A COMPARATIVE ANALYSIS BETWEEN GROUND SUBSIDENCE AT ABANDONED UNDERGROUND COAL MINE AND ELECTRICAL RESISTIVITY SURVEY RESULTS USING GIS

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ABSTRACT. Ground subsidence near abandoned underground coal mines has become a serious social problem in Korea. The purpose of this study is to perform a comparative analysis between the ground subsidence area and the electrical resistivity measured by field survey at Samcheok City. A raster database composed of ground subsidence areas and electrical resistivity data was constructed for GIS. To analyze correlation between the two constructed raster datasets, we used a frequency ratio model. The results show that low and high electrical resistivity anomaly zones coincide with the existing subsidence areas. We infer that the high anomaly zone means saturated and low anomaly zone means vacant. It suggests that electrical resistivity might be a useful factor for analyzing ground subsidence hazard zone.

KEY WORDS: Ground subsidence, GIS, electrical resistivity, frequency ratio model, abandoned underground coal mine

1. INTRODUCTION

Ground subsidence occurred by underground mined tunnels and excavates may damage buildings on the surface and can make a disaster (Jung *et al.*, 2002). Many researches of analyzing the ground subsidence have been carried out. But researches using geophysical survey and GIS have not been carried out yet.

1.1 Abandoned Underground Coal Mines

Near abandoned underground coal mines (AUCM), the structures and the geological properties of underground are very complicated. So it is difficult to exactly understand the mechanism and the amount of displacement of the underground subsidence with depth.

Geophysical survey for seismic and electrical resistivity is one of the most efficient methods to find out the characteristics of ground media and structure quantitatively. One can produce a two-dimensional or three-dimensional scene of underground from the geophysical survey data, and therefore it is frequently used to measure the geological structure of the underground near unsaturated zone and AUCM (Yong *et al.*, 2002; Lee *et al.*, 2002; Ko *et al.*, 2003).

In this study, we performed a comparative analysis using GIS between the ground subsidence area and the electrical resistivity measured at Samcheok coalfield. We overlaid the result to the ground subsidence hazard map produced by Kim *et al.* (2006) for comparison.

1.2 Study Area

The coal resource of South Korea mainly consists of anthracite and 85% of them had been deposited during the upper Paleozoic era and the lower Mesozoic era in the Jangseong Formation of the Pyeongan Supergroup (Geological Society of Korea, 1999).

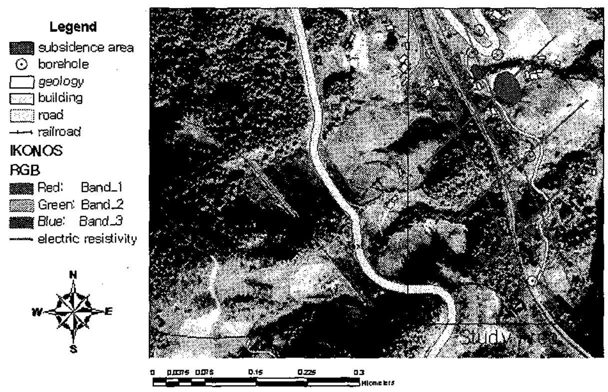

Figure 1. Location map of study aea and IKONOS image acquired at 2002. 8.

The study area is within Samcheok coalfield and locates at Simpo-Ri at Samcheok City. The Nampoong gallery on the Jangseong Formation is near the study area. Along the study area the Oship fault, the Oship creeks, Youngdong rail road, and no.38 local road pass by (CIPB: Coal Industry Promotion Board, 1999). The location map and electrical resistivity survey lines of this study appear in Figure 1.

2. FORMER STUDY

Electrical resistivity survey was carried out to depict two-dimensional underground pictures. Each survey line was designed to derive a very reasonable and accurate image of the subsurface along quarry mine area (Yi *et al.*, 2002).

Recently, some researches which aimed at analyzing the ground subsidence mechanism and assessing the ground subsidence hazard have been carried out using GIS. Kwon *et al.* (2000) reported that most types of the ground subsidence curves are similar so it can be used to analyze the weight of input factors quantitatively using GIS. Van Schoor (2002) studied the technique of discrimination between developing sinkholes and mature sinkholes with the electrical resistivity tomography.

3. THEORY AND APPLICATION

3.1 Electrical Resistivity Survey

Among the various geophysical exploration methods, electrical resistivity survey has been used widely for prospecting the metal deposit, coal mine and ground water. With that method we can obtain information about the electrical resistivity distribution of the subsurface using the various arrays of electrode (Ward, 1990). It is very hard to understand the underground lightfaces directly from the relative difference. Generally, the sheared zones or fault zones have lower resistivity than fracture free bed rocks because they contains electrically low resistant materials such as ground water, clay minerals, etc. (Van Nostrand and Cook, 1966).

The 2D-schlumberger array method was used in this study area and 6 survey lines were selected to examine. The length of survey line was average 450 m (survey line 1, 2, 3), the unit distance of measured point was 10 m to 20 m and possible depth of survey was 100 m.

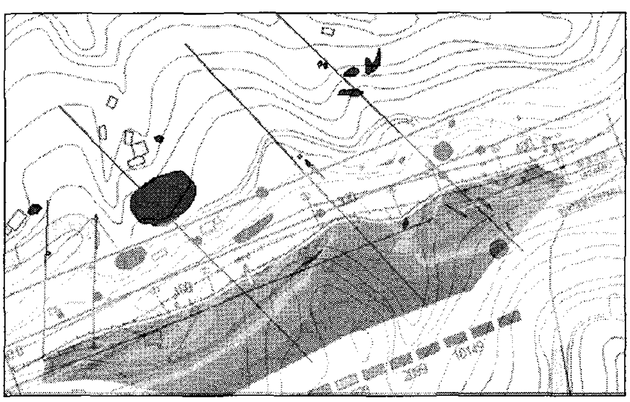

Figure 2. Overlay of the electrical resistivity image to the survey line

We carefully registered the cross section images of electrical resistivity survey to the exact position of study area. First, we overlapped the cross section images to the survey line and drew the anomaly line along the survey line manually. The processing of overlapping the electrical resistivity image to the survey line appears in Figure 2.

3.2 Frequency Ratio Model

The ratings were calculated using the probability method (frequency ratio) of a previous study (Lee *et al.*, 2004). They generated a landslide susceptibility map expending the study with the frequency ratio at Yongin in Korea, and Kim *et al.* (2006) applied that method to the case of ground subsidence and obtained the presumptive ground subsidence area.

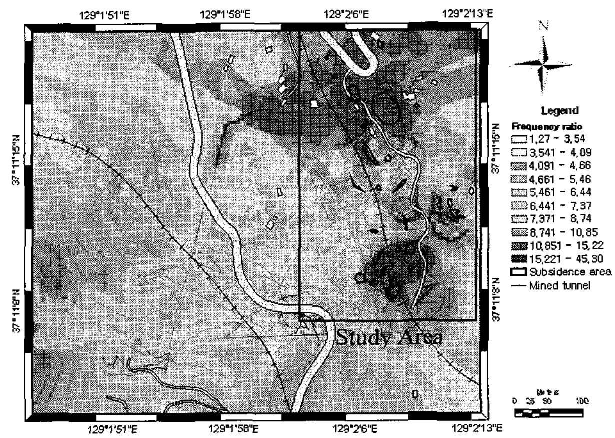

Figure 3. Ground subsidence map using frequency ratio (Kim *et al.*, 2006)

We used the frequency ratio from the study of Kim *et al.* (2006). The electrical resistivity survey result data was transformed to 1 m resolution grid file. The transformed grid file was evaluated using the frequency ratio to review the correlation between ground subsidence and the electrical resistivity anomaly zone. The probabilistic approaches are based on the observed relationships between each grade of electrical resistivity and the distribution of monitored ground subsidence area.

The value of frequency ratio 1 means an average value. It is a higher correlation if the ratio is greater than 1, while it means a lower correlation if the value of the ratio is less than 1 (Lee *et al.* 2004)

4. DATA AND PROCESS

4.1 Data

We used the investigation reports of the stability test at Samcheok City (CIPB, 1999). From the report, we extracted the electrical resistivity survey line and borehole points. The borehole points were used to fit the cross section image to the survey line.

Table1. Constructed GIS database related to ground subsidence in the study area

Category	Layer	Type
Topography	Bldg	polygon
	Contour	line
	Road	line
	Railroad	line
Geology	Geology	polygon
RS Data	IKONOS	GRID
From report	Borehole	point
	Electrical Resistivity	line

4.2 Process

We selected the study area, and collected electrical resistivity survey data and the ground subsidence areas monitored in 1999. We then generated the shape format data from the cross section images and calculated correlation with frequency ratio. The overall process of this study is shown in Figure 4.

Select study area
↓
Collect data related ground subsidence and electrical resistivity survey
↓
Conversion the cross section images to shape
↓
Correlation analysis using frequency ratio
↓
Deduction of result
↓
Overlay result to ground subsidence hazard map
↓
Deduction of conclusion

Figure 4. Flow chart of this study

5. RESULTS

5.1 Low and High Anomaly Zones

We classified the electrical resistivity into nine grades. The blue colour (darkest grey, 1) means low anomaly, the red colour (second dark gray, 8) means high anomaly and the yellow colour(bright grey, 5) means the normal. After dividing the survey lines, we buffered 3 m by ArcGIS feature buffering function because the unit distance of measured point was 10 m to 20 m. The result image with subsidence area is shown at Figure 5.

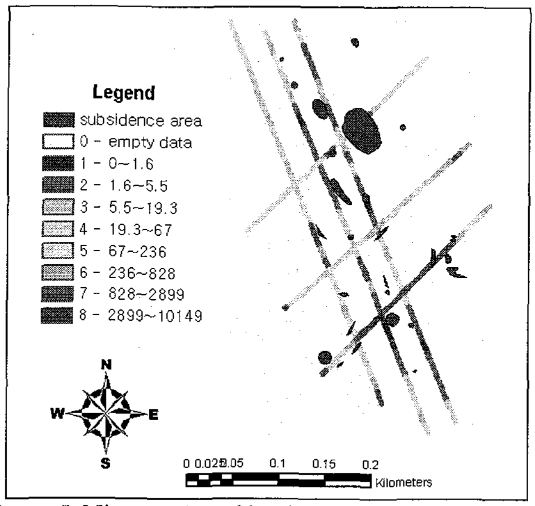

Figure 5. Nine grades of low and high anomaly zones

5.2 Correlation Analysis

To calculate the frequency ratio, we computed the count and percentage of the nine-graded electrical resistivity anomaly zones to the total domain and also computed the count and percentage of the nine graded subsidence areas. After that we divided the subsidence percentage to domain percentage for calculating the frequency ratio value. Table 2 shows the frequency ratio..

Table2. Frequency ratio of each range of electrical resistivity result

VALUE	domain count	dom%	subsidence count	sub%	FR
0	118125	90.14	2462.000	84.20	0.93
1	411	0.31	14.000	0.48	1.53
2	2602	1.99	253.000	8.65	4.36
3	1651	1.26	76.000	2.60	2.06
4	2394	1.83	36.000	1.23	0.67
5	2906	2.22	23.000	0.79	0.35
6	1243	0.95	3.000	0.10	0.11
7	1625	1.24	30.000	1.03	0.83
8	83	0.06	27.000	0.92	14.58
	131040.000	100.00	2924.000	100.00	

As shown in Table 2, the frequency ratio of empty data was 0.93, the lowest resistivity frequency ratio 1.53 and the highest resistivity frequency ratio 14.58. As we mentioned above, the frequency ratio value is over 1 at value 1, 2, 3, 8, and the low and high anomaly zone is highly correlate with the ground subsidence area.

After reclassifying the frequency ratio according to the values, we overlaid the result to the existing ground subsidence hazard map.

6. CONCLUSION

In this study we focused on the method of quantitative analysis of the electrical resistivity and on how we could use the results in spatial analysis using GIS.

We overlapped the cross section images to the survey line and we drew the anomaly line along the survey line manually. Next step, we will study using the raw data of geophysical survey so it can be easily used in GIS.

As a result both the high and low anomaly zones closely correlate with ground subsidence areas near AUCM. One grade of high anomaly zone and three grades of low anomaly zones showed higher frequency ratio. The domain count of the low anomaly is larger than the domain count of the high anomaly so 3 grades of the low anomaly have high frequency ratio. We expect that electrical resistivity can be added to ground subsidence hazard map as an additional factor.

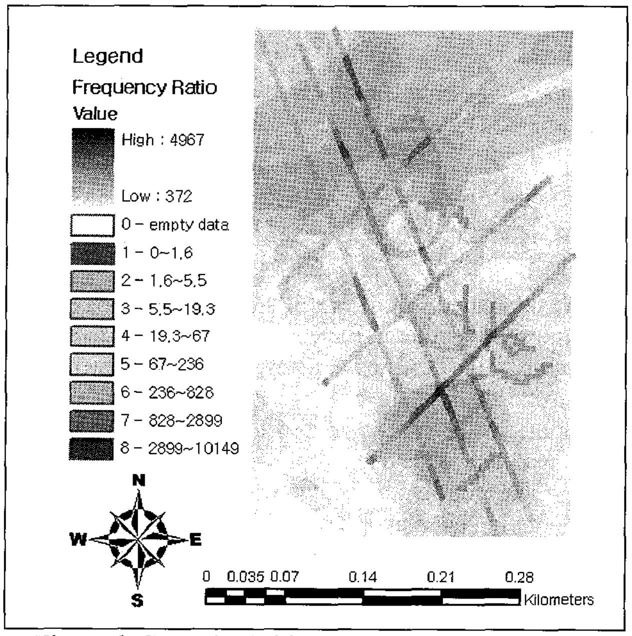

Figure 6. Ground subsidence map with the electrical resistivity result

7. ACKNOWLEDGEMENT

The Korea Mine Reclamation Corp. provided the investigation reports and basic GIS database.

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