Man-made Cavity Imaging with 2D Resistivity Technique

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ABSTRACT

This study evaluates the usefulness and capability of subsurface cavity imaging using the two-dimension resistivity technique. A two-dimension resistivity survey was conducted across a man-made tunnel and conduit. Synthetic resistivity data of various electrode configurations, including Wenner, half-Wenner, dipole-dipole, pole-pole, Schlumberger, and half-Schulumberger, were generated from a synthetic model similar to known subsurface geology and subsurface structures of the tunnel and the conduit. At the tunnel location, three field survey lines were acquired in different directions across the tunnel. The first line was perpendicular to the tunnel axis and the other two lines were inclined with the tunnel axis. At the conduit location, only one line was acquired. Field data show that the dipole-dipole and Wenner configurations provide good imaging of cavities. A cavity image appears as a lateral anomaly in a homogeneous medium. The anomalous zones of the cavities inside the tunnel and the conduit are distinguishable by being a higher resistivity zone, and is surrounded by lower background resistivity. However, the cavity images from both the tunnel and the conduit appear to have either vertically and/or laterally misplaced locations. This suggests there are strong three-dimension effects from subsurface structures.

KEYWORDS: Resistivity survey, electrode array, cavity, resistivity anisotropy

INTRODUCTION

Subsurface structural geology of the Maha Sarakham Formation of rock salt and claystone in the Khorat and Sakon Nakon basins is commonly known as complex structure. The complexity of the subsurface structure in the Maha Sarakham Formation is attributable to the rock salt strata in the formation. This rock salt was deposited during the Cretaceous Period and the basins were later filled with other sediments. The rock salt became deeply buried as a consequence of tectonic stress from the Himalayan orogeny during the Tertiary Period. The rock salt behaved as a viscous fluid, being able to move and flow upward to form salt domes. Due to this fluidity property of salt, the thickness of rock salt strata varies significantly. Results from hundreds of bore holes drilled into the Maha Sarakham Formation showed that the thickness of the rock salt strata and depths to rock salt strata ranges between ten and one thousand meters (Suwanich, 1986). Furthermore, because the rock salt is a soluble mineral that is easily dissolved, collapse of near-surface rock salt cavities from the shallow salt domes to form sinkholes in the Khorat and Sakon Nakorn basins...
becomes one of the geo-environmental hazards (Hinthong and Charoenprawat, 1990; Solgosoom and others, 1999; Satarugsa and others, 2001). Thus, detailed subsurface mapping leading to identification of sinkhole-prone areas is urgently needed in order to relieve a fear of the sinkhole hazard and to help prevent possible and significant damages from the hazard.

Applied geophysical techniques are inexpensive and effective methods to obtain subsurface information and, hence, they have been used widely. Each geophysical technique requires sufficient contrast in measurable physical properties and has different limitations and resolution depending on the instruments used. It is necessary to understand instrument limitations and resolutions in order to select the appropriate geophysical methods for successful applications (Zhou and others, 2002; Dahlin and Bing, 2003).

A resistivity survey has been documented as a powerful method to detect a cavity in a karst region where the cavity can be distinguished on the basis of a resistivity anomaly from background (Loke, 1999; Van Schoor, 2002; Satarugsa and other, 2004). However, there are many electrode configurations and layouts for resistivity data acquisition. Different electrode configurations provide different results and are suited for different geological conditions (Zhou and others, 2002).

This study shows the results of a two-dimension resistivity survey in imaging both a nature-formed subsurface cavity and a man-made subsurface cavity. The purpose of this study was to evaluate the usefulness and suitability of the two-dimension resistivity technique for detecting these types of subsurface cavities.

**METHOD**

A Syscal R1 Plus instrument was used for measuring apparent resistivity. The procedural steps were first to generate predictable resistivity tunnel and conduit models with different configurations. This was done using dipole-dipole, pole-pole, Wenner, Schlumberger, half-Wenner, and half-Schlumberger configurations and the rapid two-dimension resistivity forward modeling, RES2DMOD, of Loke (1999). After this, resistivity data across the tunnel and the conduit were acquired (Figures 1 and 2). At the tunnel, three lines were surveyed. The direction of one line was perpendicular to the tunnel axis and the directions of the other two lines were inclined to the tunnel axis (Figure 1). At the conduit, only one line was surveyed. The field data were measured using the same survey configurations as for the synthetic data. After the field surveying was completed, the synthetic and field data were compared. This led to determining the best electrode configuration for mapping the cavity filled with air inside both the square tunnel and the conduit. The resistivity data were interpreted using the two-dimension inversion program, RES2DINV, of Loke (1999).

**RESULTS AND DISCUSSIONS**

The measurement results from the various electrode configurations used along the tunnel and conduit survey lines show that all electrode configurations can detect the underground tunnel (Figures 2 and 3). Of these various configurations, the Wenner and dipole-dipole configurations provide the best tunnel imaging (Figure 3). The underground tunnel can be considered as a lateral anomaly in a homogenous medium. An anomalous zone of the tunnel can be distinguished as the higher resistivity zone that is surrounded by lower background resistivity (Figures 2 and 3). Both predicted and the measured square tunnel resistivity images have a semi-square shape at the high anomalous zone (Figure 4). However, location of the tunnel anomaly from the survey lines inclined with the
tunnel axis appears to be laterally misplaced on the resistivity pseudosections (Figures 2, 3, and 4). This suggests influence of three-dimension subsurface structures.

![Figure 1](image)

**Figure 1**
Photograph showing directions of three survey lines across a tunnel axis. Line 1 has a line direction perpendicular to the tunnel axis. Line 2 and Line 3 have line directions inclined to the tunnel axis.

The resistivity profiles across the conduit measured with the Wenner and dipole-dipole configurations show a cavity anomaly inside the conduit (Figures 5). An anomalous cavity zone inside the conduit can be distinguished as the higher resistivity zone. It is surrounded by lower background resistivities (Figure 5). However, the location of the cavity anomaly shown on the resistivity pseudosections appears to be vertically and laterally misplaced. This misplaced location of the conduit’s cavity anomaly is similar to the misplacement of the tunnel’s cavity anomaly (Figures 2 to 5). This confirms the influence of three-dimension structure effects, or subsurface anisotropy. Thus, interpretation of subsurface resistivity anomaly locations need to be done with caution, taking into consideration three-dimension structure effects, or the subsurface anisotropy.

**CONCLUSIONS**
Two-dimension resistivity surveys can be used successfully to detect a cavity in the near-ground subsurface. Survey results can be used as a basis for mapping subsurface cavities. A well-defined structure with either high resistivity, i.e., filled with air, or low resistivity, i.e., filled with water, surrounded with a lower or higher resistivity is suggestive evidence for the presence of a subsurface cavity. However, any vertically and/or laterally misplaced cavity anomaly suggests strong three-dimension effects of subsurface structures. Thus, interpretation of any subsurface resistivity anomaly location needs to take into consideration the three-dimension effects of subsurface anisotropy.

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Figure 2.
Imaging of 2D resistivity pseudosections from Line3. The actual tunnel is located at the centre of the line, 1 metre deep, 8 metres long and 3 metres wide. The inversion interpretation sections from field apparent resistivity with: (a) Wenner array, (b) Dipole-Dipole (Wenner Beta), (c) Dipole-Dipole, (d) Pole-Pole, (e) Half Schulumberger.
Figure 3.
The inversion interpretation sections from field apparent resistivity with: (a) Wenner from Line 1, (b) Wenner from Line 3, (c) Dipole-Dipole from Line 1 and (d) Dipole-Dipole from Line 3.
Figure 4.
The inversion interpretation sections from apparent resistivity with: (a) Wenner array generated by a synthetic test model similar to the actual tunnel physical properties, (b) Wenner array from the profile with the line direction incline to the tunnel axis, (c) Dipole-Dipole array generated by synthetic test model, and (d) Dipole-Dipole array from the profile with the line direction incline to the tunnel axis. Note that an outline in a box is a zone of the actual tunnel’s body.
Figure 5.
(a) Photograph showing location of survey line. (b) Imaging of 2D resistivity pseudosections acquired Wenner configuration. (c) Imaging of 2D resistivity pseudosections acquired Dipole-Dipole configuration. Note that an outline in a box is an actual location the conduit.
REFERENCES


