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International Symposium on Earth Science and Technology 2021

Greetings from Cooperative International Network for Earth Science and Technology (CINEST)

We are facing with global environmental problems with problems on resources depletion at behind. In particular, the rapid increases in mineral resources and energy consumptions have cast a shadow over the sustainability of human activities. The CINEST was founded in 2008 to enhance cooperative studies and activities by young researchers and engineers, because their boldly tackles must be keys and absolute foundation to solve problems found on the earth, especially in Asia and Africa. I would like to emphasize to young researchers that performing research “by hand” rather than “by manual” may develop their potential to find new solutions.

This international symposium started from 2008 cooperating with The JSPS International Training Program during 2008 to 2012, supported by Mitsui-Matsushima Co., Ltd. from 2013 to 2020, and supported by Leading an Enhanced Notable Geothermal Optimization (LENGO) Project of Science and Technology Research Partnership for Sustainable Development (SATREPS) from 2021. The important objective of the symposium is strong networking of young researchers to enhance international collaboration to solve both of global and domestic problems on mineral resource and environment.

Finally, I would like to sincerely thank all of the organizations and participants, and believe the symposium will provide fruitful successes for all.

Welcome to “International Symposium on Earth Science and Engineering 2021”.

Y. Fujimitsu

Yasuhiro Fujimitsu
CINEST Chair

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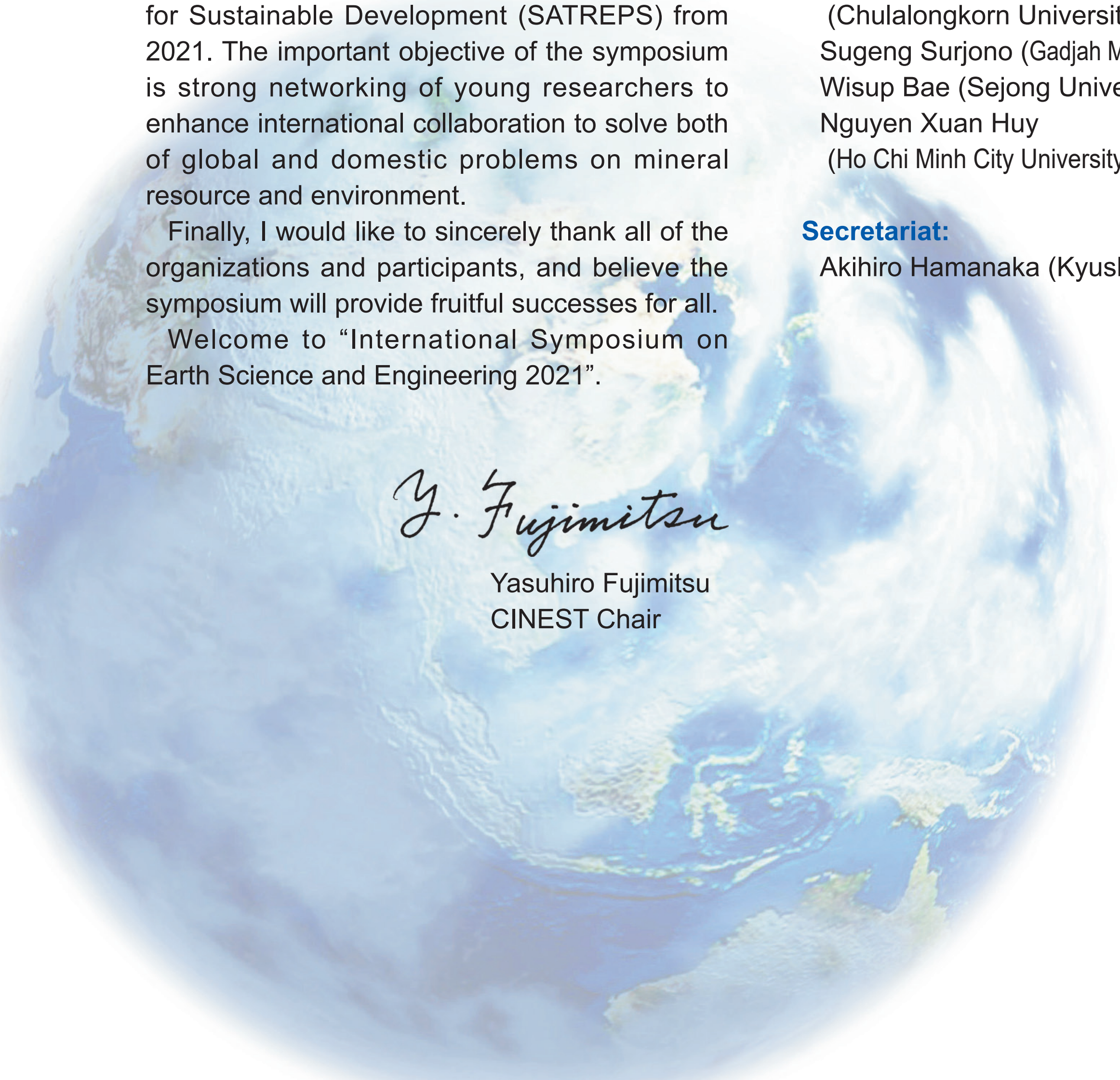

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Nov. 25, 2021

9:00~ 9:10	Opening Session
9:10~ 9:45	Plenary Lecture I: Quantitative Analysis of Nano-porous Microstructures Naoki Shikazono (The University of Tokyo)
9:45~ 10:20	Plenary Lecture II: Basic Geological Survey to Lower Exploration Risk of Rare Geothermal Manifestation Prospectus Area Agung Harijoko (Universitas Gadjah Mada)
10:20~ 10:40	Coffee Break
10:40~ 12:00	Technical Sessions I
12:00~ 13:20	Lunch
13:20~ 15:00	Technical Sessions II JPSRE Special Session
15:00~ 15:20	Coffee Break
15:20~ 17:40	E-Poster Session Advanced Research Network for Biohydrometallurgy of Double Refractory Gold Ore

Nov. 26, 2021

10:20~ 12:00	Technical Sessions III
12:00~ 13:20	Lunch
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15:00~ 15:20	Coffee Break
15:20~ 16:40	Technical Sessions V
16:40~ 17:10	Awards Ceremony* & Closing Session

* Best Papers, Best Presentations and Best Posters will be announced at the Awards Ceremony.

Contents

Pore Fractal Dimensions and Coal Facies Role in the Adsorption of Methane Gas, a Case Study on Coal for the Tanjung Formation, Arang Alus Area, Binuang District, Tapin Regency, South Kalimantan

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ABSTRACT

This research aims to determine the role of coal facies and the value of pore fractal dimensions on changes in the adsorption of coal methane gas. This study location is in the Arang Alus area, Binuang District, Tapin Regency, South Kalimantan Province.

As many as 4 (four) coal seams were observed, namely, seam D (oldest layer), C, B, A (youngest), each seam was sampled using the Channel Sampling method. The method for determining the facies of coal uses maceral, for calculating the value of the pore fractal dimensions using the box counting method, while gas adsorption using the Adsorption Isotherm method is carried out in Lemigas Jakarta, Indonesia.

Based on the analysis of coal facies, seams D and B are included in the Fen facies, seams C and A are included in the Wet Forest Swamp facies. The value of the pore fractal dimensions of seam D and B = 1.91 – 1.92, the value of the pore fractal dimension is 1.895 – 1.896, while the adsorption volume of methane gas in seam D and B coal = 425 – 315 Scf/ton, seam C and A = 214 Scf/ton and 431 Scf/ton.

The changes in coal facies from Fen to Forest Wet Swamp affect the changes in pore fractal dimension values and adsorption of coal methane gas. Coal in the Fen facies has a pore fractal dimension and the adsorption of methane gas is greater than in the Wet Forest Swamp facies. Mineral matter is a contaminant in the Fen facies which can cause reduced adsorption of methane gas.

Keywords: Facies, Fractal Dimension, Adsorption, Fen, and Wet Forest Swamp

INTRODUCTION

According to Mavor and Nelson (1997), that coal is a reservoir of methane gas with heterogeneous pore structures such as irregular size, shape, and distribution of pores, but nevertheless between pores are connected through the medium between pores in the matrix and cleats (coal fracturing), therefore Coal's pore structure can serve as a gas absorber (gas adsorption)and gas storage (gas content). The structure of coal pores is relatively more complex than the pore structure of conventional reservoirs such as in sandstone. The uptake value of coal methane gas both vertically and laterally in the coal seam is variable. Hal is caused by changes in maceral characteristics and the quality of coal such as: rank (reflectant vitrinite & calories), moisture content and mineral matter content. The process of methane gas in coal is the process of attaching gas molecules that are in the liquid phase on the surface of the pore through chemical and physical bonds with the amount of gas adsorption more than 95%. The thing is referred to as *adsorption gas* and the rest is referred to as *free gas.*

According to Zhang et al.(2014), characteristics of coal pore structure such as pore size, pore shape and pore distribution are interconnected. Conditions like this are caused by coal facies, namely changes in the environment of peat swamps and plant types. Therefore changes in coal facies can be to determine the maceral characteristics of coal that serves as a matrix of pores i.e. micropores, mesopores, and macropores.

Zhang et al. (2014) and Liu & Nie (2016), explained that in general the nature of coal pores (shape, distribution, and size of pores)is irregular (complex), so to know the dimensions of coal pores i.e. by means of fractal geometry analysis. Fractal geometry method is a very effective method for determining the character of the surface conditions of irregular coal pores. In general, fractal geometry analysis can be used to determine coal pores in both matrix and *cleats* (coal fracturing) (Cai et al, 2011; Wang, 2017). The use of fractal geometry analysis of coal pores can help determine the gas content and coal methane gas uptake (Liu &Nie, 2016).Thus fractal geometry analysis can be used to determine the nature of coal pores (size, shape, and distribution of pores) so as to help find out the information on the adsorption value of coal methane gas.

SAMPLE AND METHOD

Primary data collected from the field data of four sampling locations representing coal seam A, B, C, and D. The sampling locations can be seen in the following table (Table1.)

Table 1 Location sampling coordinates

Seam Coals	Mether East	Meter North
A	294610	9638026
B	294612	9638039
C	294613	9638040
D	294620	9638085

Coal sample data is taken using the channel sampling method from the top to the bottom of each coal seam. Each coal seam correlated with wells at coordinates 292858,693 meters East and 9638682,718 meters North (Fig.1).

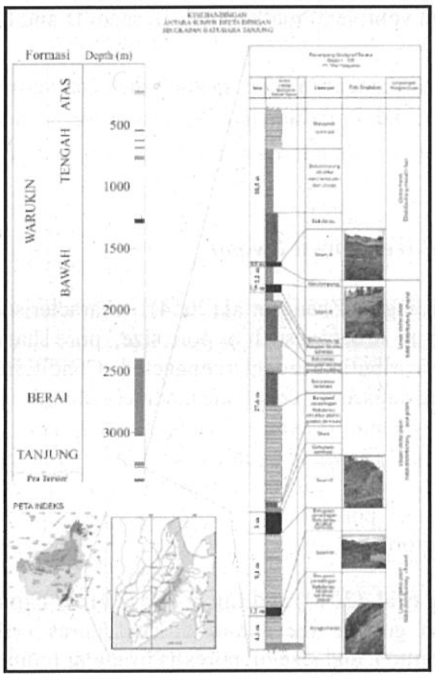

Fig.1 Correlation well log with outcrop along with number sampling

Subsequent samples were conducted laboratory tests to determine coal maceral and vitrinite reflectors using the Craic Coal Microscope.

To determine coal facies using model of diagram Diessel (1989) with Gelification Index (GI) and Tissue Preservation Index (TPI) parameters. Other parameters used to determine coal facies by knowing the value of the Ground Water Index (GWI) and Vegetation Index (VI), these values are then plotted in a diagram made by Calder et al, 1991 modified by Zhao, 2017

The adsorption isotherm test is carried out based on the volumetric method to determine sorption capacity as a function of pressure; the gas used is methane gas (CH_4) purity 99.9%.

The relationship of volume - pressure at a certain temperature (sorption isotherm) can be used to determine the gas storage capacity and estimate the volume of released gas from the sample in line with the decrease in reservoir pressure. In general, the relationship between storage gas capacity and pressure uses the Langmuir equation:

$$Gs = (VLP)/ (PL + P) \qquad (1)$$

Where: Gs = Storage gas capacity, m3 / ton
P = Pressure, KPa
VL = Langmuir Volume Constant, m3 / ton
PL = Langmuir pressure constant, KPa

Fractal dimension calculation is done with the following procedure: there is a stage of processing samples imagery in analysis with SEM, then samples is done scanning with a large enough current sum of 50 μA with voltage source 60 kV, 8 seconds exposure length. Images resulting from the scanning process in the form of digital images. Image of samples in the form of grayscale. The next process is to process images using the **fractal program version of Sugeng, 2020** made by researchers run in *Matlab software*. This process distinguishes between solids and coal pores by converting the image of validity into a binary image, then *thresholding*. This binary image serves to distinguish between black pores and the edges of white grain solids. Each border area of the edge of the black pores is given a value of 0 *pixels* (black) and the edge limit of the solid pores is rated 254 *pixels* (white)**(fig. 2).** Calculation of pore fractal dimensions using *the box counting* method, the usual dimension is denoted by *D* which states the topological dimensions on each fractal object. The number of subunits or subsegments of iterations of a fractal object is denoted by N, while the length of the subsegment is denoted by *r*, the relationship between D, N, and *r* is expressed as follows: N, = (r) with takes logarithms from both segments of the equation, dimensions can be found with equations in Below:

$$D = -\lim_{r\to 0} \log N(r) / \log r \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where log (N_r)is the number of squares that cover pores, log(r)is the size of the length of the pore side of the box.

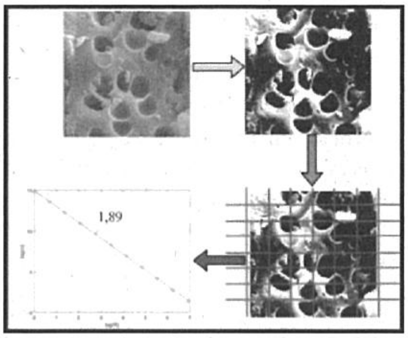

Fig.2 Procedure for Finding Pore Fractal Dimensions (D) from Example: (a). Grayscale Photo from SEM, (b) Binary Image, (c) Image in Close Box, (d) Result of Pore Fractal Dimension

RESULT AND DISCUSSION

Based on the results of calculations of Gelification Index (GI), Tissue Preservation Index (TPI) Groundwater Index (GWI) and Vegetation Index (VI) (Table **2).** Diessel (1986) established a correlation between coal and environmental facies indicators according to the Gelification Index (GI) and Tissue Preservation Index (TPI) for Perm coal in the Sydney basin. TPI represents the effect of the input of wood materials and their preservation before final deposition. Increased TPI values are thought to indicate the dominance of arborescent plants where peat is formed. GI reflects water level or continuity of water availability during peat accumulation. Another common method is used to determine peat formation with Groundwater Index (GWI) and Vegetation Index (VI) (Calder et al, 1991). VI shows a many vitrinite content compared to existing mineral elements. GWI indicates the presence of water in the peat formation process.

Table 2. Results of proximate, maceral, and calculation TPI, GI, GWI, and VI

	Proximate				Maceral									
SC	Ash %,Adb	VM %,Adb	M %,Adb	FC %,Adb	Te %	Des %	TV %	TI %	Tl %	Py %	TPI	GI	GWI	VI
A	2.56	48.75	3.74	44.95	26.6	43.4	70	28.2	0	1.8	2.24	2.93	0.02	0.79
B	14.94	45.26	2.51	37.29	21.5	41.1	62.6	31	0.4	6.0	1.1	2.39	0.10	0.75
C	5.44	43.16	3.7	47.7	46	29	75	23.8	0	1.2	2.36	3.22	0.02	1.72
D	23.16	38.02	2.91	35.91	24.6	42.4	67	27.3	1.7	4	1.11	2.77	0.06	0.81

SC = Sample coal, VM = Volatile matter, M = Moisture, FC = Fix carbon, Te = Telocolinite

Des = Desmocolinit, TV = Total Vitrinite, TI = Total Inertinite, TL = Total Liptinite, Py = Pyrite

TPI = Tissue Preservation Index, GI = Gelification Index, GWI = Ground Water Index, VI = Vegetation Index

Based on the plot of the GWI and VI value diagrams of the modified Calder et al (1991) diagram Zhao et al (2017) the coal fccies in the Tanjung Formation can be grouped into two types of coal facies:

a)Wet Forest Swamp: is a peat formation zone or *mire* controlled by variations in the water surface. These facies are characterized by relatively moisture coal with a slight herbaceous percentage peat filler plant. Wet forest swamp are conditions where peat formation is far from the sea with dominant woody plants, this is evidenced by the analysis of coal petrography of higher maceral telovitrinite composition. Coal in the area of research is included in this facies, namely: in coal seams A and C.

b). Fen:is a peat formation zone or mire controlled by the process of rising and falling water. Plants formed at this stage are herbaceus plants that supply the formation of peat in wet conditions. Arborecent plants very rare at this stage, plant tissues at this stage decompose very strongly. Strong decomposition leads to a reduction in micro-pores. In the facies fen at the time of the flood causes high preservation of organic sulphur which causes high sulfur content. Fen occurs as a transitional stage between herbaceous and forest swamps (Diessel, 1992), as well as the formation of peat in wet conditions, Fen is dominated by herbaceous plants based on maceral consisting mostly of desmocollinite. Coal in the area of research is included in this facies, namely:in the coal seams D and B.

Based on the results of laboratory tests on adsorption isotherm of methane gas in coal seams in the

Tanjung Formation, wet forest swamp volume of adsorption gas methana (samples coal seams A and C) the bigger more than coal in deposits in fen facies conditions (samples coal seams B and D) (Table **3).**

Table 3 Results of methane gas adsorption tests fractal dimensions of pores, and coal facies

Sample	Adsorbed CH4 storage capacity at seam depth Scf/ton as recieve	Pore fractal dimentions D	Coal Facies
Seam A	294	1,896	Wet Forest Swamp
Seam B	315	1,91	Fen
Seam C	431	1,895	Wet Forest Swamp
Seam D	425	1,92	Fen

Condition Wet Forest Swamp has a larger maceral telovitrinite content compared to *detrovitrinite,* the ash content is less than the coal deposited in fen facies. *Wet Forest Swamp* shows the process of peat formation in humid plant conditions so that the process of gelification in plants containing lignin runs well as a result of the opening of plant tissues (Teichmuller, 1989), in addition to the reduced decomposition process causing the formation of mesopores and micropores that regular. The regularity of the pores causes the process of adsorption of methane gas to be greater. The process of destroying cell structure by organisms is easier to walk on shrub plants than in plants containing lignin. Although gelocolinite and corpocolinite are assumed to be derived from lignin and tannins, the more obvious macerals derived from lignin and tannins are telinite and telocolinite (Rahmad B, 2014). Facies Wet Forest Swamp in the research area the percentage of telocolinite, semifusite,and fusinite is quite large (samples coal seams A and C) means the research area at the time of peat formation the position of water is below the surface of the peat so that there will be good decomposition, in addition to the general ash the percentage is small.

Fen deposition environment has a smaller maceral telovitrinite content compared to detrovitrinite, more ash content than wet forest *swamp.* This facies has a large GWI, this shows the process of peat formation of water logged plant conditions as a result of the gelification process in plants containing cellulose running optimally so as to cause the opening of plant tissues. Large GWI also results in process decomposition running fast causing mesopores and micropores to spread irregularly, so that the adsorption of methane gas is reduced.

The regularity and irregularity of the shape of the pores is due to the maceral composition of the vitrinite group in the wet forest swamp and fen differently. Facies Wet Forest Swamp is composed of maceral telovitrinite (33.5 – 46%) and maceral detrovitrinite (28.4 -29%), Fen facies composed of maceral telovitrinite (21.5 - 31.6%) and detrovitrinite (33.6 -42.5%). High detrovitrinite causes the coal will have the dominant primary pores, namely the pores between detritus (maceral granules) (Zhang et al, 2014). Pore detritus resulting from the process of the influence of surface water fluctuations at the time of the watering. Fluctuations in surface water cause maceral fragments to occur, as a result of which the pores between fragments are irregular.

Fractal dimensions of pores are used to describe the characteristics of pore structure (pore distribution and pore shape) (Liu and Nie,2016). The shape of the pores causes a large value of fractal dimensions of pores, regular pores have a relatively smaller pore fractal dimension value compared to irregular pores (Norsiah et al,2017). Regularity of the shape of the pores is influenced by the facies where peat is deposited, Facies Wet Forest Swamp form regular pores because it is dominated by telovitrinite so that it has fractal dimension values Small. Fen facies form irregular pores because they are predominantly maceral detrovitrinite so the fractal dimension value is relatively greater.

The relationship of fractal dimensions (D) with maceral detrovitrinite and telovitrinite in each maceral from research results show that maceral telovitrinite has a downtrend if Fractal dimensions of the pore go down, whereas maceral detrovitrinite indicates an uptrend if fractal dimensions rise at different facies conditions

The regularity of pores affects the adsorption of methane gas, this is reflected in the relationship of fractal dimensions of pores (D) with Langmuir Volume (VL) and Pressure Langmuir (PL). The relationship between the fractal dimensions of the pore with PL and VL in the Wet *Forest Swamp* and *Fen* facies has a positive correlation relationship. The correlation value between PL and the dimensions of fractal pores in wet forest swamp facies is $R^2 = 0.6010$, this relationship is weaker than coal in *fen* facies ($R^2 = 0.7201$).

The relationship between the volume of Langmuir and the dimensions of the fractal pore in the Wet Forest Swamp facies showed a positive correlation with the correlation value (R2 =0.6014), while in the Fen facies the correlation value was more High (R2 = 0.7409), this relationship indicates roughness and surface irregularity of coal in methane gas adsorption (Liu and Nie,2016). Wet Forest Swamp facies roughness and irregularities of pores are relatively smoother and regular compared to fen facies. The regularity of the pore will affect the value of the fractal dimensions of the pore, if the pores are regular it will have a smaller fractal dimension than the pores that are Irregular. Large fractal dimensions of pores will have a large adsorption of methane gas, while the fractal dimension of small pores will have a relatively smaller adsorption of methane. The presence of mineral matter in the Fen facies will cause disturbances in the adsorption of methane gas, the fen facies has large pore fractal dimensions with small gas adsorption due to mineral matter that fills the pores in coal, on the other hand the wet forest swamp facies will have relatively smaller fractal dimensions with The large adsorption is due to the absence of mineral matter that fills the coal pores.

CONCLUSION

Coal facies greatly affect the adsorption of methane gas, wet forest swamp facies are good facilities for gas adsorption

Coal pore structure (size, shape, and distribution) affects the size of the fractal dimensions of the pore, coal with a regular pore structure will cause the fractal dimension of the pore. Smaller than irregular pore structures.

The fractal dimension of the pore correlates with the adsorption of methane gas the greater the fractal dimension of the pore will cause the adsorption of methane gas to rise, vice versa.

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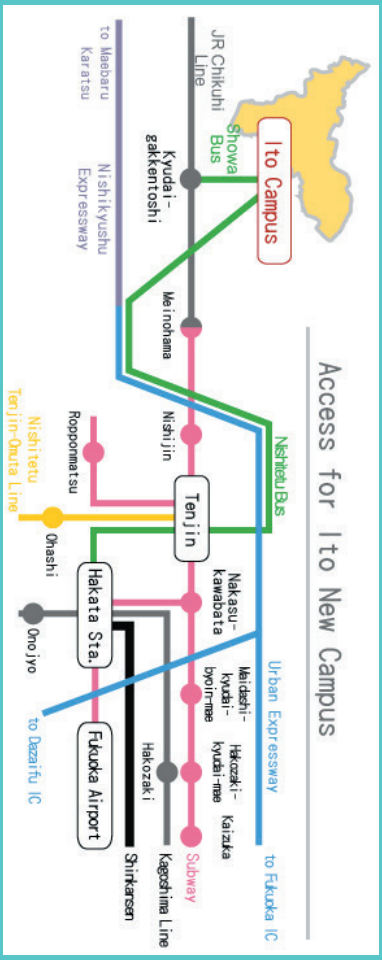

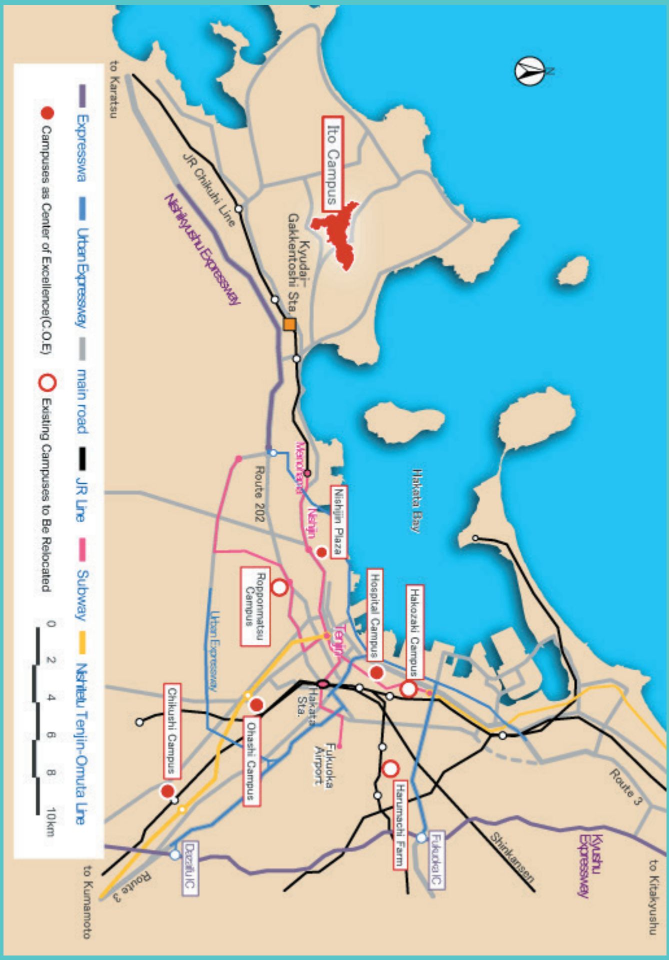

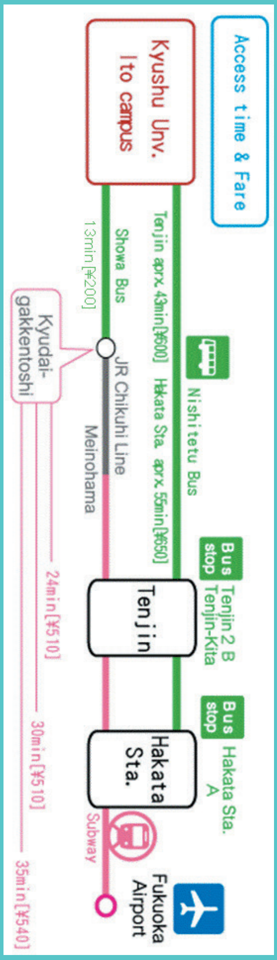

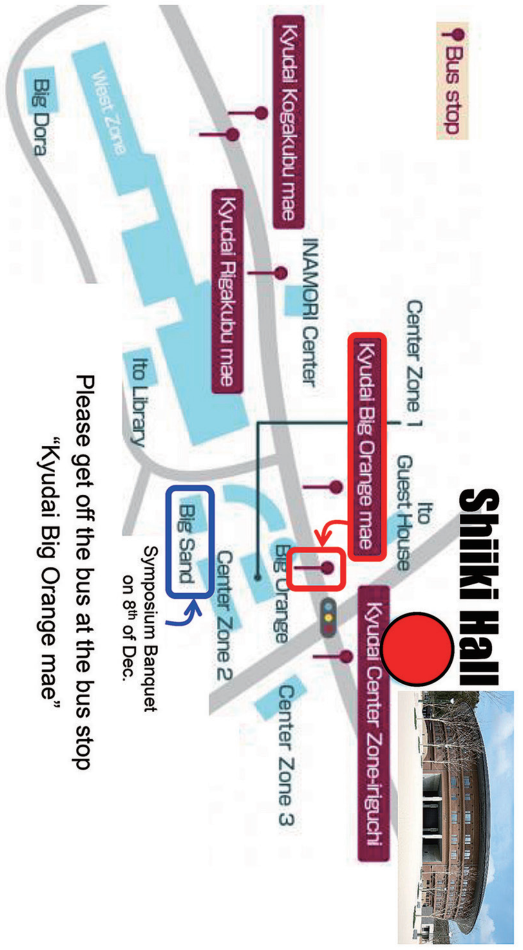

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