Investigation of fresh and salt water distribution by resistivity method in Yellow River Delta

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Introduction:

Purposes of Yellow River Delta group are 1) to evaluate groundwater and river water discharges and their dissolved material transports into the Bo-Hai Sea, 2) to evaluate the effect of recent Yellow River cut-off due to changes in land utilization and water management on groundwater and Bo-Hai Sea, and 3) to evaluate the interactions between Yellow River, groundwater and Bo-Hai Sea in the delta. Therefore, we have to know the condition of present groundwater in the delta for our goal.

Yellow River Delta is expanding at a speed of about 500m/y by sedimentation (Yu 2002). However, speed of groundwater flow is very slow in general. Therefore, it is assumed that there is a possibility which paleo-seawater remains under the delta. Moreover, it is also assumed that saltwater intrusion into the subsurface under the delta occurs, because Yellow River basin has some problems concern water environment such as the cut-off of river water and over-pumping of groundwater. Therefore, purpose of this study is to clarify of fresh and salt water distribution under the land.

Methods

Study methods are resistivity measurement and conductivity measurement of groundwater. Resistivity method is the technique for understanding of subsurface construction by applying the electric current to the subsurface. Resistivity values and conductivity has negative correlation. Therefore, if we clarify the relationship between resistivity and conductivity in this delta, we can estimate the distributions of fresh and salt water in the area where there is no observation well. Additionally, measurements of stable isotope and carbon 14 dating of groundwater were done for the clarifying the origin.

Results and discussion:

Fig.1 shows groundwater levels in the Yellow River Delta. In this figure, it is seen that the flow to the Bo-hai sea from the Yellow River. Fig.2 shows spatial distributions of electric conductivity in the Yellow River Delta. We can see high concentrations of groundwater conductivity at the central part and the coastal zone of the Yellow River Delta. And related to the fig.2, fig.3 indicates the relationship between conductivity and depth of groundwater in the Yellow River Delta. There are few wells at the deeper part, and it is difficult to take the groundwater samples to measure the conductivity (in fact, there is a few wells at deeper part than 200m depth).

We apply the resistivity method to assume the conductivity of groundwater in the Yellow River Delta, because it is difficult to take the groundwater samples at deeper part. Fig.4 shows all results of resistivity measurement. In these figures, darker color indicates high resistivity values, and lighter color indicates low resistivity values. And, width and height of figure are 150m and 100m. Comparisons of resistivity and conductivity have been done to confirm whether it has negative correlation in the delta also. Comparison was done by datasets of the point where both measurements were done. For example, if groundwater was corrected from 5 to 20m depths, resistivity datasets at the same depth were used for the comparison. Fig.4 is the result of comparison. Resistivity and conductivity have the negative correlation clearly. Therefore, it is thought that low resistivity indicates high conductivity and saltier water, and high resistivity indicates low conductivity and fresher water.

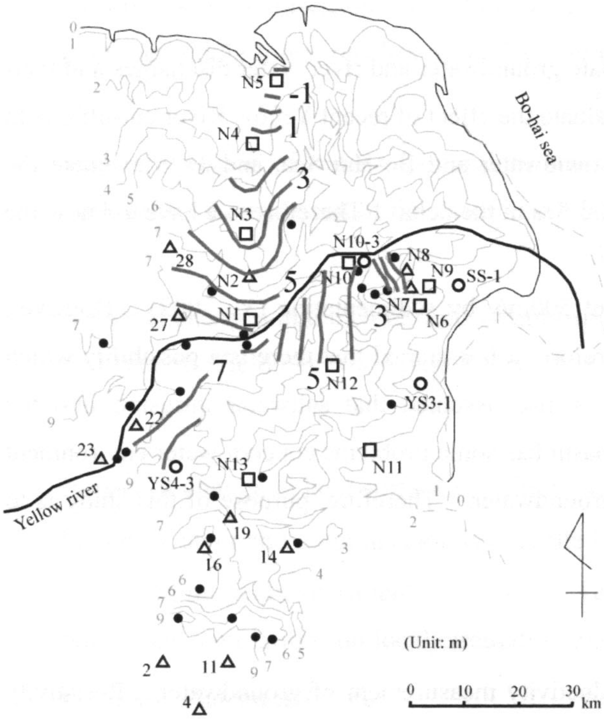

Fig.1 Spatial distributions of groundwater table

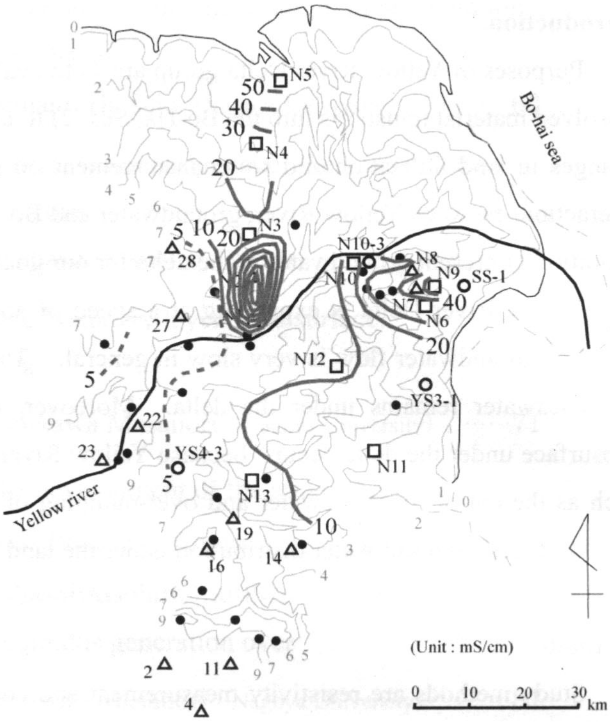

Fig.2 Spatial distributions of groundwater conductivity

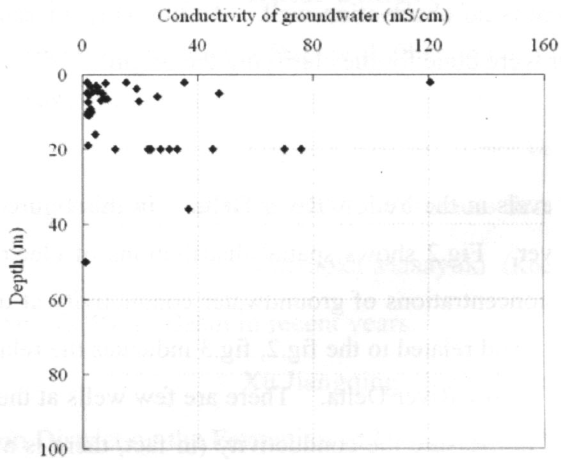

Fig.3 Conductivity of groundwater vs depth

Fig.4 indicates results of resistivity measurement. It shows several patterns of resistivity distributions under the ground. We can separate it to three patterns, first one is low resistivity regions at shallower part and high regions at deeper part (N1, YS3-2, YS4-1 and etc), second one is high regions at shallower part and low regions at deeper part (N3, N4, YS4-2, YS4-3 and etc), and last one is little change of resistivity values in the result (N4, YS3-1 and etc).

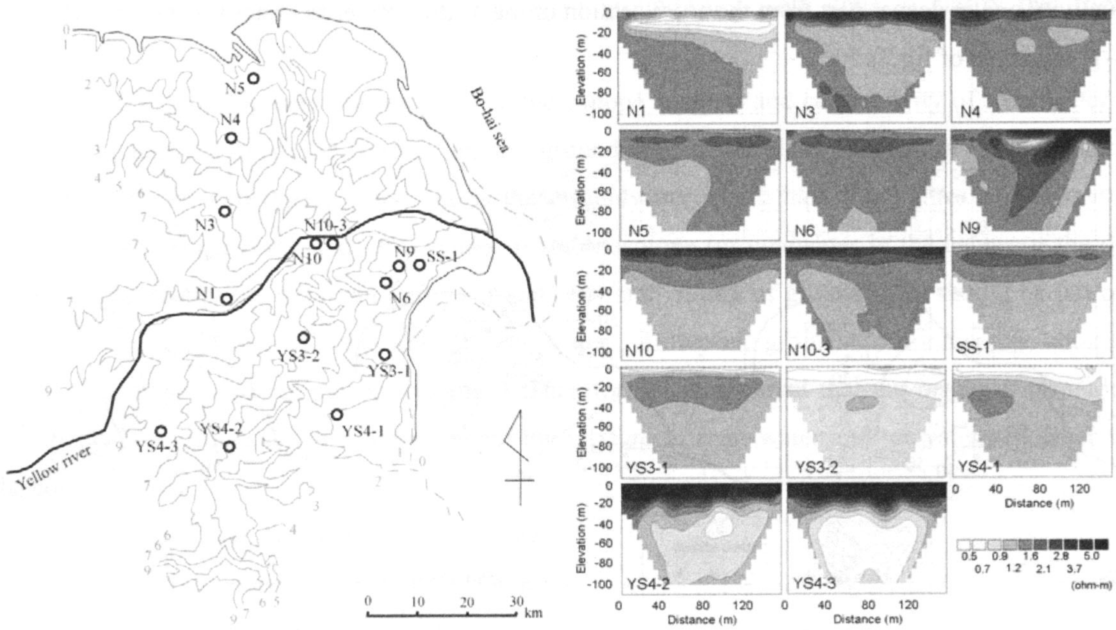

Fig.4 Results of resistivity measurement in the Yellow River delta

Fig.5 indicates conductivity of groundwater and resistivity under the ground. According to fig.5, we can see the negative correlation between conductivity and resistivity clearly. Below expression was from fig.5.

$$Cg = 44.469\ \rho^{-1.1636} \qquad (1)$$

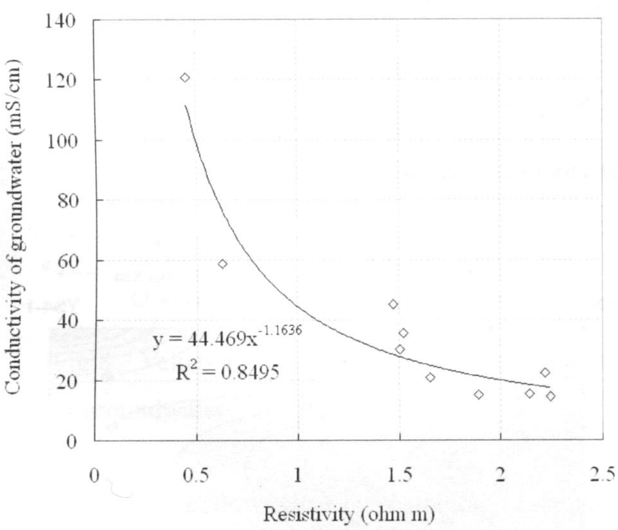

Fig.5 Conductivity of groundwater and resistivity under the ground

Therefore, we can assume the conductivity of groundwater at the point where we can not take water samples from the results of resistivity measurement and (1) expression. Spatial distributions of estimated conductivity from resistivity measurement were indicated in fig.6. From the result of 10m depth in fig.6, low conductivity values were seen in southern part (YS4-3 and N13), eastern part (N9) and northern part (N5) of the delta. On the other hand, high conductivity values were seen in center part of the delta (N1 and N12). In fact, we can see low conductivity values at YS4-3 and N13, and high conductivity values at N1 and N12 from fig.2. According to the result of 20m depth in fig.6, low conductivity values were seen at N9, YS4-3 and N13 as the result of 10m depth. It is estimated that there are saltwater widely in deeper part than 30m depth under the ground. Fig.7 shows cross sections of conductivity estimated based on fig.6. From the cross section of the Yellow river to northern part of the delta (N1 to N4, left side of fig.7), it was seen the high conductivity region near the Yellow River, and this region expands to the sea side related to the groundwater flow. On the other hand, there is the lower conductivity groundwater recharged from the Yellow River above the high conductivity one in deeper part from the cross section of the Yellow River to eastern part of the delta (YS4-3 to YS 4-1, right side of fig.7).

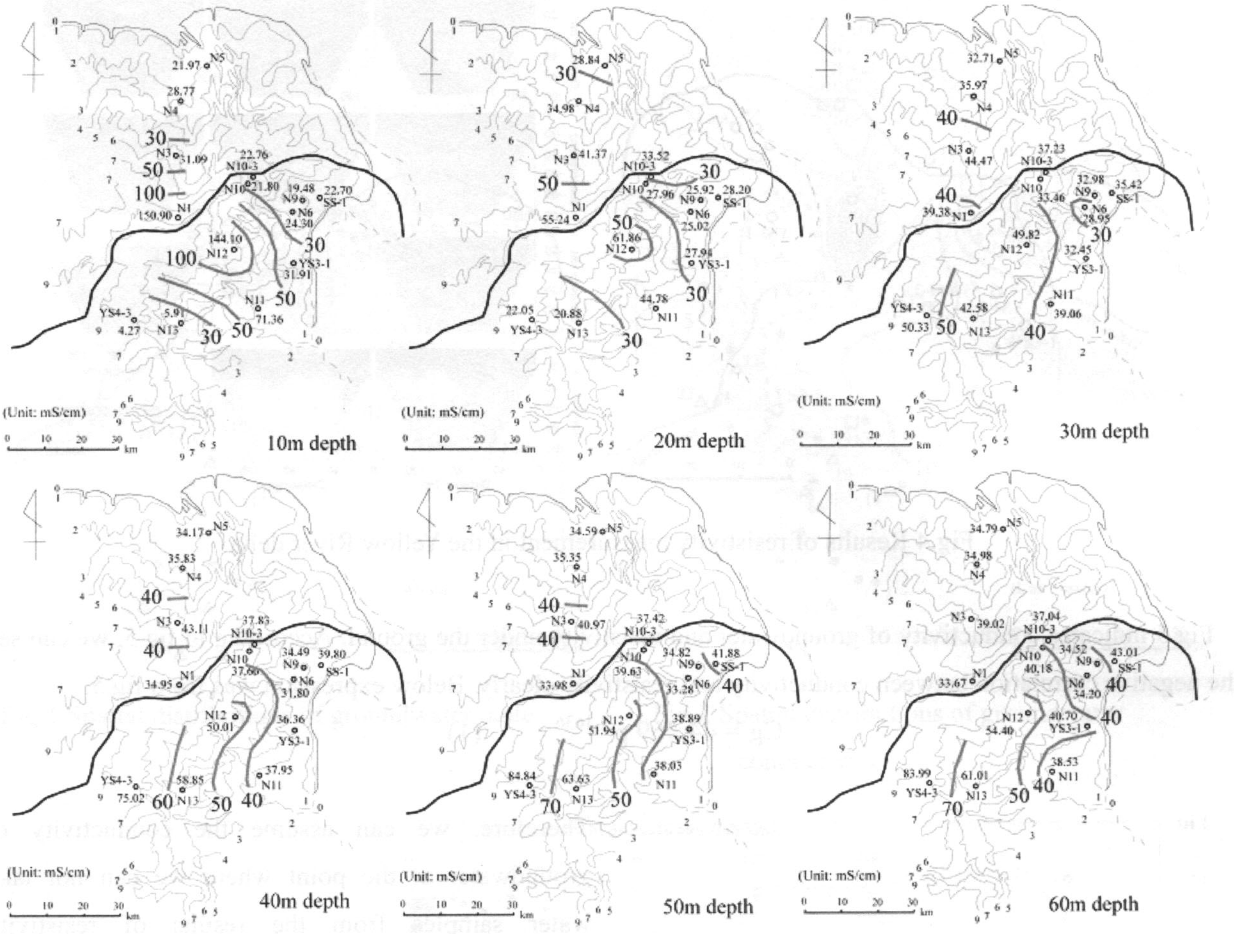

Fig.6 Spatial distributions of groundwater conductivity estimated by resistivity measurements

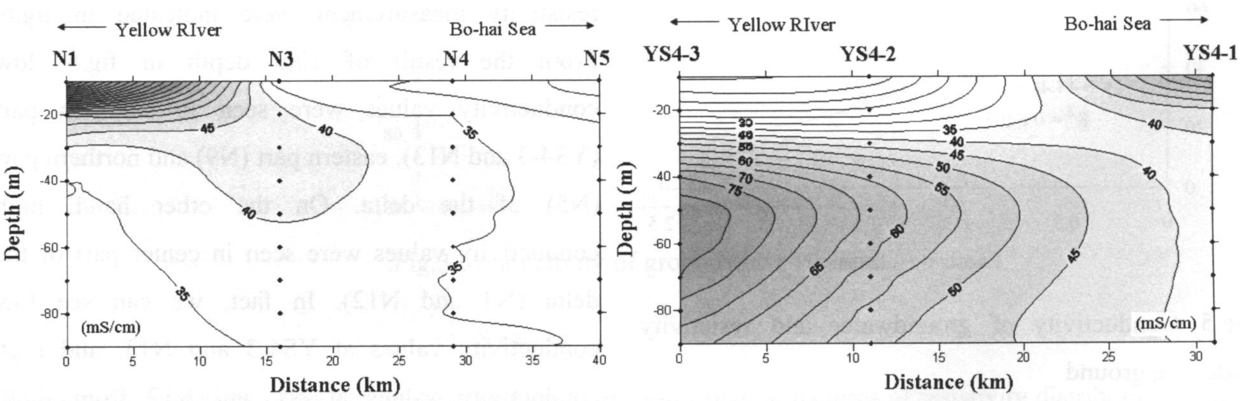

Fig.7 Cross sections of groundwater conductivity estimated by resistivity measurements

(left side – north line (N1 to N5), right side – east line (YS4-3 to YS4-1))

It was clarified that saltwater was distributed in broad area by measurements of conductivity and resistivity. Analysis of stable isotope and carbon 14 age dating of groundwater were done to clarify the origin of groundwater.

Fig.8 shows the relationship between results of stable isotope analysis and conductivity of river water from the Yellow River, seawater from the Bo-hai Sea and groundwater in the delta. Results of groundwater in 5 points could be separate two types. First one is the groundwater which has -6‰ values of stable isotope (groundwater in the coastal zone) and -3‰ values of stable isotope (groundwater in the center of the delta). If saltwater in the delta are the mixture river water and saltwater, values of groundwater should be put on the regression line from the value of river water to sea water. However, groundwater indicating about -3‰ values of stable isotope were not put on this line. Therefore, it is assumed that the origin of groundwater indicating about -3‰ values of stable isotope is not the mixture of river water and seawater and other factor should be consider.

Fig.9 shows results of age dating by carbon 14 age dating. Ages of groundwater are much differ each area. Coastal zone of the delta (N5, N9 and etc) indicate the younger age about 50yrBP. On the other hand, center of the delta (N1, N12 and etc) indicate the older age of 4000yrBP to 12000yrBP. In addition to, southern part of the delta indicate the middle age about 1000yrBP.

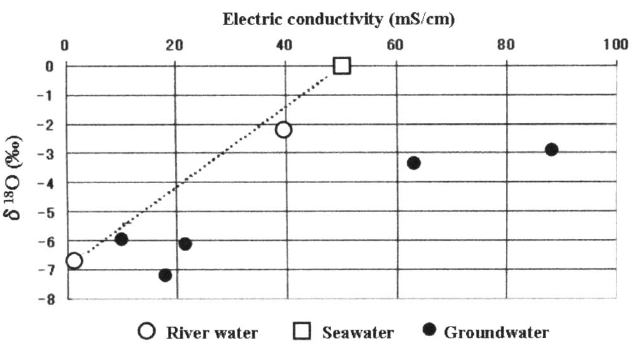

Fig.8 Values of stable isotope and conductivity of groundwater

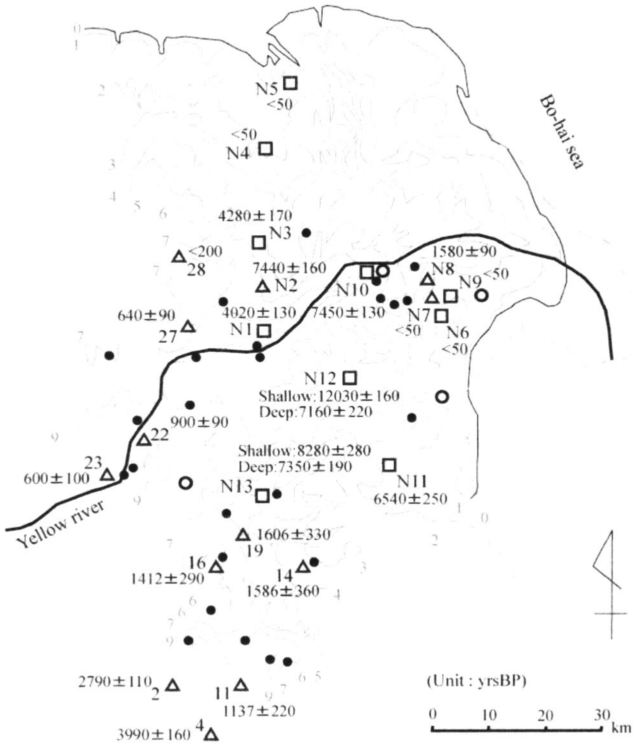

Fig.9 Results of carbon 14 age dating of the groundwater

The delta of Yellow River is expanding by the sedimentation since 1855 (fig.10). Therefore, it is assumed that there is the groundwater which has younger age and high conductivity made by caught seawater in the ground by the rapid sedimentation in the coastal zone (N5, N9 and etc).

About groundwater which has older age and high conductivity in the center of delta (N1, N12 and etc), it is assumed that groundwater made by concentration the density through remaining in this area for long-term and exists in this area. In fact, sedimentation ages are differing around N1-N12 and N5-N9.

On the other hand, groundwater which has about 1000 yrBP values exits in the southern part of delta. According to fig.2 and fig.6, it is assumed that this groundwater came from the western inland because low conductivity groundwater was confirmed in this area (Chen *et al.*, 2007).

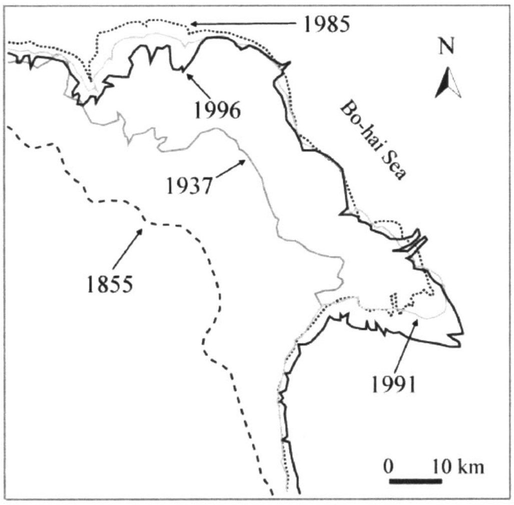

Fig.10 Change of the coastal line in the delta

From the mentioned, conditions of groundwater in the delta can be separated three types. First one is the groundwater which has younger age and high conductivity in the coastal zone, second one is the groundwater which has older age and high conductivity, and last one is the groundwater which has middle age and low conductivity.

Conclusion

1) Negative correlation between conductivity of groundwater and resistivity under the land in Yellow River Delta was confirmed by comparison of conductivity and resistivity.

2) Existence of paleo-seawater was clarified by resistivity measurements in every point.

3) Distributions of fresh and salt water were assumed by resistivity measurements.

4) Conditions of groundwater in the delta were separated three types.

References

Chen J., Taniguchi M., Liu G., Miyaoka K., Onodera S., Tokunaga T. and Fukushima Y. (2007): Nitrate pollution of groundwater in the Yellow River delta, China. *Hydrogeology Journal*, doi 10.1007/s10040-007-0196-7.

Yu L. (2002): The Huanghe (Yellow) River: a review of its development, characteristics, and future management issues, *Continental Shelf Research*, 22, 389-403.