

RAPID DRILLING THROUGH DEEP ICE INTO BEDROCK IN ANTARCTICA: RESEARCH PROGRESS AND FUTURE PLAN

Monday 15 September 2025 12:30 (20 minutes)

Rapid penetration through Antarctic ice sheets to directly recover subglacial bedrock core and samples for cosmogenic nuclide and mineralogical analyses holds critical significance in advancing research on Antarctic geological structures, reconstructing ice sheet evolution history, and evaluating future climate change. Current drilling technologies face substantial challenges under Antarctica's extreme surface environments and complex subglacial geological conditions, particularly due to heterogeneous ice-rock interfaces and the technical difficulties of maintaining borehole stability while recovering bedrock cores. Internationally, only a few shallow subglacial bedrock boreholes (with limited core recovery) have been completed to date, falling short of supporting comprehensive scientific investigations. This underscores the urgent need for innovative multi-process drilling theories and methodologies tailored to Antarctica's subglacial geological complexity.

This project aims to establish novel multi-process drilling techniques capable of increasing penetration rates by 50–100%, while developing lightweight modular drilling rigs and multi-process systems with an ice-penetration capacity exceeding 1,000 meters and subglacial bedrock core recovery of ≥ 10 meters. To achieve these objectives, four key research components have been implemented: (1) research of rapid drilling technology with air reverse circulation for firn/ice layers, (2) research and development of ice-rock interface/core sampling tools, (3) research and development of low-temperature drilling fluid formulation for ice-rock interlayers, and (4) research and development of polar drilling equipment and system integration. The resulting technological suite includes: a fully hydraulic top-drive rig with large channel capacity, high-performance air compression and purification systems, cryogenic drilling fluid circulation/pumping modules, a 300-kW power supply system, and multi-process downhole toolkits (e.g., 550m-long Ø89 aluminum alloy dual-wall drill pipes, Ø110/102 reverse circulation bits, wireline coring tools, and vertical rock-entry tooling for ice-rock interfaces).

The operational drilling technology strategy combines: (1) Air reverse circulation (ARC) full-face drilling using aluminum dual-wall drill pipes for rapid ice sheet penetration; (2) Hydraulic reverse circulation (HRC) with cryogenic fluids for ice-rock transition zones; (3) Wireline coring or continuous HRC coring for bedrock core recovery.

Field validation commenced in July–October 2024 at Zhangjiakou City (China), demonstrating successful performance in full-face drilling, core recovery, and system integration. Subsequently deployed during China's 41st Antarctic Expedition, the entire system was transported to Princess Elizabeth Land, East Antarctica (69°35'10.12"S, 76°23'03.87"E) in January 2025 (2024/2025 summer season). Initial field tests achieved a 110mm-diameter borehole penetrating 110m of ice using ARC and HRC methods, confirming equipment functionality under Antarctic conditions.

Identified operational challenges from these trials will guide system optimizations. The research team plans to participate in China's 42nd Antarctic Scientific Expedition to conduct extended experiments targeting 500m ice penetration and subglacial bedrock core recovery. This phased approach ensures iterative refinement of drilling protocols while progressively addressing technical barriers in ultra-deep Antarctic ice drilling. Upon full validation, the methodology is anticipated to enable unprecedented access to Antarctic subglacial bedrock, providing critical samples for cross-disciplinary studies in glaciology, geology, and climate science.

References

- Xinyu Lv, Zhihao Cui, Ting Wang, Yumin Wen, An Liu, and Rusheng Wang (2024) Research into mechanical modeling based on characteristics of the fracture mechanics of ice cutting for scientific drilling in polar regions. *The Cryosphere* 18: 3351–3362. <https://doi.org/10.5194/tc-18-3351-2024>
- Xinyu Lv, Zhihao Cui, Ting Wang, Yumin Wen, Rusheng Wang (2025) Particle size distribution of ice chips produced under varies drilling conditions in the process of ice core drilling. *Polar Science* 43 (2025):101136. <https://doi.org/10.1016/j.polar.2024.101136>
- Wang R, Liu A, Cao P, Chen B, Sysoev M, Fan D, Talalay PG (2017) Rapid ice drilling with continual air transport of cuttings and cores: General concept. *Polar Science* 14: 21–29. <https://doi.org/10.1016/j.polar.2017.09.004>
- Ni Sun, Ting Ye, Zehong Xia, Zheng Feng, Rusheng Wang (2024) Gaussian smoothed particle hydrodynamics: A high-order meshfree particle method. *Engineering Analysis with Boundary Elements* 168 (2024): 105927. <https://doi.org/10.1016/jenganabound.2024.105927>
- Ni Sun Ting Ye Rusheng Wang (2024) Direct simulations of bedrock core and cuttings transport

Primary author: WANG, Rusheng (Jilin University)

Co-authors: Mr CUI, Zhihao (Jilin University); Dr TU, Guigang (Jilin University); Prof. YE, Ting (Jilin University); Prof. LIU, Baochang (Jilin University); Ms HONG, Siqi (Jilin University); Dr LV, Xinyu (Jilin University); Prof. TALALAY, Pavel (Jilin University); Dr ZHANG, Nan (Jilin University); Dr FAN, Xiaopeng (Jilin University); Dr GONG, Da (Jilin University)

Presenter: WANG, Rusheng (Jilin University)

Session Classification: Oral sessions

Track Classification: Subglacial drilling and sampling