes, wrapping the sediment cores and give updates about the progress. The videos covered both the sampling parties in January and May 2025.

As an element of NamCore, the SNF-funded DIGESTED project investigates *Deep biosphere-geosphere interactions at the top of the world.* The project structure, research packages and involved researchers, the research approach, as well as current activities, communications and publications are presented on the webpage https://www.namcodigest.org/.

Fig. 16: Screenshot of the Instagram account of the Geology Department of the University of Bern (3 Dec 2025). NamCore reels are accessible via the "Beijing 2025" collection.

11.6. Outreach during conferences

We presented initial results during multiple national and international conferences. Additionally, the NamCore project was invited to give a talk at the ICDP-CSD Facility Townhall Meeting during the AGU Annual Meeting in Washington, D.C., USA, on 9 December 2024 (Fig. 17). Junbo Wang presented the talk "Drilling on the Third Pole: the highest ICDP lake drilling Project (Tibetan Plateau, China)" and included an overview on why to drill, how the project developed, how it was drilled and future perspectives.

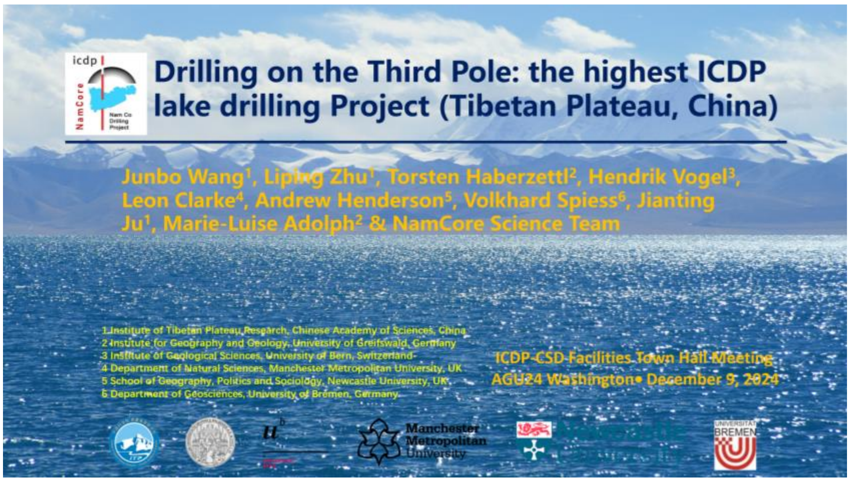

Fig. 17: Introduction slide to the presentation at the ICDP-CSD Facility Townhall Meeting during the AGU Annual Meeting in Washington, D.C., USA, on 9 December 2024

12. Summary

This operational report summarises the relevant operational aspects of the Nam Co Drilling Project. Overall, the drilling operation in remote Tibet was challenging not only during preparation and planning but also for all participants working at an altitude of 4718 m asl. For example, to accommodate the unique setting of Nam Co and to successfully carry out the drilling campaign, we had to set up a camp at the northern shoreline, including accommodation, meeting rooms and a canteen.

After several iterations in the first several days of drilling to optimise the drilling protocols, drilling operations went smoothly overall. Drilling Nam Co's sediments was challenging due to highly variable, unconsolidated and difficult to predict lithological changes. These lithological changes, in particular up to several m-thick sand layers, required a modification of the drilling strategy during drilling operations. Instead of drilling three sites, we focused on one site to drill a sediment succession as complete as possible. In total, we drilled 1415.45 m and recovered 950.45 m of sediment cores across seven holes. The research on the sediment cores recovered is only just beginning and will continue over the coming years.

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References

Adolph, M.-L.; Wang, J.; Zhu, L.; Clark, L. J.; Henderson, A. C. G.; Vogel, H.; Hofmann, P.; Ju, J.; Kunkel, C.; Noren, A.; Schnurrenberger, D.; Spiess, V.; Thomas, C.; Ulfers, A.; Haberzettl, T. (2025): Explanatory Remarks on the Operational Dataset: The Nam Co Drilling Project, Tibet (NamCore): A one million year sedimentary record from the Third Pole. GFZ Data Services. https://doi.org/10.48440/ICDP.5073.001

Adolph, M.-L.; Wang, J.; Zhu, L.; Clark, L. J.; Henderson, A. C. G.; Vogel, H.; Hofmann, P.; Ju, J.; Kunkel, C.; Noren, A.; Schnurrenberger, D.; Spiess, V.; Thomas, C.; Ulfers, A.; Haberzettl, T. (2026): Operational Dataset: The Nam Co Drilling Project, Tibet (NamCore): A one million year sedimentary record from the Third Pole. GFZ Data Services. https://doi.org/10.5880/ICDP.5073.001

Adolph et al: Scientific Drilling Paper

Ai, K., Shi, G., Zhang, K., Ji, J., Song, B., Shen, T. and Guo, S., 2019. The uppermost Oligocene Kailas flora from southern Tibetan Plateau and its implications for the uplift history of the southern Lhasa terrane. Palaeogeography, Palaeoclimatology, Palaeoecology, 515: 143-151, https://doi.org/10.1016/j.palaeo.2018.04.017

Aitchison, J.C., Ali, J.R. and Davis, A.M., 2007. When and where did India and Asia collide? Journal of Geophysical Research: Solid Earth, 112: 1-19, https://doi.org/10.1029/2006JB004706

Armijo, R., Tapponnier, P. and Han, T., 1989. Late Cenozoic right-lateral strike-slip faulting in southern Tibet. Journal of Geophysical Research: Solid Earth, 94(B3): 2787-2838, https://doi.org/10.1029/JB094iB03p02787

Armijo, R., Tapponnier, P., Mercier, J.L. and Han, T.-L., 1986. Quaternary extension in southern Tibet: Field observations and tectonic implications. Journal of Geophysical Research: Solid Earth, 91(B14): 13803-13872, https://doi.org/10.1029/JB091iB14p13803

Ding, L., Xu, Q., Yue, Y., Wang, H., Cai, F. and Li, S., 2014. The Andean-type Gangdese Mountains: Paleoelevation record from the Paleocene-Eocene Linzhou Basin. Earth and Planetary Science Letters, 392: 250-264, https://doi.org/10.1016/j.epsl.2014.01.045

Elliott, J.R., Walters, R.J., England, P.C., Jackson, J.A., Li, Z. and Parsons, B., 2010. Extension on the Tibetan plateau: recent normal faulting measured by InSAR and body wave seismology. Geophysical Journal International, 183(2): 503-535, https://doi.org/10.1111/j.1365-246X.2010.04754

XEngland, P. and Searle, M., 1986. The Cretaceous-tertiary deformation of the Lhasa Block and its implications for crustal thickening in Tibet. Tectonics, 5(1): 1-14, https://doi.org/10.1029/TC005i001p00001

Gibbons, A.D., Zahirovic, S., Müller, R.D., Whittaker, J.M. and Yatheesh, V., 2015. A tectonic model reconciling evidence for the collisions between India, Eurasia and intra-oceanic arcs of the central-eastern Tethys. Gondwana Research, 28(2): 451-492, https://doi.org/10.1016/j.gr.2015.01.001

Haberzettl, T., Daut, G., Schulze, N., Spiess, V., Wang, J. and Zhu, L., 2019. ICDP workshop on scientific drilling of Nam Co on the Tibetan Plateau: 1 million years of paleoenvironmental history, geomicrobiology, tectonics and paleomagnetism derived from sediments of a high-altitude lake. Scientific Drilling, 25: 63-70, https://doi.org/10.5194/sd-25-63-2019

Kapp, J.L.D.A., Harrison, T.M., Kapp, P., Grove, M., Lovera, O.M. and Lin, D., 2005. Nyainqentanglha Shan: A window into the tectonic, thermal, and geochemical evolution of the Lhasa block, southern Tibet. Journal of Geophysical Research: Solid Earth, 110(B8), https://doi.org/10.1029/2004JB003330

Kropáček, J., Braun, A., Kang, S., Feng, C., Ye, Q. and Hochschild, V., 2012. Analysis of lake level changes in Nam Co in central Tibet utilizing synergistic satellite altimetry and optical imagery. International Journal of Applied Earth Observation and Geoinformation, 17: 3-11, https://doi.org/10.1016/j.jag.2011.10.001

Maussion, F., Scherer, D., Mölg, T., Collier, E., Curio, J. and Finkelnburg, R., 2014. Precipitation Seasonality and Variability over the Tibetan Plateau as Resolved by the High Asia Reanalysis. Journal of Climate, 27(5): 1910-1927, https://doi.org/10.1175/JCLI-D-13-00282.1

Murphy, M.A., Yin, A., Harrison, T.M., Dürr, S.B., Chen, Z., Ryerson, F.J., F., K.W.S., Wang, X. and Zhou, X., 1997. Did the Indo-Asian collision alone create the Tibetan plateau? Geology, 25(8): 719-722, https://doi.org/10.1130/0091-7613(1997)025<0719:DTIACA>2.3.CO;2

Pullen, A., Kapp, P., Gehrels, G.E., DeCelles, P.G., Brown, E.H., Fabijanic, J.M. and Ding, L., 2008. Gangdese retroarc thrust belt and foreland basin deposits in the Damxung area, southern Tibet. Journal of Asian Earth Sciences, 33(5-6): 323-336, https://doi.org/10.1016/j.jseaes.2008.01.005

Schulze, N., 2020. The Sedimentary and Tectonic Evolution of the Nam Co Basin, Tibetan Plateau, since the Middle Pleistocene - A Seismoacoustic Study on Lake Sediments, PhD Thesis, University of Bremen, Bremen, 154 pp, https://doi.org/10.26092/elib/567

Wang, J., Zhu, L., Daut, G., Ju, J., Lin, X., Wang, Y. and Zhen, X., 2009. Investigation of bathymetry and water quality of Lake Nam Co, the largest lake on the central Tibetan Plateau, China. Limnology, 10(2): 149-158, https://doi.org/10.1007/s10201-009-0266-8

Xu, Q., Ding, L., Spicer, R.A., Liu, X., Li, S. and Wang, H., 2018. Stable isotopes reveal southward growth of the Himalayan-Tibetan Plateau since the Paleocene. Gondwana Research, 54: 50-61, https://doi.org/10.1016/j.gr.2017.10.005

Yao, T., Bolch, T., Chen, D., Gao, J., Immerzeel, W., Piao, S., Su, F., Thompson, L., Wada, Y., Wang, L., Wang, T., Wu, G., Xu, B., Yang, W., Zhang, G. and Zhao, P., 2022. The imbalance of the Asian water tower. Nature Reviews Earth & Environment, 3(10): 618-632, https://doi.org/10.1038/s43017-022-00299-4

Zhou, S., Kang, S., Chen, F. and Joswiak, D.R., 2013. Water balance observations reveal significant subsurface water seepage from Lake Nam Co, south-central Tibetan Plateau. Journal of Hydrology, 491: 89-99, https://doi.org/10.1016/j.jhydrol.2013.03.030

Zhu, L., Xie, M. and Wu, Y., 2010. Quantitative analysis of lake area variations and the influence factors from 1971 to 2004 in the Nam Co basin of the Tibetan Plateau. Chinese Science Bulletin, 55(13): 1294-1303, https://doi.org/10.1007/s11434-010-0015-8