FRACTAL ANALYSIS OF TIDAL CHANNEL USING HIGH RESOLUTION SATELLITE IMAGES

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ABSTRACT

Tidal channel development is influenced by sediment type, grain size, composition and tidal current. Tidal channels are usually characterized by channel development, density and shape. Quantitative analysis of tidal channels using remotely sensed data have rarely been studied. The objective of this study is to quantify tidal channels in terms of fractal dimension and compare different inter-tidal channel patterns. For the fractal analysis, we used Box counting method which had been successfully applied to streams, coastlines and others linear features. For a study, the southern part of Ganghwado tidal flats was selected where is famous for high dynamics of tidal currents and vast tidal flats. This area has different widths and lengths of tidal channels. IKONOS and Komsat-2 MSC images were used for extracting tidal channels, and the Box counting method was applied to obtain fractal dimensions (*D*) for each tidal channel.

Yeochari area possesses channels with linear pattern and less dense development and accordingly show low *D* values ranging from 1.037 to 1.038. On other hands, area (near Donggumdo and Yeongjongdo) of dendrites channel pattern and dense development resulted in high *D* values from 1.2057 to 1.2667. Also, area possesses channels with linear pattern had low density about 18~24%. Area of dendritic channel pattern had high density about 34~69%. The difference of fractal dimensions about 0.2 according to channel development in tidal flats is relatively large enough to use as an index for tidal channel classification. Also, area where channels showed linear pattern had low density about 18~24%. Area of dendritic channel pattern had high density about 34~69%. Using fractal dimension and density, it would be possible to quantify the tidal channel development in association with surface characteristics.

KEY WORDS: Fractal, Box counting, Ganghwado

1. INTRODUCTION

The tidal currents in tidal flat move along a horizontal direction not depending on the waterway of the land. For this reason, complex tidal channel and tributaries are developed (Ryu *et al*, 2004). It is well known that the relationship between a tidal flat environment and tidal channel development, which is influenced by sedimentation type, grain size, composition and currents energy, is very close. But, there had been no study which tried to quantitative analysis in tidal channel.

Many researchers have applied methods based on fractal geometry to study coastlines or frontiers between countries (Mandelbrot, 1967, 1983; Xiaohua et al, 2004). Furthermore, other authors have classified both drainage networks and single channels (Turcotte, 1989; Jelmer, 2004).

Box counting and contiguity method were used to estimate fractal dimensions of nine channels in the Bahia Blanca estuary in Argentina (Angeles, G. R. *et al*, 2004). As a result, D values of all channels were close to 1 that shows self-affinity which is the one of characteristics of fractal features. But these fractal dimensions could not represent the meandering pattern of tidal channels. According to how much the channel meander, it may show the complexity of the tidal channels. . Horton's hierarchical analysis and fractal analysis were used to depict six tidal channel systems in the Dutch Wadden Sea. From the investigation it was known that tested tidal channels have similar branching patterns each other (Jelmer C. and Albert P. O., 1999). It also neglects meandering feature of tidal channel. The main aim of this paper is to quantify tidal channels in terms of fractal dimension and compare different inter-tidal channel patterns using the high resolution satellite images.

2. STUDY AREA AND DATA

The west sea in Korea is wide difference the tidal range. Therefore, the tidal flat is wide. Ganghwado tidal flat locating in the mid-western part of Korean Peninsula is an open type and one of the biggest flats on the west coast of Korea (105km^2). Substantial amount of sediments input from the Han River. There are two prominent tidal channels (Yeomha channel located in eastern Ganghwado: 300-1500 m wide, Sukmo channel located in western Ganghwado: 1200-3800 m wide). The study area (Ganghwado south flat) is influenced by a tributary and a main stream to the Han river. Therefore around the study area makes up variety environments (Woo and Je, 2002).

Fig. 1 shows KONOS image of the southern part of the Ganghwa-Do. Four sub-regions were selected in the study areas. Site1 and 2 are located in front of Yeochari and tidal channels shows simple pattern. Site3 and 4 are located near Donggumdo and Yeonjongdo respectively and tidal channels represent complex meandering pattern.

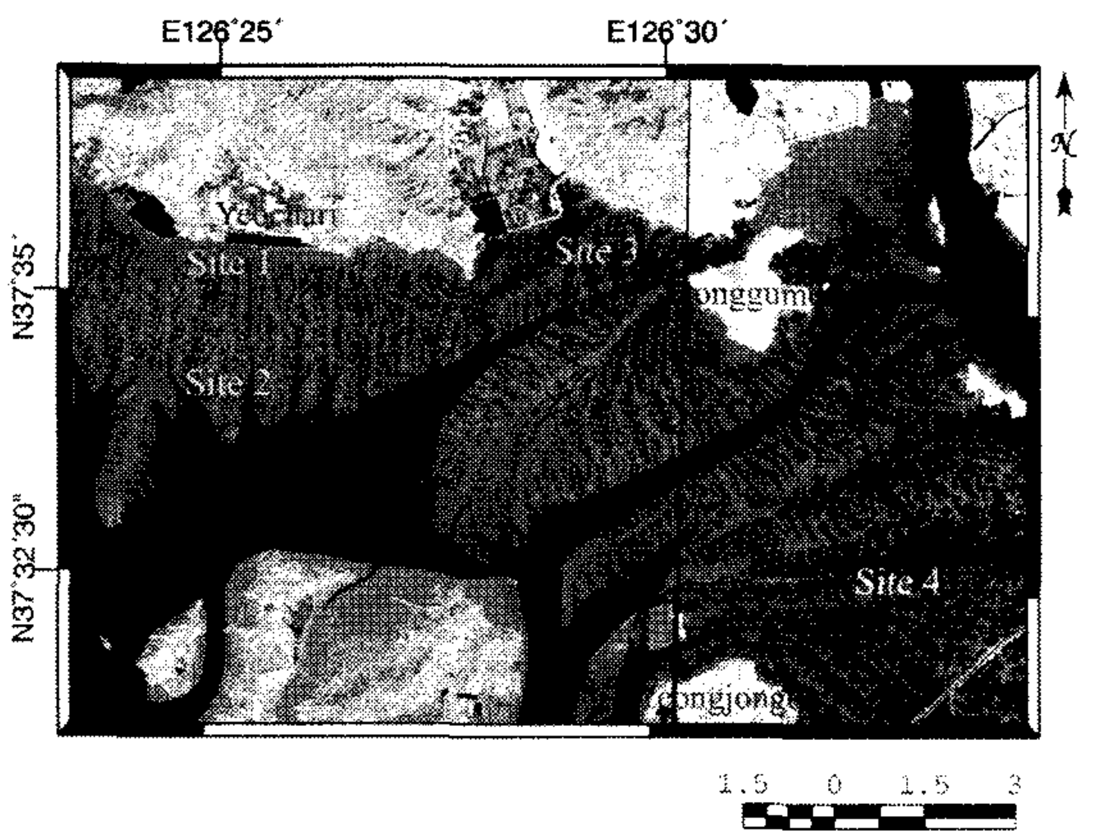

Figure 1. IKONOS image of the southern part of the Ganghwa-Do. Intertidal channels are delineated by blue lines and the red squares denote sub-areas for fractal dimension estimation and comparison.

To extract tidal channel in the tidal flat, we used IKONOS and KOMPSAT-2 image. The IKONOS-2 satellite was launched in September 1999 and has been delivering commercial data since early 2000. IKONOS data records 4 channels of multispectral data at 4 meter resolution and one panchromatic channel with 1 meter resolution. , KOMPSAT-2 which has 1m resolution in panchromatic band and 4m resolution in RGB band was launched in July 2006. Table 1 summarized characteristics of IKONOS (Jensen, 2005) and KOMPSAT-2 satellites (Lee *et al.*, 2001).

IKONOS data acquired on 28 March 2001 and KOMSAT-2 data acquired on 16 February 2007 were analyzed.

3. METHOD

Fractals are a means of describing complicated, irregular features of variation. Fractal geometry was introduced and popularized by Mandelbrot (1977, 1983) to describe highly complex forms that are characteristic of natural phenomena such as coastlines and landscapes.

Table 1. Characteristic of IKONOS and KOMPSAT-2

IKONOS		
Band	Spectral Resolution(μm)	Spatial Resolution(m)
1	0.45-0.52	4
2	0.52-0.60	4
3	0.63-0.69	4
4	0.76-0.90	4
Pan	0.45-0.90	1
KOMPSAT-2		
Band	Spectral Resolution(μm)	Spatial Resolution(m)
1	0.45-0.52	4
2	0.52-0.60	4
3	0.63-0.69	4
4	0.76-0.90	4
Pan	0.50-0.90	1

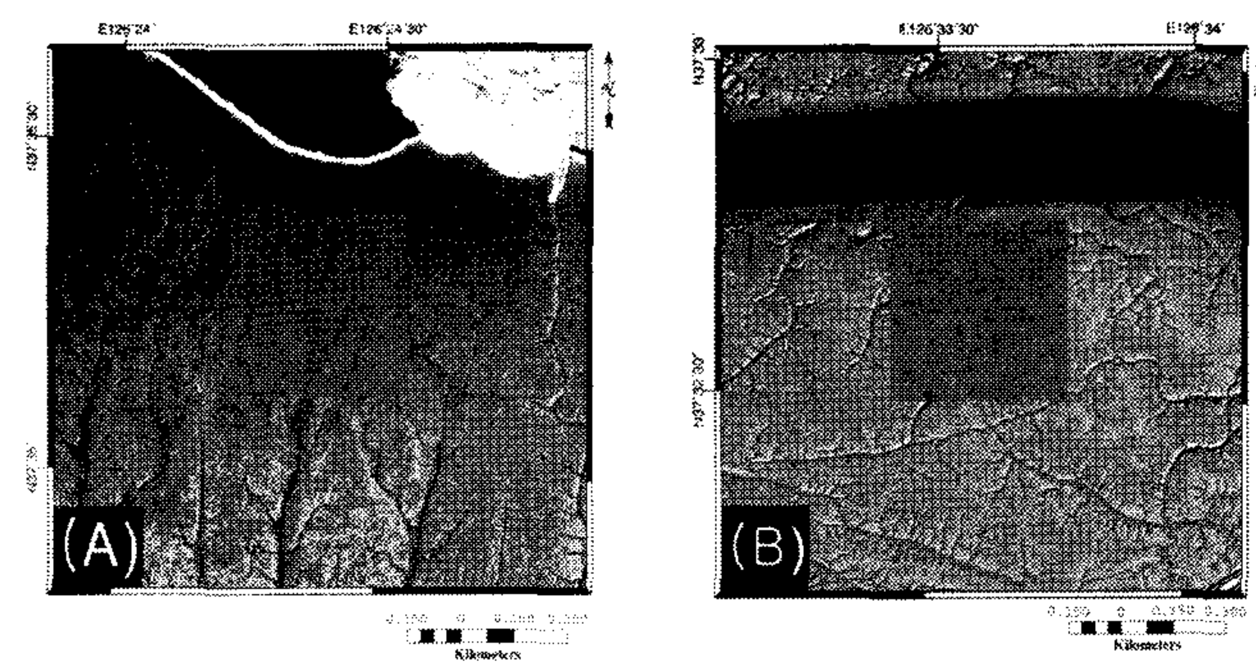

Figure 2. IKONOS image of two sites: (a) Linear pattern and less dense channel development in the southern Yeochari(site 1), and (b) dendritic pattern and dense channel development in the Northern Yeongjongdo(site 4).

Self-similarity and Self-affinity is property of fractals. Self-similarity is the statistically identical at any scale. But self-affinity changes when the scale varies whereas its fractal dimension does not change. A fractal referred to as self-similarity.

Box counting method, popular method of fractal analysis, was used in this study. It has been successfully applied in several studies about streams, coastlines, and others linear features (Trucotte, 1992). A series of grids which has uniform side length (S) is created. Each grid is independently superimposed on the channels which were extracted from satellite images. The number of boxes (N) with certain size that contain a line section defining the channel is recorded. The value of fractal dimension (D) is described as

$$D = \lim_{s \to \infty} \frac{\log N(S)}{\log(S)} \qquad (1)$$

Figure 2. IKONOS image of two sites of different intertidal channel patterns: (a) Linear pattern and less dense channel development in the southern Yeochari, and (b) dendritic pattern and dense channel development in the Northern Yeongjongdo.

In this study, we chose four sub-regions which can be divided two tidal flat having different features (Fig. 2).

4. RESULTS & DISCUSSION

Sub-regions with 300m by 300m and 500m by 500m size were used to analyze to show the characteristics of a different tidal channel patterns. In particular we calculates fractal dimension according to box size. Table 2 and 3 shows that fractal dimensions according to box size. *D1* has box size from 1m to 64m, *D2* has box size which is a multiple of 5m. D3 has box size which is divisor of study area. According to box size, fractal dimension is changed. Because if box size differs, number of box including tidal channel changes. In other words, if box size is small, it calculates detailing tidal channel. On the other hand, if box size is big, it calculate whole tidal channel. Site 1 and 2 areas possess channels with linear pattern and less dense development and accordingly show low D values near 1.0. In opposition to simple channel, site 3 and 4 areas with dendritic channel pattern and dense development show high D values near 1.3(Table 2 and 3). The fractal dimension had difference about 0.2 values according to the characteristic of tidal channel development.

Table 2. The fractal dimensions of the site 1 ~ 4 which were used channel extracted from IKONOS image. D1 has box size from 1m to 64m, D2 has box size which is a multiple of 5m. D3 has box size which is divisor of study area.

	Site1		Site2	
area / D	300 x 300	500 x 500	300 x 300	500 x 500
D1	1.0495	1.0525	1.0546	1.0385
D2	1.0389	1.0472	1.0494	1.0400
D3	1.0194	1.0123	1.0288	1.0190

	Site3		Site4	
area / D	300 x 300	500 x 500	300 x 300	500 x 500
D1	1.2683	1.2667	1.2365	1.2203
D2	1.2057	1.2107	1.1723	1.1476
D3	1.1612	1.1646	1.1510	1.1401

Table 3. The fractal dimensions of the site 1 ~ 4 which were used channel extracted from KOMSAT-2 image.

	Site1		Site2	
area / D	300 x 300	500 x 500	300 x 300	500 x 500
D1	1.0363	1.0154	1.0518	1.0615
D2	1.0205	1.0101	1.0488	1.0400
D3	1.0156	1.0051	1.0630	1.0381

	Site3		Site4	
area / D	300 x 300	500 x 500	300 x 300	500 x 500
D1	1.3648	1.4019	1.3401	1.2879
D2	1.2790	1.3234	1.2501	1.1956
D3	1.2514	1.2644	1.2073	1.1755

Table 4. The total length and density of channel in site 1 ~ 4 extracted in IKONOS image.

	Site1		Site2	
Area	300 x 300	500 x 500	300 x 300	500 x 500
Total length(m)	1999.44	4617.47	2165.60	4898.23
Density (%)	22	18	24	20

	Site3		Site4	
Area	300 x 300	500 x 500	300 x 300	500 x 500
Total length (m)	3086.16	12764.30	6216.47	11750.10
Density (%)	34	51	69	47

Fig. 3 shows box counting graphs and the fractal dimension for tidal channel extracted from IKONOS. The fractal dimension obtained from site 1 is close to the Euclidean value (D=1). On the other hand, the fractal dimension obtained from site 4 has high value about 1.2~1.3. It is known that high drainage density have a high fractal dimension revealing a nonlinear and chaotic oration, whereas a low D (Angeles *et al.*, 2004). So the result could be explained that complex channel area has higher dimension value than simple channel area. Like result of IKONOS image, site 4 has a higher value than site 1 at the channel extracted from KOMSAT-2 (Fig. 4).

Table 4 shows that area possesses channels with linear pattern had low density about 18~24%, whereas area of dendritic channel pattern had high density about 34~69%.

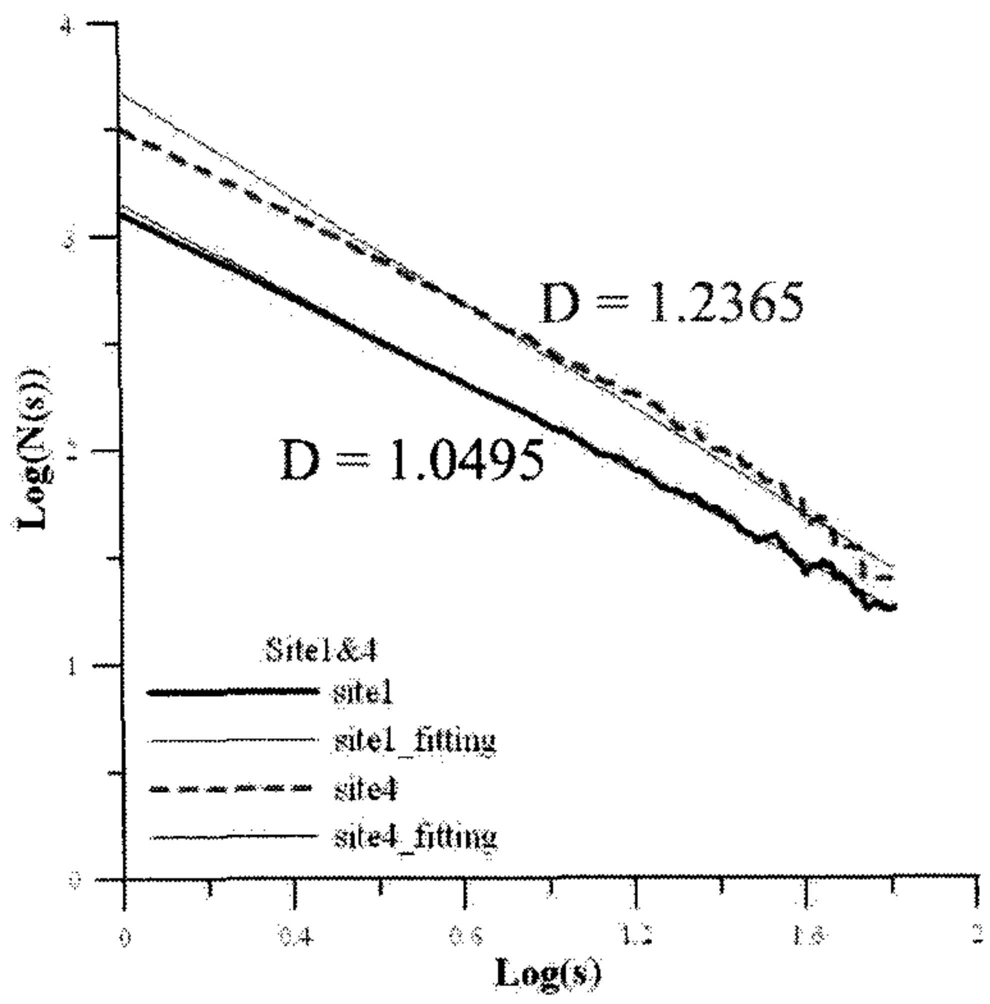

Figure 3. Box counting graphs and the fractal dimension. Comparison of fractal dimensions of site 1(blue line) and site 4(red dotted line) according to intertidal channel density and development (IKONOS image). From 1 to 64 box size were used to analyze. Site 4 has a higher fractal dimension value than site 1.

5. CONCLUSION

In fractal geometry, the fractal dimension of a curve can be any value between 1 and 2. In general, coastlines have fractal dimension values around 1.1~1.4(Zhu Xiaohua *et al*, 2004).

As a result IKONOS image resembles KOMSAT-2 image. Area where channels showed linear pattern and less dense development had low *D* values near 1.0. Area of dendritic channel pattern and dense development resulted in high *D* values near 1.2~1.3. The difference about 0.2 in fractal dimensions of tidal channel is regarded relatively large value to use as an index for tidal channel classification. Area possesses channels with linear pattern had low density about 18~24%. Area of dendritic channel pattern had high density about 34~69%.

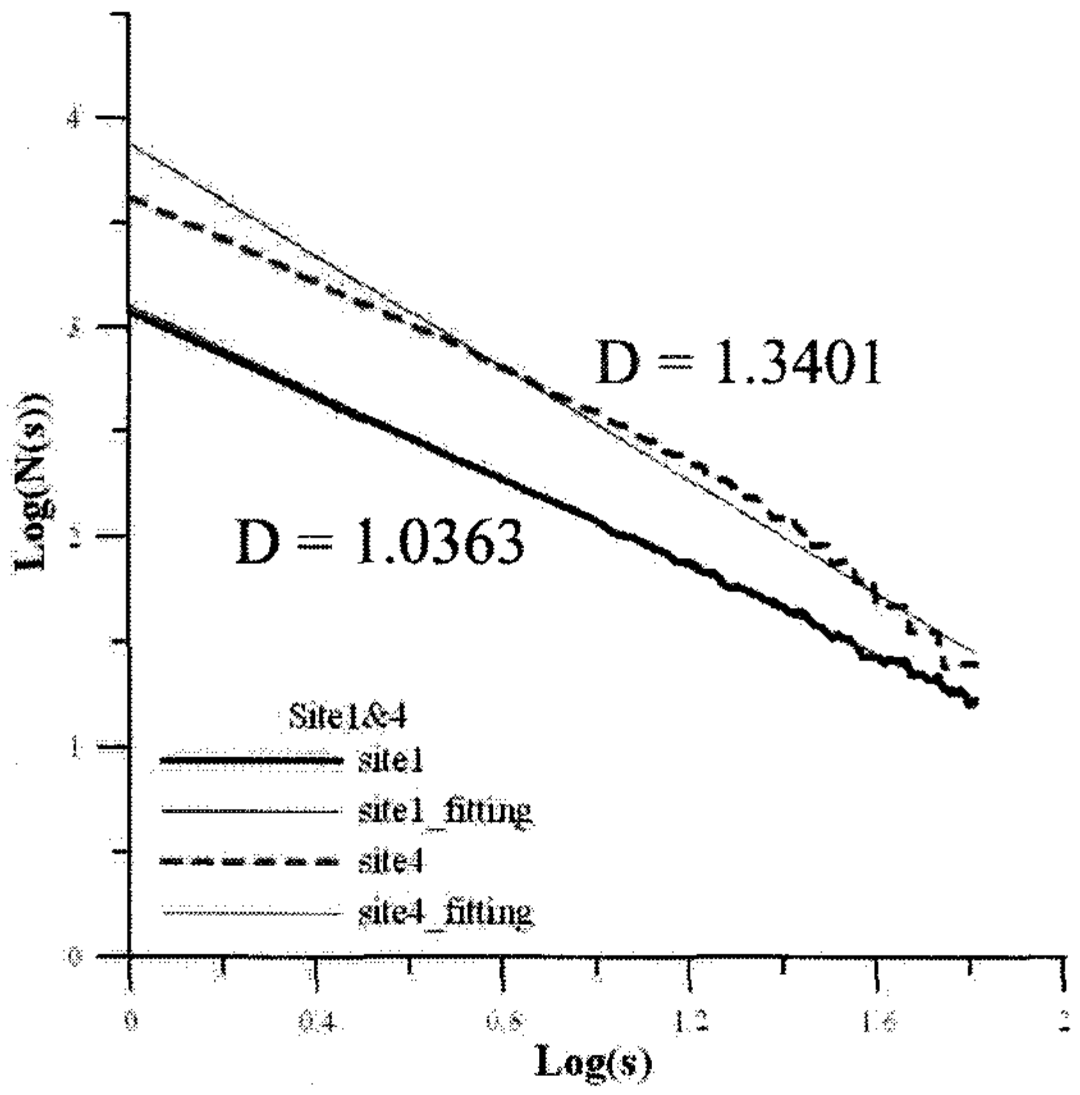

Figure 4. Result of fractal analysis of tidal channel in the KOMSAT-2 image. Study areas are 300m by 300m. From 1 to 64 box size were used to analyze. Site 4 has a higher fractal dimension value than site 1. The result of KOMSAT-2 image resembles the result of IKONOS image.

Therefore we could conclude that fractal dimension and density in tidal channel has high correlation. Using fractal dimension and density, it would be possible to quantify the tidal channel development in association with surface characteristics.

6. REFERENCES

Angeles, G. R., Perillo, G. M. E., Piccolo, M. C., Pierini, J. O., 2004, Fractal analysis of tidal channels in the Bahia Blanca Estuary (Argentina), Geomorphology, Vol.57, pp. 263~274.

Jelmer, C., Albert, P. Q., 1999, The fractal geometry of tidal-chaanel systems in the Dutch Wadden Sea, Geologie en Mijibouw, 78, pp.21~30.

John R. Jensen, 2005, Third edition, Introductory Digital Image Processing, sigmapress, pp. 96-100.

Lee, S. R., Kim, H. J., Lee, J. J., and Kim, Z. C., 2001, System design of the KOMSAT-2, 6th Asia-Pacific conference on multilateral cooperation in space technology and applications(APS-MCSTA).

Kwon. S. J., 2006, Development of demarcation criteria to determine the geo-engineering structural domain based on fractal dimension, Yonsei University.

Mandelbrot, B. B., 1967, How long is the coast of Britain? Statistical self-similarity and fractional dimenstion, Science, 156, pp.636~638.

Mandelbrot, B. B., 1977, Fractals: Form, Chance and Dimension, San Francisco, Freeman.

Mandelbrot, B. B., 1983, The fractal geometry of nature, Freeman, New York.

Iqnacio, R. I., Rinaldo, A., 1997, Fractal River basins: Chance and Self-Organization. Cambridge Univ. Press, Cambridge, pp 547.

Okubo, P. G., Aki, K., 1987, Fractal Geometry in the San Andreas Fault System, J.Geophys, Res.92, pp.345~355.

Rodriguez-Iturbe, I., Rinaldo, A., 1997, Fractal River Basins: Chance and Self-Organization, Cambridge Univ. ress, Cambridge, pp.547.

Ryu. J. Y., Woo. H. J, Ryu. H. R., Ahn. Y. H., 2004, Analysis of relationship between Kanghwa tidal flat channel and sedimentary facies using EOC, Geographic information system association of Korea, pp. 475-479.

Turcotte, D. L., 1989, Fractals in geology and geophysics. Pure and Applied Geophysics, 131, pp.171~196.

Turcotte, D. L., 1992, Fractals and Chaos in Geology and Geophysics. Cambridge Univ. Press, Cambridge. pp.2-193.

Woo, H. J., Je. J. G., 2002, Changes of sedimentary environments in the Southern Tidal Flat of Kanghwa Island , Ocean and Polar Research, 24, pp. 331-343.

Xiaohua Z., Yunlong C., Xiuchun Y., 2004, On Fractal Dimension of China's Coastlines, Mathematical Geology, Vol.36, pp.447~461.