# High-Resolution Electrical Resistivity Tomography (ERT) Measurements Along Paved Roads in Permafrost Regions of Mongolia

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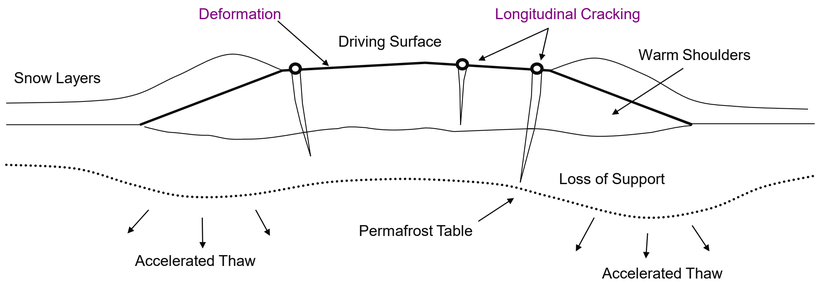
Running for the PYRN Award — Permafrost Researchers Young Network

## INTRODUCTION

Mongolian road network currently amounts to 12722 km, including 5354 km of paved roads, 6213 km of unpaved roads, and 1153 km of planned roads (Adhikari, 2013). Of this, approximately 1200 km of paved roads were constructed on warm permafrost with a mean annual ground temperature higher than -2.0°C (Jambaljav, 2017). Along paved roads in warm permafrost zones, significant settlement and deformations related to creep were found at many places where the embankments are unusually tin. Therefore, the stabilization of the embankments must be taken into consideration, particularly for those embankments directly underlain by the warm permafrost layer.

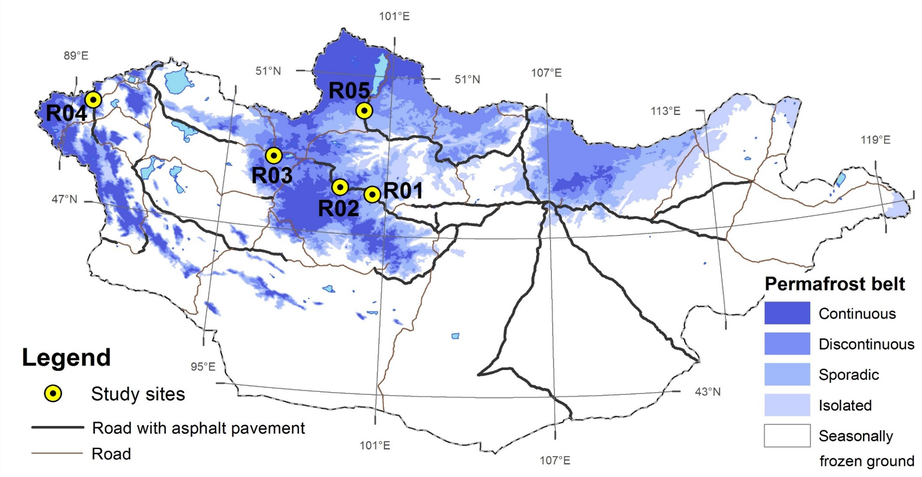
Objective of this study was to investigate the settlement and deformation of the embankments constructed in the Mongolia.

### Embankment Problem





## STUDY AREA




### General environmental characteristics of study sites

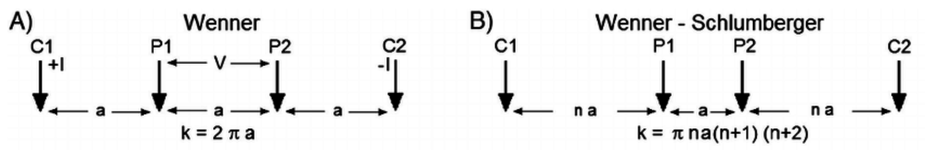
| | R01 site | R02 site | R03 site | R04 site | R05 site |
|---|---|---|---|---|---|
| **Permafrost zone** | Sporadic | Continuous & discontinuous | Continuous & discontinuous | Discontinuous | Sporadic |
| **Permafrost temperature (°C) at depth of 10-15 m*** | -0.45°C | -1.2°C | -0.4°C | -0.65°C | -0.7°C |
| **Active layer (m)** | 1.6 – 3 m | 3 m | 3 - 4 m | 3.5 - 4 m | 4.5 m |
| **Permafrost thickness (m)**** | 36 m | 105 m | 24 - 28 m | > 15 m | 15 – 40 m |
| **Ice content (%)***** | Medium 10-20% | Medium 10-20% | Medium 10-20% | Medium 10-20% | Medium 10-20% |
| **Sediments*** | Gravel, sand, silt, and clay | Gravel, and sand | Fine sand, and gravel | Coarse sand, and gravel | Medium and coarse sand, and gravel |
| **Permafrost phenomena** | Thermokarst lake, pingo, hummock | Pingo, hummock, solifluction, dog hole | Hummock, dog hole | Thermokarst lake, hummock | - |

** Jambaljav et al., 2017 ; **Sharkhuu, 2011; ***Jerry Brown et al., 1998*

## METHODS

### Electrical Resistivity Tomography Measurements

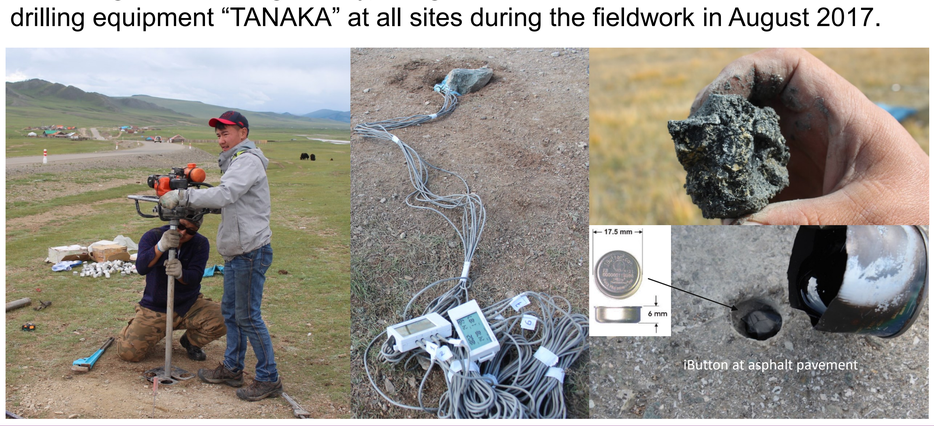
- Wenner and Wenner-Schlumberger arrays (A & B)
- the multi-electrode resistivity technique uses a syscal R+
- a switch pro and several multi-core cables
- 96 electrodes was plugged into the ground at a fixed distance of 1-5 m





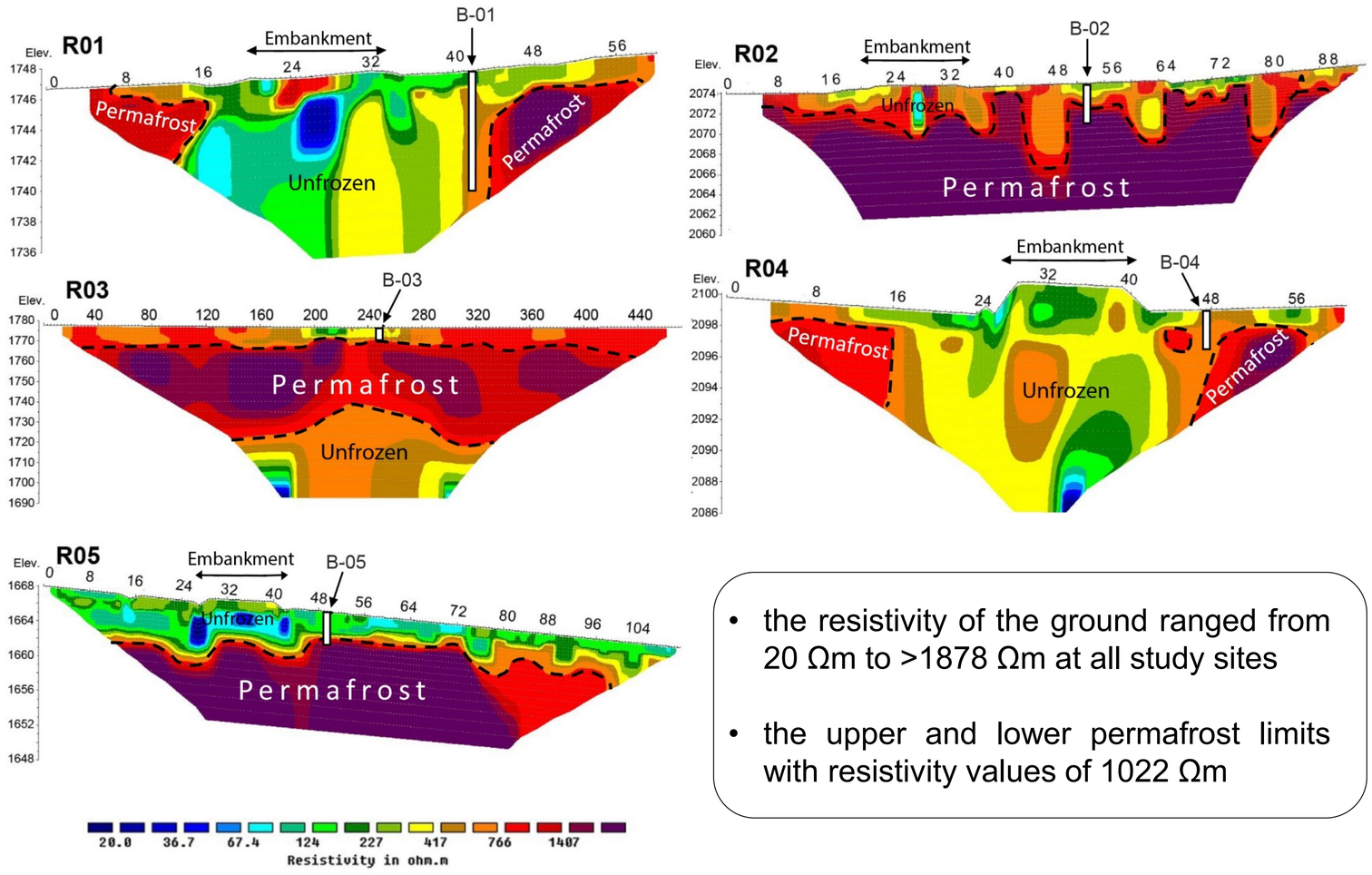
### Drilling

According to the drilling survey, the ground materials were identified with hand drilling equipment “TANAKA” at all sites during the fieldwork in August 2017.



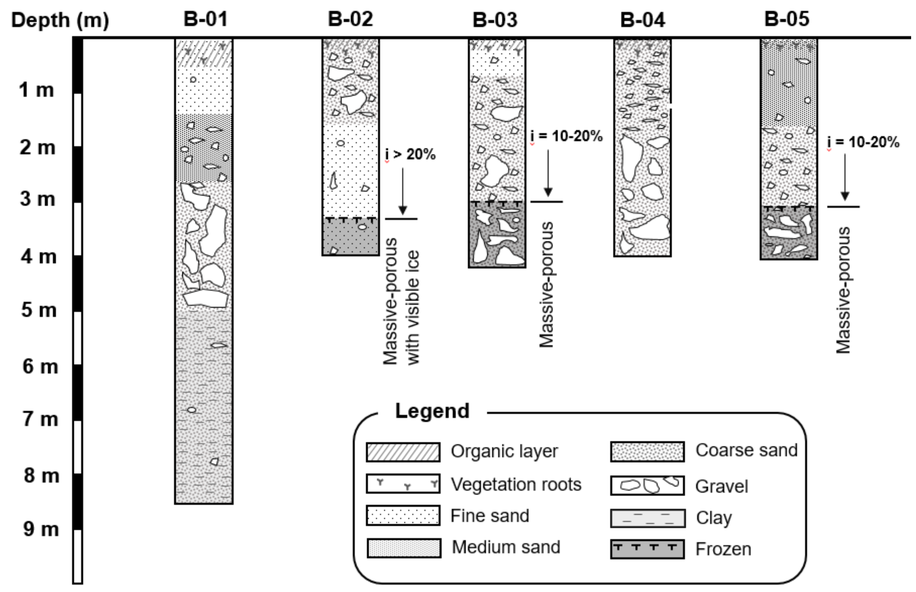

## RESULTS AND DISCUSSION

### 2- D Profile of Electrical Resistivity Tomography (ERT)

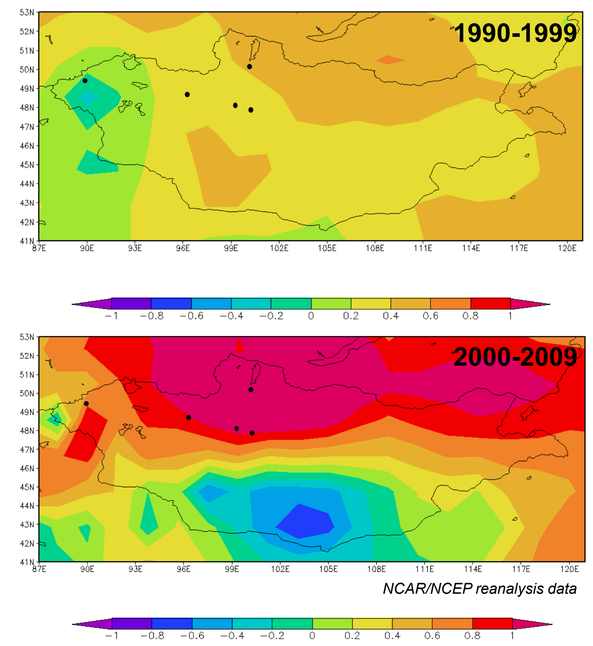



- the resistivity of the ground ranged from 20 Ωm to >1878 Ωm at all study sites
- the upper and lower permafrost limits with resistivity values of 1022 Ωm

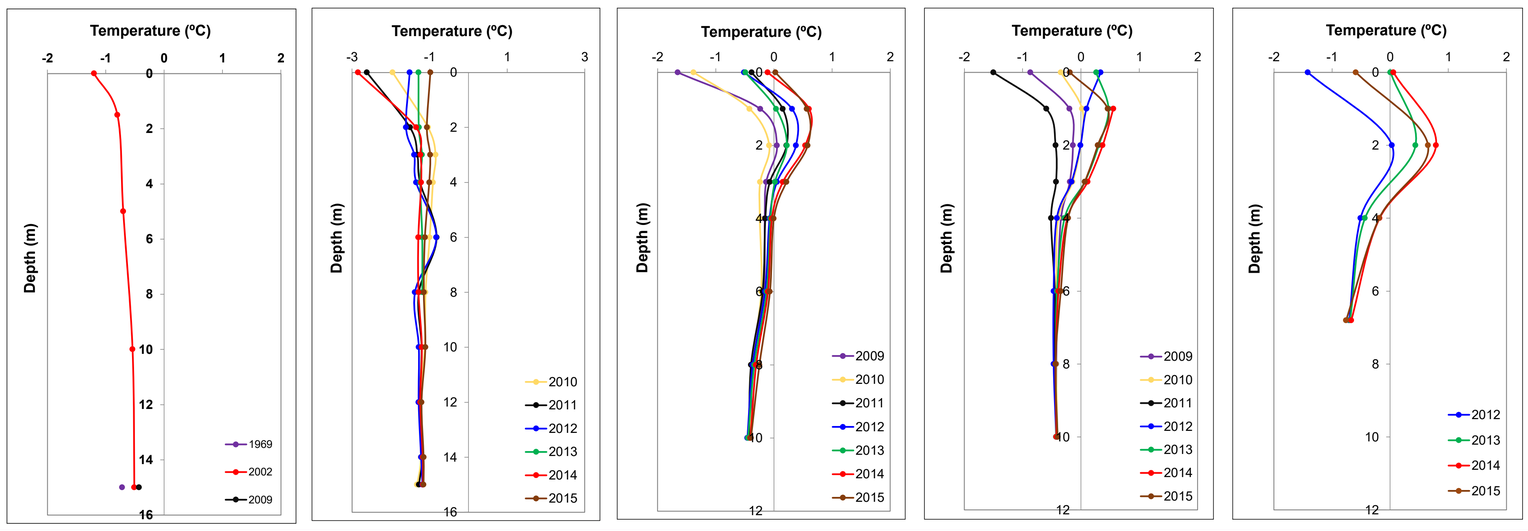
### Soil profile of Boreholes on Study Sites




### Air Temperature Increases (ºC)




### Changes in Permafrost Temperatures




## CONCLUSIONS

Embankment settlements of paved roads in Mongolia are closely related to permafrost warming and degradation. Generally, thawing settlement of ice-rich permafrost and creep of warming permafrost are main sources of embankment deformation.

- Permafrost limits were associated with drilling results of the boreholes at study sites.
- Settlement and deformations of the embankment surface were found with different rates between 5 cm and 30 cm at all sites, except the R03 site.
- High-resolution ERT measurements and permafrost temperatures clearly show the permafrost thawing, especially underneath the embankment in the R01, and R04 sites, where the permafrost thawed down to 11 m.

## ACKNOWLEDGEMENTS

This study is financed by the Mongolian Foundation for Science and Technology. I greatly appreciate the efforts of project team in Permafrost Department at the Institute of Geography-Geoecology, Mongolian Academy of Sciences. Finally, I would like to express my sincere appreciation to the organizing committee of PYRN Workshop during the EUCOP5 for travel grant.

INSTITUTE OF GEOGRAPHY-GEOECOLOGY

MONGOLIAN FOUNDATION FOR SCIENCE AND TECHNOLOGY

5th EUropean COnference on Permafrost CHAMONIX Mont-Blanc 23 June - 1st July 2016 EUCOP5

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