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2D Electrical Resistivity Tomography to Investigate Paleochannels at Wiang Ched Lin Ancient Town, Northern Thailand

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ABSTRACT

Wiang Ched Lin was an ancient town in Lanna history, located on the foot of Doi Suthep Mountain in Mueang Chiang Mai district, northern Thailand. The shape of Wiang Ched Lin is a circle with a water spring at the center. According to an analysis of aerial photos, Wiang Ched Lin was traversed by seven streams, as indicated by the name "Ched Lin", which means seven streams. Recent utilizing the land of Wiang Ched Lin caused destruction of architectural evidence, resulted in the inability to view Wiang Ched Lin city plan and some of the seven streams cannot currently be identified on a map. This study aims to verify an existence of the disappeared paleochannels in Wiang Ched Lin by using an electrical resistivity method. Several high resolution 2D electrical resistivity tomography (ERT) survey lines across the proposed streams were acquired. The ERT data show the resistivity distribution of the subsurface with suspected anomalous zones that may indicate buried paleochannel locations. To verify the ERT results, additional high resolution methods such as ground penetrating radar surveys and drillings are suggested.

Keywords: 2D electrical resistivity tomography, ERT, paleochannel survey

1. INTRODUCTION

Wiang Ched Lin located on the foot of Doi Suthep Mountain, northeast of Chiang Mai city, northern Thailand. It was an important ancient community in Lanna history. The characteristics of Wiang Ched Lin is a circular shape with a diameter of approximately 900 m and a spring at the center. The circle shape seems to be formed from folk wisdom of local people before the Buddhist century 19th. Wiang Ched Lin was an important ancient community since archaeological evidence and evidence of the use of Wiang Ched Lin in the Lanna period have been excavated. A study of aerial photographs from 1967, seven streams traversed Wiang Ched Lin were proposed (Fig.1) corresponding to the meaning of the words “Ched Lin” in Lanna language, which means seven streams [1]. Recent utilizing the land of Wiang Ched Lin caused the destruction of architectural evidence resulting in the inability to view Wiang Ched Lin city plan. Traces of the ridges and the ditches still remain in the area. In the present day, some streams may have dried out and disappeared so they cannot be depicted from the topographic map.

Paleochannels are streams that used to flow but have dried out or disappeared in the present. The paleochannel contains ancient sediment deposits of inactive streams and is filled by newer deposits [2] so the characteristics of paleochannels and surrounding deposits are different. Investigation of where the streams might have flowed through in Wiang Ched Lin area is needed to verify that the seven streams have existed as proposed from the aerial photograph study. Investigating the location as well as the width and depth of the paleochannels will help as evidence used in architectural work to verify the existence of Wiang Ched Lin in the past, including help in visualizing the Wiang Ched Lin city plan. It allows us to know the lifestyle of people in the past.

In this study the 2D electrical resistivity tomography (ERT) method is used to investigate the paleochannels in Wiang Ched Lin area. The ERT is a geophysical method widely used for shallow subsurface investigation. It images the subsurface resistivity distribution of the subsurface [3] and is useful in detecting the paleochannels [4-7]. The ERT surveys were conducted across the proposed paleochannels from the study of the aerial photographs.

2. STUDY SITE

Wiang Ched Lin is located on the foot of Doi Suthep Mountain in Chiang Mai, northern Thailand (Fig. 2). At present, Huay Kaew road runs through Wiang Ched Lin. Parts of Wiang Ched Lin area now are locations of Chiang Mai University, Rajamangala University of Technology Lanna, Chiang Mai Zoo, Office of Regional Livestock 5, Phuping Rajanivej Police Station, Huaykaew Arboretum, and Chiang Mai Animal Breeding Station which occupies most of the Wiang Ched Lin area [8].

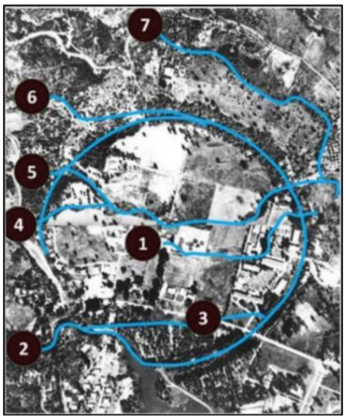

Fig. 1 An aerial photograph from an architectural research showing locations of the seven streams that nourished Wiang Ched Lin. The numbers represent each stream. [9]

A geologic map of the study area is shown in Fig. 3. The map shows that the Wiang Ched Lin study site is divided into eastern and western geologic units. The eastern unit is Quaternary sediment of terrace deposit (Qt) composed of gravel, sand, silt, laterite, and rock fragments. This unit is the westernmost part of the Chiang Mai Basin. The western unit is a foothill of Doi Suthep Mountain. This unit is Triassic granite and granodiorite (Trgr). Based on [10] study, west of Chiang Mai city where Wiang Ched Lin is located is the area around Doi Suthep Mountain underlined by orthogneiss and metasedimentary rocks. There are defined to be the Doi Suthep Metamorphic Complex. Three groundwater wells located in Wiang Ched Lin area (Fig. 2) indicated that there are layers of sand, gravel and hard rock granite with a depth of about 57 m as shown in Table 1 [11-13].

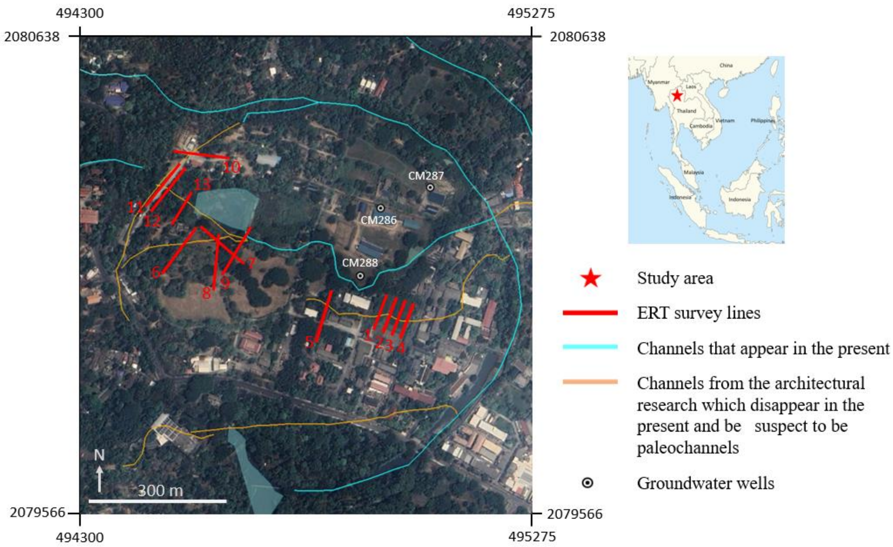

Fig. 2 Satellite map of the study area showing locations of suspected paleochannels, present channels, ERT survey lines, and Groundwater wells.

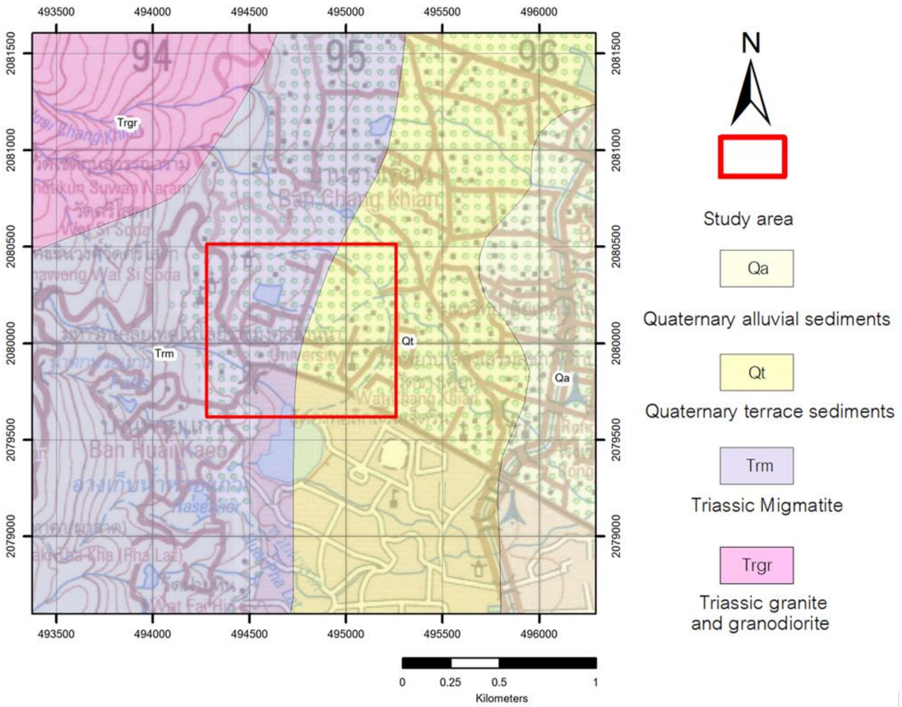

Fig. 3 Geologic map of Wiang Ched Lin area. (Modified from [14], [15])

Table 1. Drilling data from groundwater wells in Wiang Ched Lin. [11-13]

Groundwater wells	Depth (m)	Lithology
CM286	0-1.5	Clay
	1.5-9	Clay/Sand
	9-15	Clay/Rock
	15-27	Gravel
	27-48	Clay/Sand
	48-57	Sand
	57-121	Granite
CM287	0-6	Clay/Sand
	6-15	Gravel
	15-34.5	Sand
	34.5-54	Gravel
	54-72	Granite
CM288	0-1.5	Clay
	1.5-9	Clay/Sand
	9-112.5	Sand
	12.5-40.5	Clay/Sand
	40.5-60	Gravel
	60-120	Granite

3. ERT Method

ERT is a geophysical method used to determine the resistivity distribution cross section of the subsurface by measuring on the ground surface [3]. The subsurface resistivity relates to geological parameters such as porosity, pore fluid, saturation, and rock and sediment type. By injecting a DC current (I) into the subsurface via 2 electrodes, a voltage difference (ΔV) of the subsurface would be measured by another 2 electrodes. Then an apparent resistivity (ρ_a) can be calculated if the geometric factor (k) which is dependent on the 4-electrode configuration of the survey is known. By using Ohm's law, the general equation to calculate the apparent resistivity is $\rho_a = k\ (\Delta V/I)$. To determine the true resistivity of the subsurface, an inversion method must be used to invert the apparent resistivity data. In this study, the apparent resistivity data are inverted by using AGI EarthImager^{TM} 2D Software.

The inversion is a method to estimate subsurface model which starts with an initial model then calculates the data set of the model by forward modeling. The calculated data of the model were compared with measured data from observation. The difference between calculated data set of the model and measured data from observation was minimized by updating the model until inversion stop criteria is satisfied, stop the inversion [16].

4. ERT Data Acquisition

In this preliminary study, 13 ERT survey lines were acquired. Locations of the ERT lines are shown in Fig. 2. The ERT lines are across the suspected paleochannels interpreted from the aerial photograph.

Fig. 4 shows photos during the field data acquisition. The ERT data in this study were collected by ABEM Terrameter SAS4000 with ABEM Electrode Selector (Fig. 4a). The dipole-dipole electrode array (Fig. 5) is used in this study due to its relatively high horizontal resolution [17]. Survey Lines 1-4 and survey line 13 were 80 m long, using 1 m minimum electrode spacing. Survey Lines 5-12 were 120 m long, using 1.5 m minimum electrode spacing 1.5 m. Survey line coordinates and elevations were collected by a real time kinematic GPS and an auto level electronic distance measurement as shown in Fig. 4b and 4c).

Fig. 4 (a) Electrical resistivity survey instruments, (b) real time kinematics GPS, (c) auto level with electronic distance measurement for survey coordinates, and (d) some of survey lines.

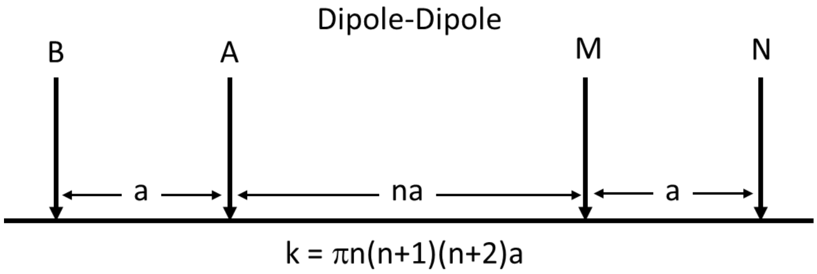

Fig. 5 The dipole-dipole electrode configuration. A and B are the current electrode pair, M and N are the potential electrode pair, a is the dipole length, k is the geometric factor, n is the dipole separation factor.

5. RESULTS AND DISCUSSION

Inverted ERT sections of Lines 1-5 are displayed in Fig. 6 and those of Lines 6-13 are shown in Fig. 7, respectively. Inverted ERT sections indicate low resistivity anomalous zones to be possible paleochannels with 10 to 45 m wide and 5 to 25 m deep which can be found in ERT Lines 5-13.

ERT Lines 1-4 are oriented in the south-north direction and parallel to each other with a line separation distance of 21 m. These 4 ERT lines present similar resistivity distributions. ERT can be separated into 3 zones (Fig. 6a). The top zone at very shallow depth from the surface up to 1 m shows a very thin layer of high resistivity at the surface and underlain by a low resistivity layer. This top zone is interpreted as a sandy clay layer with dry surface on top. The middle depth zone ranging from 4 m to 12 m shows relatively high resistivity layer interpreted as sand gravel. The bottom zone at depth below 12 m shows low resistivity interpreted as saturated sand and gravel. There are no anomalies that are expected to be paleochannels. This might be due to the direction changing of suspected paleochannels from architectural research out of survey lines.

ERT Line 5 is close to ERT Lines 1-4 and close to the spring at the center of Wiang Ched Lin. This ERT section (Fig. 6b) shows low resistivity anomalous zones in valley shape (dashed ovals) with resistivity lower than 15 ohm.m The low resistivity anomalous zones are interpreted as saturated sand gravel and suspected to be possible paleochannels.

ERT Lines 6-9 (Fig. 7a) were laid through the hilly area in Wiang Ched Lin. The inverted ERT sections show high resistivity areas in the middle and bottom of the sections along with low resistivity zones in the middle of the sections. These low resistivity zones are interpreted as saturated sand and gravel which may indicate possible paleochannels. In addition, ERT Line 9 which is close to the channel that appears in the present shows a low resistivity anomaly corresponding to the same location as the suspected paleochannels. Since ERT Lines 6-9 are close to the Doi Suthep Mountain, the high resistivity zones with resistivity values of more than 700 Ohm.m are interpreted as granite.

ERT Line 10 was laid on a hilly area, while ERT Lines 11-13 were laid on flat area on the northwest side of the study area. The inverted ERT sections of these survey lines (Fig. 7b-7c) are similar to the results of ERT Lines 6-9 with low resistivity anomalous zones which are suspected to be possible paleochannels and high resistivity anomalous zones are interpreted as granite.

The interpreted paleochannels have different sizes and depths. This might be due to the time Wiang Ched Lin was built, ditches were built to control water flowing through Wiang Ched Lin. As a result, channels have different rates of sediment deposit.

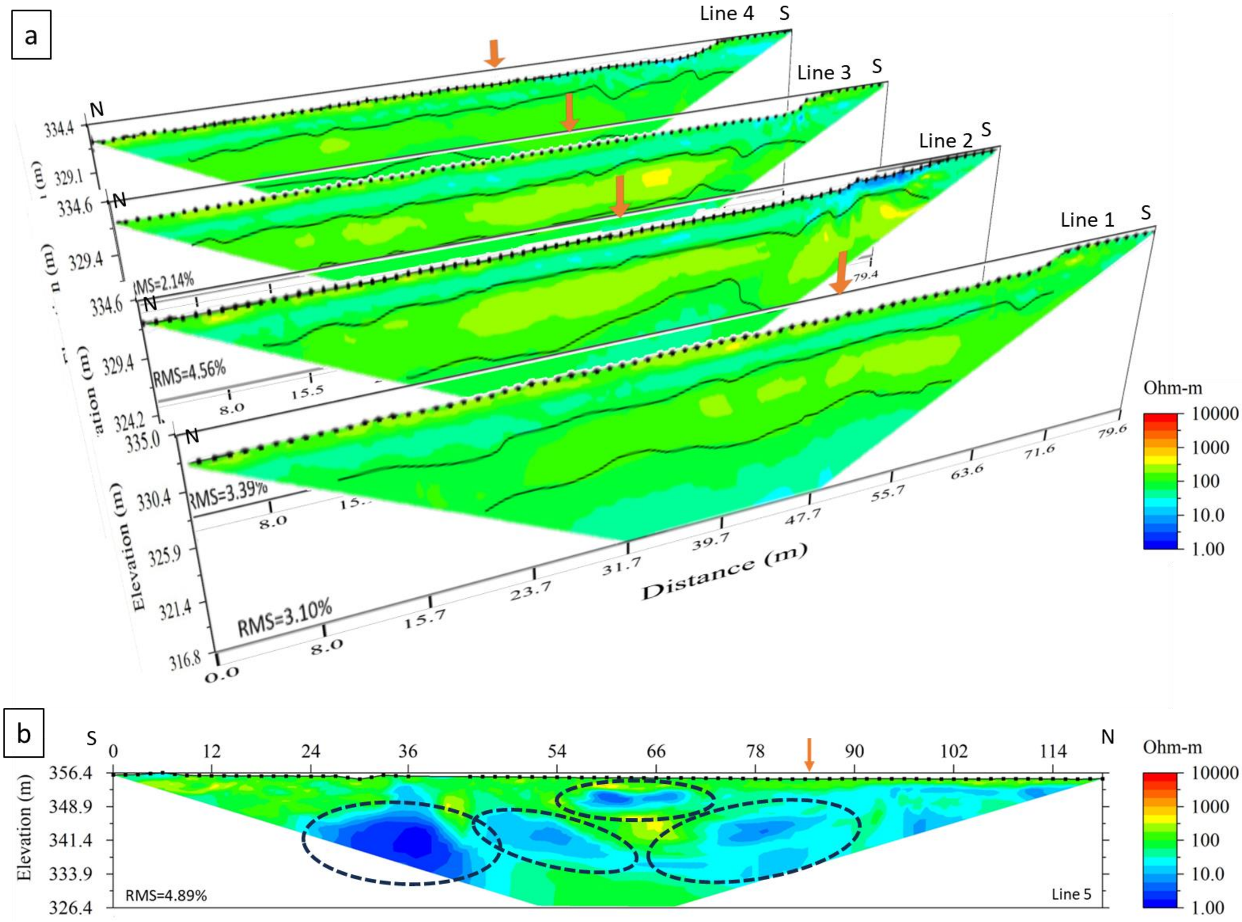

Fig. 6 Inverted ERT sections of (a) Line 1-4 (the solid black lines are the boundaries between the zones), (b) Line 5. Dash ovals are suspected possible paleochannels and orange arrows are suspected paleochannels from architectural research.

6. CONCLUSIONS

The ERT method was used to identify locations of possible paleochannels in the study area of Wiang Ched Lin, Chiang Mai, Thailand. 9 out of 13 ERT results show low resistivity anomalies interpreted as saturated sand gravel which may indicate possible paleochannels. However only the ERT survey might not accurately verify the results of paleochannel locations. Additional surveys such as ground-penetrating radar (GPR) are suggested to be applied. The findings from integrated geophysical surveys can guide future drilling locations to verify the paleochannel locations.

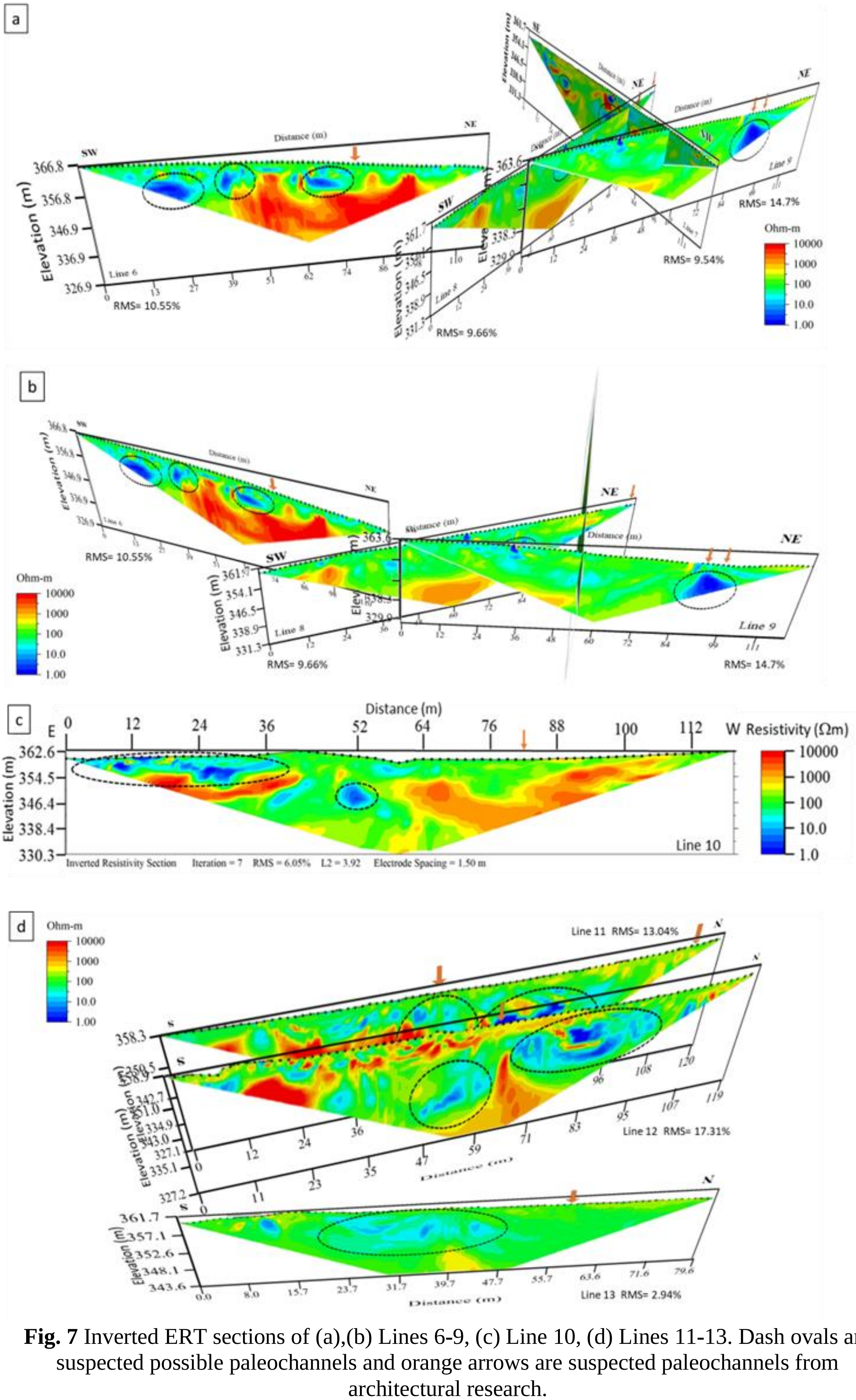

Fig. 7 Inverted ERT sections of (a),(b) Lines 6-9, (c) Line 10, (d) Lines 11-13. Dash ovals are suspected possible paleochannels and orange arrows are suspected paleochannels from architectural research.

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REFERENCES

[1] Chao-ngiw S., Wiang Jed Lin; Available at: https://issuu.com/rmutlculture/docs/ journal 7lin.y2v1 ?utm_medium=referral&utm_source=culture.rmutl.ac.th

[2] Kumar V., Palaeo-Channel,; Available at: https://link.springer.com/referenceworkentry/ 10.1007/978-90-481-2642-2_386.

[3] Loke M.H., Tutorial : 2-D and 3-D electrical imaging surveys; Available at: https://sites.ualberta.ca/~unsworth/UA-classes/223/loke_course_notes.pdf.

[4] Nimnate P., Thitimakorn T., Choowong M., and Hisada K., *Open Geosciences*, 2017; **9**: 675-688. DOI 10.1515/geo-2017-0051.

[5] Maillet G.M., Rizzo E., Revil A. and Vella C., *Marine Geophysical Researches*, 2005; **26**: 317-328. DOI 10.1007/s11001-005-3726-5.

[6] Muangnoi S., Chaimanee N. and Pananont P., *Proceedings of Siam Physics Congress 2021, SPC 2021*, Thailand, 24-25 May 2021; 012050.

[7] Torrese P., Rainone M. L., Colantonio F. and Signanini P., *Proceedings of the 26th Symposium on the Application of Geophysics to Engineering and Environmental Problems 2013, SAGEEP 2013*, Denver, Colorado, USA, 17-21 March 2013; 321-331.

[8] Chao-ngiw S., *Wiang Jed Lin,* Cultural Studies center, Rmutl, 2020.

[9] Guntang I., Geometric Circular Town: Gables: Architecture, Design and Environment academic journal of the Faculty of Architecture Silpakorn University, 2015; 29: 87-104. https://so04.tci thaijo.org/index.php/ NAJUA-Arch/article/view/44221.

[10] Rhodes P.B., Blum J. and Davine T., *Journal of Asian Earth Sciences*, 2000; **18**: 97-108. DOI 10.1016/S1367-9120(99)00019-X.

[11] Department of Groundwater Resources, CM286; Available at: http://app.dgr.go.th/newpasutara/showwell1.php?wellid=CM286.

[12] Department of Groundwater Resources, CM287; Available at: http://app.dgr.go.th/newpasutara/showwell1.php?wellid=CM287.

[13] Department of Groundwater Resources, CM288; Available at: http://app.dgr.go.th/newpasutara/showwell1.php?wellid=CM288.

[14] Royal Thai Survey Department, *Changwat Chiang Mai, Thailand, 4746 I, L7018*, Prepared by the National Imagery and Mapping Agency in cooperation with the Royal Thai Survey Department, 2012.

[15] Department of Mineral Resources, The geological map of Chiang Mai; Available at: http://www.dmr.go.th/download/pdf/North/Chiangmai.pdf.

[16] Advanced Geosciences, Inc., *Instruction Manual for EarthImager 2D Version 2.4.0 Resistivity and IP Inversion Software*, Advanced Geosciences, Inc., 2009.

[17] Okpoli C.C., *International Journal of Geophysics*, 2013; **2013**: DOI 10.1155/2013/608037.