

10<sup>th</sup> Year of the SDGs: Reflections, Realignments, and the Way Forward  
18–19 November 2025 at the Ministry of Foreign Affairs in Bangkok



# Sustainable Development Goals

## Integrating Science, Policy, and Local Knowledge for Ecosystem Restoration



unite science, policy, and community to conserve nature,  
co-create solutions, and build resilient ecosystems | **Geoparks**

Associate Professor Vimoltip Singtuen, Ph.D.  
Associate Dean for Academic Affairs, Digital and Student Affairs  
Department of Geotechnology, Faculty of Technology, Khon Kaen University  
Geologist & Geoscientific Staff of Khon Kaen Geopark (NE Thailand)

# Presentation Highlights



**Part 1:** Introduction

**Part 2:** Geoparks in Thailand

**Part 3:** Overview of Khon Kaen Geopark

**Part 4:** Ecosystem Restoration & Geo–Cultural Research

**Part 5:** Community Engagement & Empowerment

**Part 6:** Integration of Science, Policy, and Technology

**Part 7:** Reflections & Key Messages



# Introduction

- 10 Years of SDGs  
Reflections and Urgency for Action
  - 2025 marks the 10th Anniversary of the Sustainable Development Goals (SDGs).
  - Despite progress, ecosystem degradation continues—deforestation, soil erosion, and biodiversity loss.
  - The next five years are critical for realigning science, policy, and community actions toward restoration and sustainability.



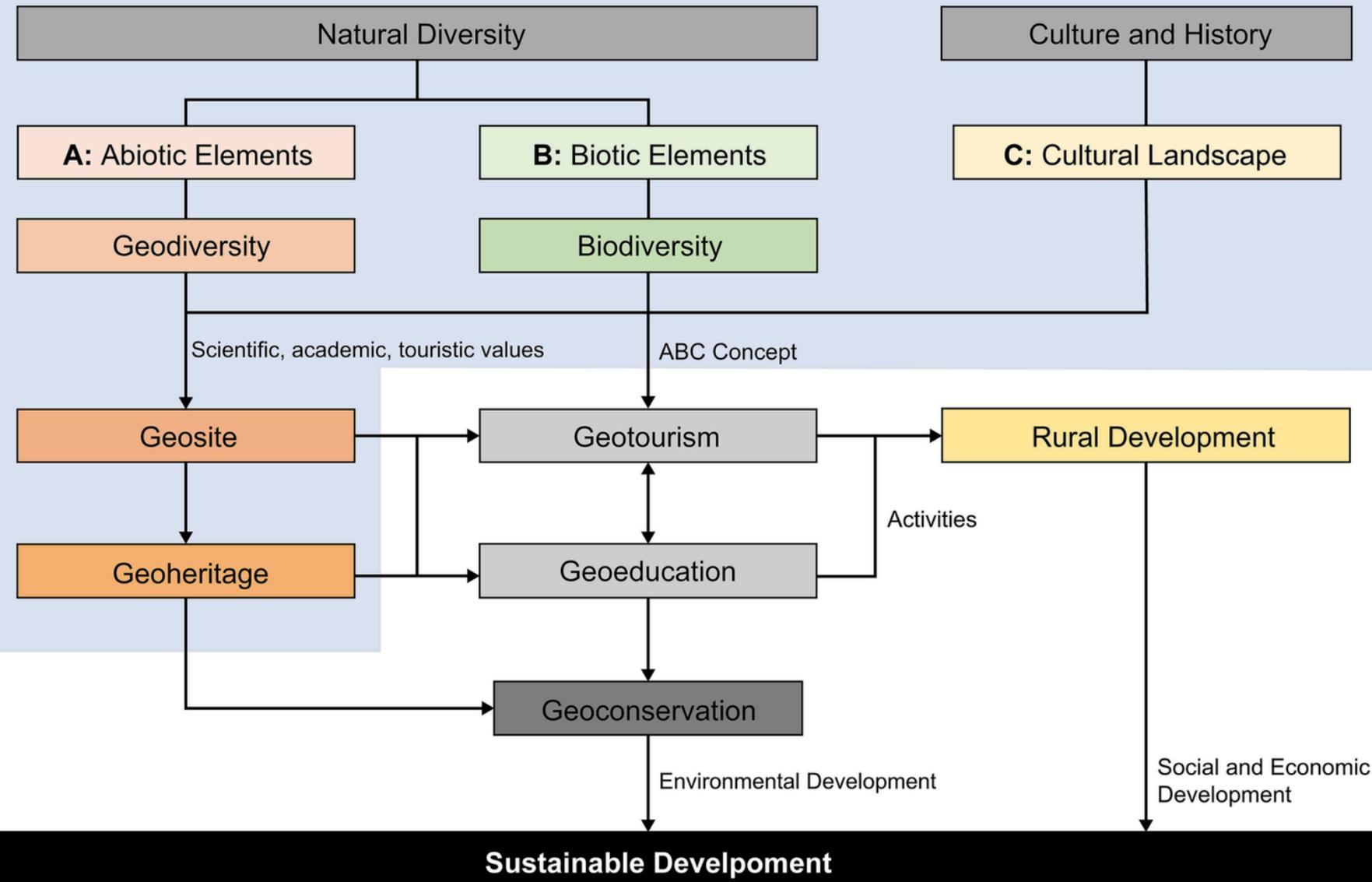
# Introduction

## 🔗 Bridging Science, Policy, and Local Wisdom for Sustainability

- Science provides evidence and innovation for restoration.
- Policy creates frameworks and ensures long-term impact.
- Local Wisdom connects people, place, and tradition.
- Together, they form the foundation for sustainable ecosystem management.



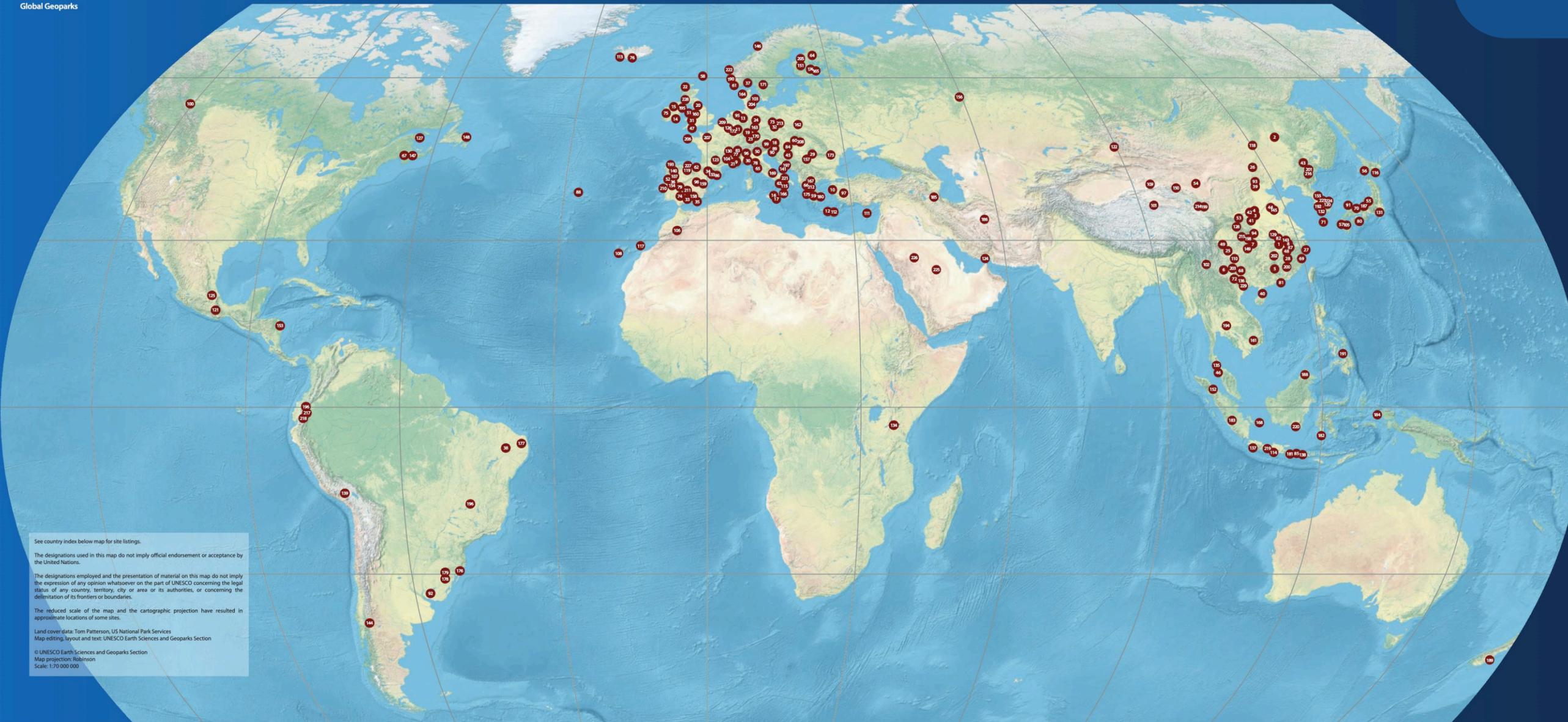
## GEOPARK COMPONENTS



# Introduction

Geopark: A Living Laboratory for Sustainability

- Geoparks connect geoheritage, biodiversity, and cultural identity.
- Serve as platforms linking research, governance, and community participation.
- Demonstrate how place-based science supports restoration and resilience.
- Empower communities through education, geotourism, and local innovation.



See country index below map for site listings.

The designations used in this map do not imply official endorsement or acceptance by the United Nations.

The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of UNESCO concerning the legal status of any country, territory, city or area or its authorities, or concerning the delimitation of its frontiers or boundaries.

The reduced scale of the map and the cartographic projection have resulted in approximate locations of some sites.

Land cover data: Tom Patterson, US National Park Services  
Map editing, layout and text: UNESCO Earth Sciences and Geoparks Section

© UNESCO Earth Sciences and Geoparks Section  
Map projection: Robinson  
Scale: 1:70 000 000

- |  |   |  |   |  |   |   |  |  |   |
|--|---|--|---|--|---|---|--|--|---|
| <p><b>Austria</b></p> <p>18. Styrian Eisenwurzen</p> <p>99. Ore of the Alps</p> <p><b>Belgium</b></p> <p>126. Famenne-Ardenne</p> <p><b>Brazil</b></p> <p>38. Araripe</p> <p>176. Southern Canyons Pathways</p> <p>177. Sério</p> <p>178. Caçapava</p> <p>179. Quarta Colônia</p> <p>196. Uberaba</p> <p><b>Canada</b></p> <p>67. Stonehammer</p> <p>100. Tumbler Ridge</p> <p>127. Percé</p> <p>147. Cliffs of Fundy</p> <p>148. Discovery</p> <p><b>Chile</b></p> <p>146. Kúitralkura</p> <p><b>China</b></p> <p>5. Danxia Shan</p> <p>8. Huangshan</p> <p>6. Shilin</p> <p>3. Songshan</p> <p>2. Wudailanchi</p> <p>4. Yuntaishan</p> <p>7. Zhangjiajie</p> <p>26. Hexigten</p> | <p>28. Taining</p> <p>25. Xingwen</p> <p>27. Yangangshan</p> <p>39. Fangshan</p> <p>41. Funiushan</p> <p>43. Jingpohu</p> <p>40. Leiqiong</p> <p>44. Taishan</p> <p>42. Wangwushan-Daimaishan</p> <p>48. Longshushan</p> <p>49. Zigong</p> <p>54. Alxa Desert</p> <p>53. Qilng Zhongnanshan</p> <p>69. Ningde</p> <p>68. Leye Fengshan</p> <p>81. Hong Kong</p> <p>82. Tianzhushan</p> <p>87. Sanqingshan</p> <p>94. Shennongjia</p> <p>93. Yanqing</p> <p>101. Mount Kunlun</p> <p>102. Dali-Cangshan</p> <p>109. Dunhuang</p> <p>110. Zhijindong Cave</p> <p>118. Anxan</p> <p>122. Keketuohai</p> <p>128. Guangwushan-Nuoshuihe</p> <p>129. Huanggang Dabieshan</p> <p>145. Yimengshan</p> <p>143. Juhuasshan</p> <p>149. Xiangxi</p> <p>150. Zhangye</p> <p>198. Enshi Grand Canyon</p> <p>Tenglongdong Cave</p> <p>203. Xingyi</p> | <p>202. Wugongshan</p> <p>199. Linxia</p> <p>200. Longyan</p> <p>201. Mount Changbaishan</p> <p>214. Kanbula</p> <p>215. Yunyang</p> <p><b>Croatia</b></p> <p>45. Papuk</p> <p>141. Vls Archipelago</p> <p>197. Biokovo-Imotski Lakes</p> <p><b>Cyprus</b></p> <p>111. Troodos</p> <p><b>Czechia</b></p> <p>32. Bohemian Paradise</p> <p><b>Democratic People's Republic of Korea</b></p> <p>216. Mt. Paektu</p> <p><b>Denmark</b></p> <p>103. Odsherred</p> <p>164. Vestjylland</p> <p>204. The South Fyn Archipelago</p> <p><b>Ecuador</b></p> <p>142. Imbabura</p> <p>217. Napo Sumaco</p> <p>218. Tungurahua Volcano</p> <p><b>Finland</b></p> <p>64. Rokua</p> <p>151. Lauhanvuori-Haemeen kangas</p> | <p>165. Saimaa</p> <p>174. Salpausselkä</p> <p>205. Impact Crater Lake Geopark Lappajärvi</p> <p><b>France</b></p> <p>9. Haute-Provence</p> <p>21. Luberon</p> <p>77. Massif des Bauges</p> <p>83. Chablais</p> <p>104. Monts d'Ardèche</p> <p>123. Causses du Quercy</p> <p>130. Beaujolais</p> <p>206. Armorique</p> <p>207. Normandie Maine</p> <p><b>Germany</b></p> <p>11. Vulkaneifel</p> <p>13. TERRA.vita</p> <p>19. Bergstraße-Odenwald</p> <p>23. Swabian Alb</p> <p>24. Harz, Braunschweiger Land-Ostfalen</p> <p>163. Thuringia Inselberg - Drei Gleichen</p> <p>170. Ries</p> <p><b>Greece</b></p> <p>10. Lesvos Island</p> <p>12. Psiloritis</p> <p>59. Chelmos Vouraikos</p> <p>66. Vikos-Aoos</p> <p>112. Sitia</p> <p>167. Grevena-Kozani</p> <p>175. Kefalonia-Ithaca</p> | <p>180. Lavretski</p> <p>212. Meteora Pyli</p> <p><b>Hungary</b></p> <p>84. Bakony-Balaton</p> <p>208. Bükk Region</p> <p><b>Iceland</b></p> <p>76. Kata</p> <p>113. Reykjanes</p> <p><b>Indonesia</b></p> <p>85. Batur</p> <p>114. Gunung Sewu</p> <p>137. Ciletuh - Palabuhanratu</p> <p>138. Rinjani-Lombok</p> <p>152. Toba Caldera</p> <p>168. Belitung</p> <p>181. Ijen</p> <p>182. Maros Pangkep</p> <p>183. Merangin Jambi</p> <p>184. Raja Ampat</p> <p>219. Kebuamen</p> <p>220. Meratus</p> <p><b>Iran (Islamic Republic of)</b></p> <p>124. Qeshm Island</p> <p>185. Aras</p> <p>186. Tabas</p> <p><b>Ireland</b></p> <p>75. Copper Coast</p> <p>175. Burren and Cliffs of Moher</p> <p><b>Italy</b></p> | <p>16. Madonie</p> <p>30. Beigua</p> <p>17. Rocca di Cerere</p> <p>50. Adamello-Brenta</p> <p>63. Cilento, Vallo di Diano e Alburni</p> <p>65. Tuscan Mining Park</p> <p>78. Apuan Alps</p> <p>96. Sesia Val Grande</p> <p>115. Pollino</p> <p>166. Aspromonte</p> <p>169. Majella</p> <p>221. MurGeopark</p> <p><b>Japan</b></p> <p>55. Itoigawa</p> <p>57. Unzen Volcanic Area</p> <p>56. Toya-Utsu</p> <p>70. Saru' in Kaigan</p> <p>80. Muroto</p> <p>91. Oki Islands</p> <p>105. Aso</p> <p>116. Mt. Apoi</p> <p>131. Izu Peninsula</p> <p>187. Hakusan Tedorigawa</p> <p><b>Luxembourg</b></p> <p>172. Mellerdall</p> <p><b>Malaysia</b></p> <p>46. Langkawi</p> <p>188. Kinabalu</p> <p><b>Mexico</b></p> <p>125. Comarca Minera, Hidalgo</p> <p>121. Mixteca Alta, Oaxaca</p> | <p><b>Morocco</b></p> <p>106. M' Goun</p> <p><b>Netherlands (Kingdom of the)</b></p> <p>95. De Hondsrug</p> <p><b>New Zealand</b></p> <p>189. Waitaki Whitestone</p> <p><b>Nicaragua</b></p> <p>153. Rio Coco</p> <p><b>Norway</b></p> <p>37. Gea Norvegica</p> <p>57. Unzen Volcanic Area</p> <p>146. Trolljell</p> <p>190. Sunnhordland</p> <p>222. The Fjord Coast</p> <p><b>Peru</b></p> <p>139. Colca y Volcanes de Andagua</p> <p><b>Philippines</b></p> <p>191. Bohol</p> <p><b>Poland</b></p> <p>162. Holy Cross Mountains</p> <p>213. Land of Extinct Volcanoes</p> <p><b>Portugal</b></p> <p>52. Arouca</p> <p>88. Azores</p> <p>36. Naturtejo</p> <p>107. Terras de Cavaleiros</p> | <p>154. Estrela</p> <p>210. Oeste</p> <p><b>Republic of Korea</b></p> <p>71. Jeju</p> <p>120. Cheongsong</p> <p>132. Mudeungsan</p> <p>155. Hantangang River</p> <p>192. Jeonbuk West Coast</p> <p>223. Danyang</p> <p>224. Gyeongbuk Donghaean</p> <p><b>Romania</b></p> <p>29. Hațeg Country</p> <p>173. Buzău Land</p> <p><b>Russian Federation</b></p> <p>156. Yangan Tau</p> <p><b>Saudi Arabia</b></p> <p>225. North Riyadh</p> <p>226. Salma</p> <p><b>Serbia</b></p> <p>157. Djerdap</p> <p><b>Slovenia</b></p> <p>90. Idrija</p> <p><b>Spain</b></p> <p>62. Basque Coast</p> <p>35. Cabo de Gata-Níjar</p> <p>88. Azores</p> <p>34. Sobrarbe-Pirineos</p> <p>74. Sierra Morena de Sevilla</p> | <p>79. Villuercas Ibores Jara</p> <p>86. Central Catalonia</p> <p>98. Molina &amp; Alto Tajo</p> <p>108. El Hierro</p> <p>117. Lanzarote and Chinijo Islands</p> <p>119. Las Loras</p> <p>133. Origen</p> <p>140. Courel Mountains</p> <p>158. Granada</p> <p>159. Maestrazgo</p> <p>193. Cabo Ortegal</p> <p>211. Calatrava Volcanoes - Ciudad Real</p> <p>227. Costa Quebrada</p> <p><b>Sweden</b></p> <p>171. Platåbergens</p> <p><b>Tanzania</b></p> <p>134. Ngorongoro Lengai</p> <p><b>Thailand</b></p> <p>135. Satun</p> <p>194. Khorat</p> <p><b>Türkiye</b></p> <p>97. Kula Salihli</p> <p><b>United Kingdom of Great Britain and Northern Ireland</b></p> <p>20. North Pennines AONB</p> <p>22. North-West Highlands</p> <p>31. Forest Fawr</p> <p>47. English Riviera</p> <p>51. GeoMón</p> | <p>58. Shetland</p> <p>160. Black Country</p> <p>195. Moune Gullion Strangford</p> <p>228. Arran</p> <p><b>Uruguay</b></p> <p>92. Grutas del Palacio</p> <p><b>Viet Nam</b></p> <p>72. Dong Van Karst Plateau</p> <p>136. Non nuoc Cao Bang</p> <p>161. Dak Nong</p> <p>229. Lang Son</p> |
|--|---|--|---|--|---|---|--|--|---|

# 229

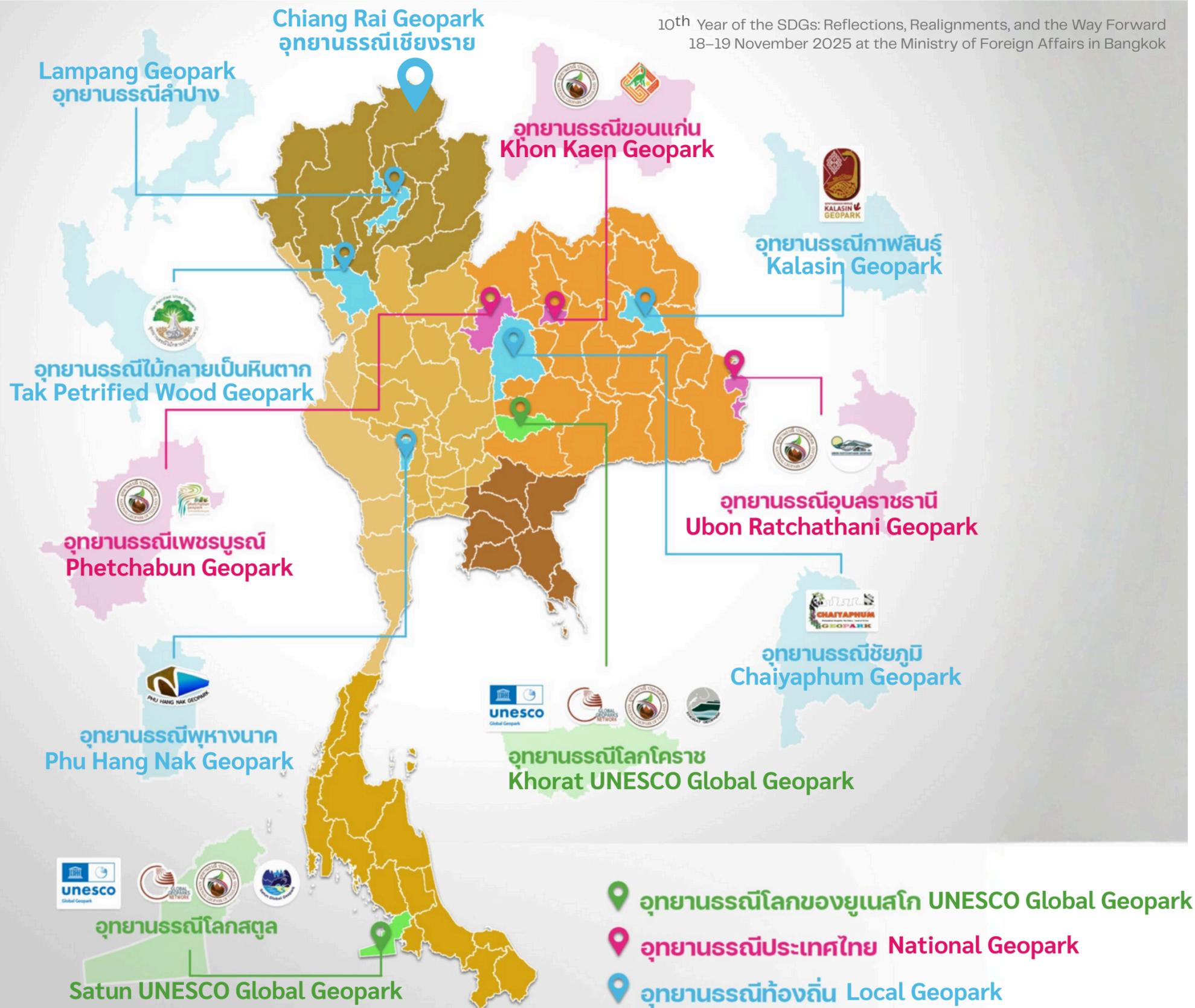
## GLOBAL GEOPARKS

including 5 transboundary UNESCO Global Geoparks

present in **50** MEMBER STATES

& covering more than **816,629** km<sup>2</sup>

Associate Professor Vimoltip Singtuen, Ph.D.  
Khon Kaen University



# Geoparks in Thailand

## 1 UNESCO Global Geopark

- Satun UNESCO Global Geopark
- Khorat UNESCO Global Geopark

## 2 National Geopark

- Ubon Ratchathani Geopark
- Khon Kaen Geopark
- Phetchabun Geopark

## 3 Local Geopark

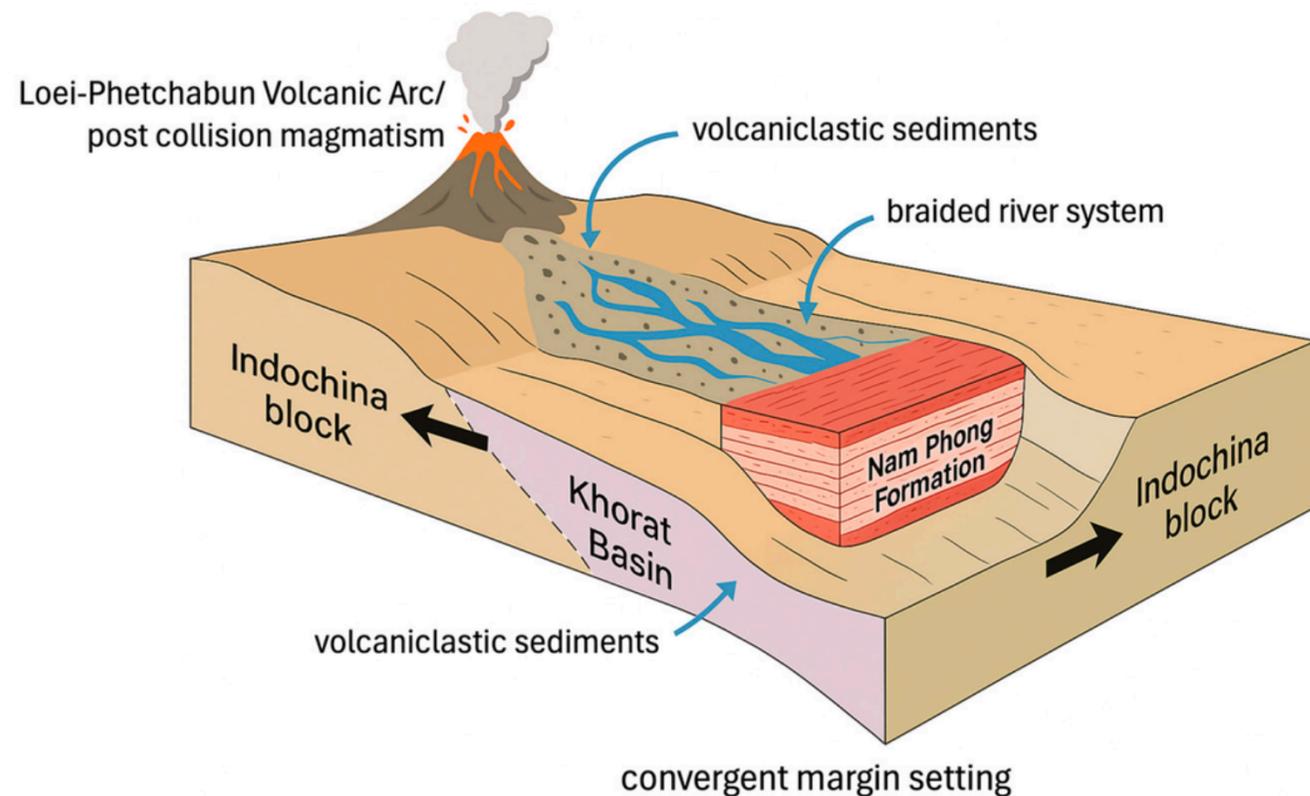
- Tak Petrified Wood Geopark
- Lampang Geopark
- Chiang Rai Geopark
- Chaiyaphum Geopark
- Kalasin Geopark
- Phu Hang Nak Geopark



# Ecosystem Restoration Geo-Cultural Research

## 🌋 Pre-Khorat Paleoenvironments 🏔️

- The Nam Phong Formation in the western Khorat Plateau (Khon Kaen Geopark) records Late Triassic–Early Jurassic continental deposition.
- Stratigraphic analysis shows litharenite and lithic wacke sandstones, interbedded with red paleosols and polymictic conglomerates, reflecting a braided fluvial system with episodic subaerial exposure.
- Geochemical and REE analyses (notably negative Ce anomalies) indicate derivation from an active continental margin under oxidizing and semi-arid to subhumid paleoclimate.
- The formation represents a tectonically active syn-rift basin, comparable to the modern Ebro Basin (Spain), emphasizing uniformitarian analogs for interpreting ancient continental systems.

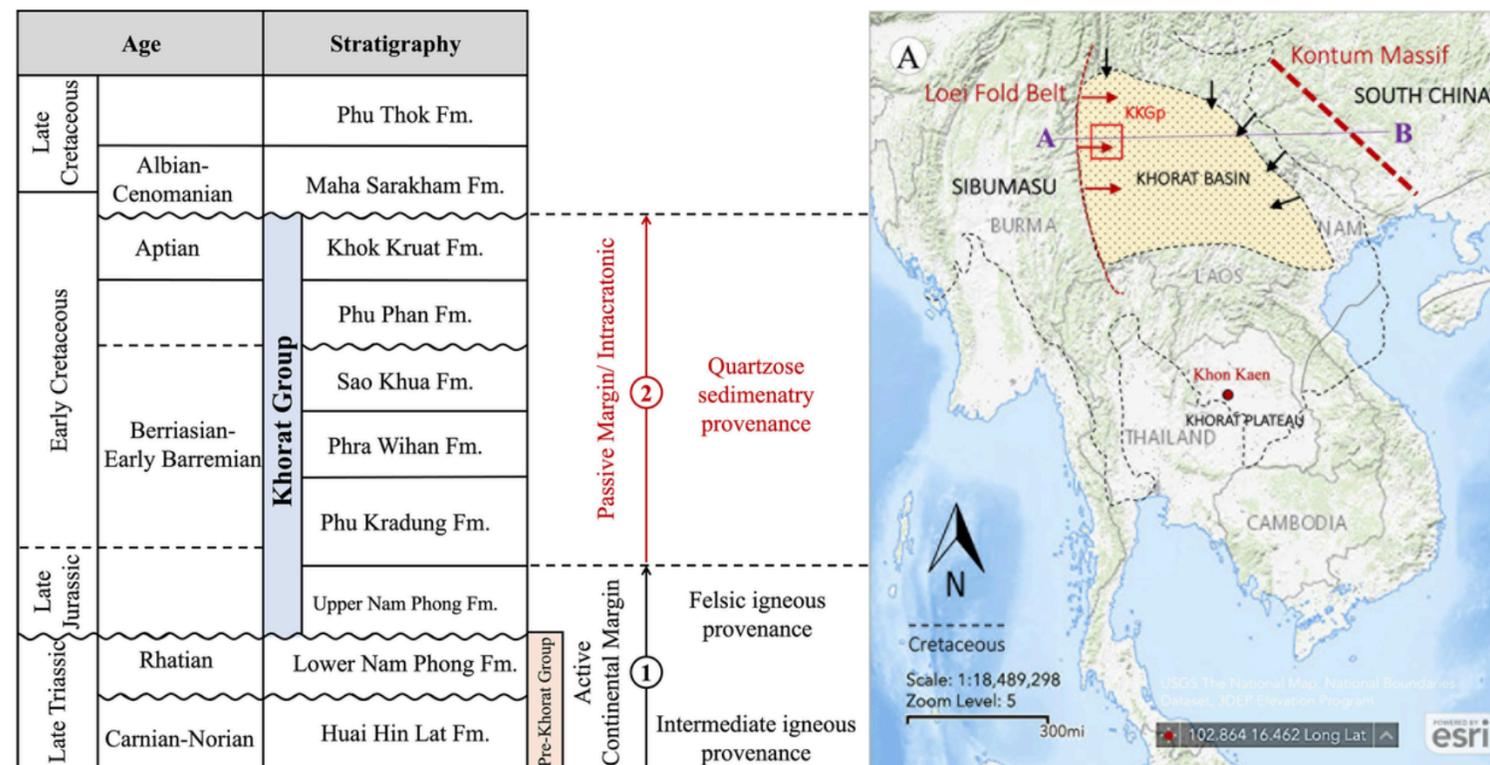


# Ecosystem Restoration Geo-Cultural Research



## Mesozoic sandstones of the Khorat Group

- The Khon Kaen Geopark exposes Mesozoic sedimentary rocks of four formations—Phra Wihan (PWF), Sao Khua (SKF), Phu Phan (PPF), and Khok Kruat (KKF)—within the Khorat Group.
- Field and petrographic analyses show immature, clast-supported pebbly sandstones and siltstones, with minor calcretes.
- Petrographic (Q–F–L) and geochemical (major–trace–REE) data indicate sources from quartzose sedimentary and felsic–intermediate igneous rocks.
- REE patterns and element ratios suggest deposition in a passive continental margin or upper continental crustal setting, reflecting recycled orogen provenance of the Mesozoic Khorat Basin.



# Ecosystem Restoration Geo-Cultural Research

## ▲ Geological framework & morphotectonics

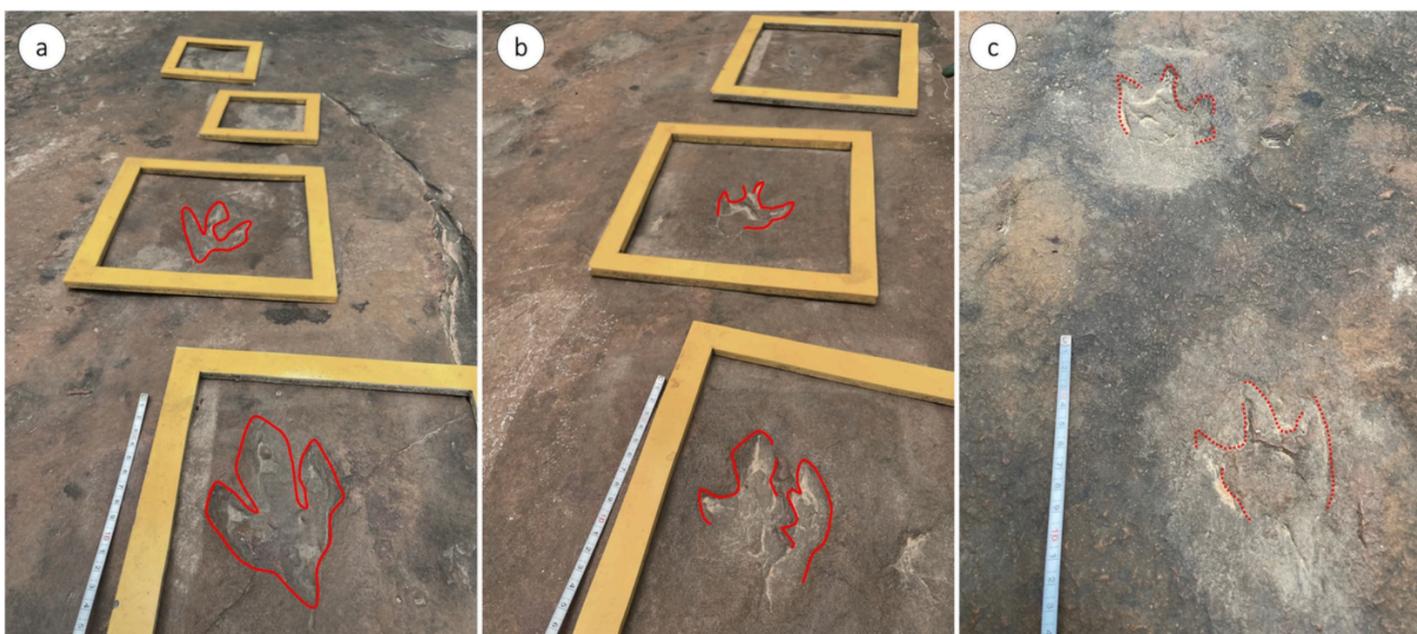
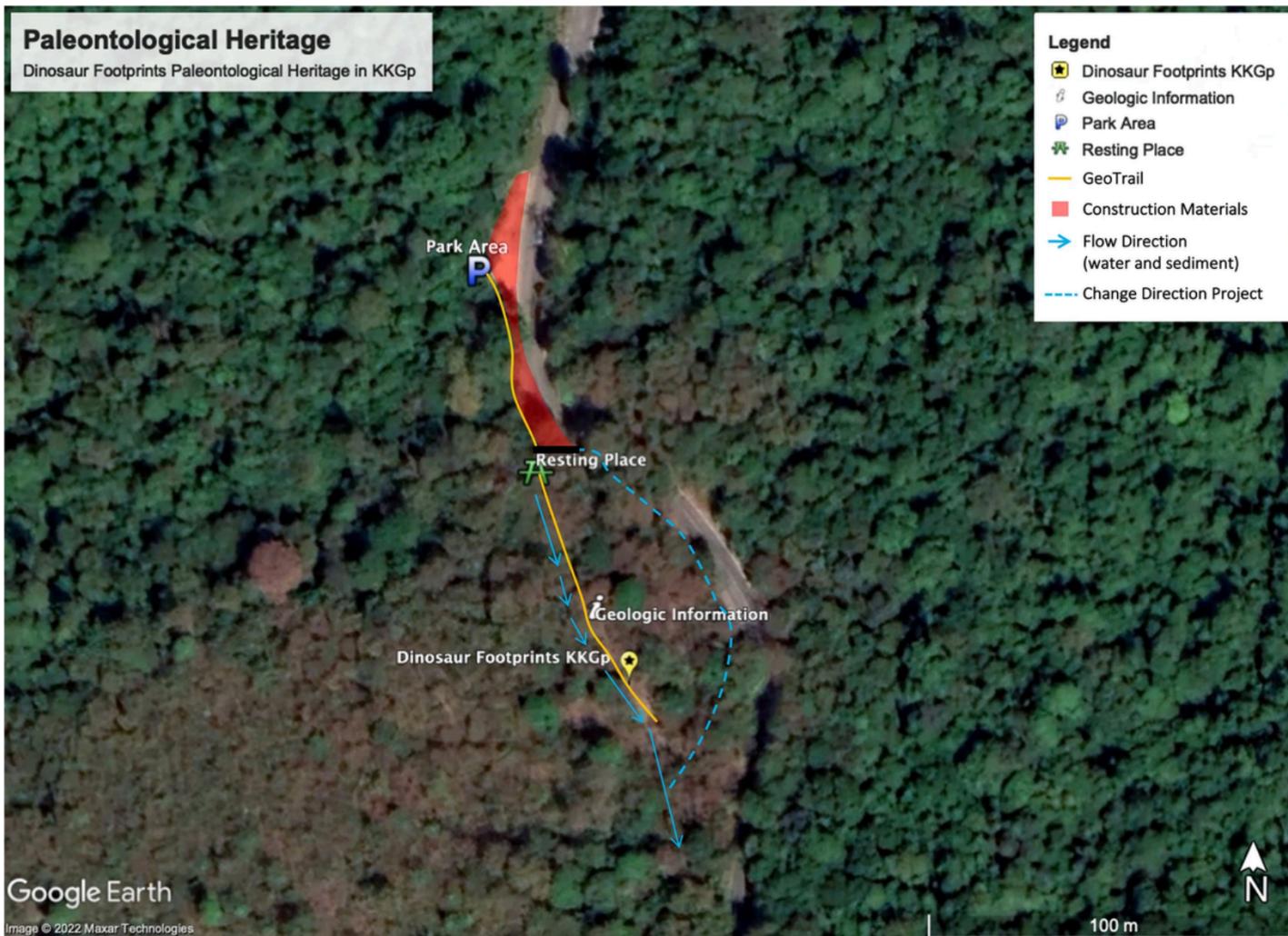
- Located on the western margin of the Khorat Plateau, Northeastern Thailand. Composed of Mesozoic Khorat Group formations.
- Study integrates field data, satellite imagery, and seismic interpretation.
- Western sector shows multiphase syncline and strike-slip faults.
- Eastern sector features anticline and reverse faults with gentle topography.
- Main structural trends: N-S, NW-SE, and NE-SW, indicating multiple tectonic phases.
- Tectonic activity and lithological variation shaped the present geomorphology.



# Ecosystem Restoration Geo-Cultural Research

## Geoconservation of Dinosaur Footprint

- The Hin Lat Pa Chad geosite in the Khon Kaen National Geopark preserves dinosaur footprints of *Carmelopus* isp. (theropod) and *Neoanomoepus* isp. (ornithischian) within the Phra Wihan Formation (Early Cretaceous).
- Evaluation shows high scientific, moderate educational and touristic value, but high deterioration risk.
- Main degradation factors: humid climate, stream erosion, road construction, and human activity.
- Geoconservation measures proposed: redirecting water flow, removing construction sediments, and implementing continuous monitoring and geoeducation programs.



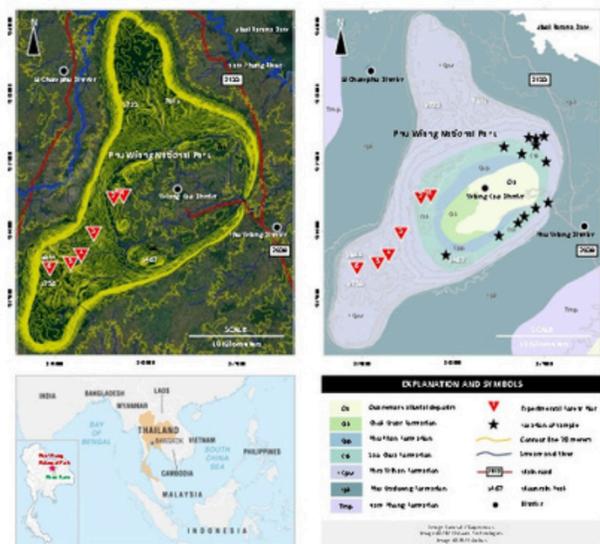


Figure 1 The location of forestry experimental plots in satellite image (Google Earth) and geologic map of Khon Kaen Province. Geological data modified from [2]

The geologic map of the Department of Mineral Resources (2007) suggests that plots 1-2 are covered by the Sao Khrua Formation (Cretaceous), while plots 3 to 6 are covered by the Phra Wihan Formation (Jurassic to Cretaceous) as shown in Figure 1.

### METHODOLOGY

- Bibliographic Bibliometric Survey**
- Literature Review**
- Geological Field Investigation**
- Lithological Study**
- Petrographic Study**
- Geochemical Analysis**

Vimoltip Singtuen<sup>1,\*</sup> and Burapha Phajuy<sup>2,\*\*</sup>

<sup>1</sup> Department of Geotechnology, Faculty of Technology, Khon Kaen University, Khon Kaen, Thailand  
<sup>2</sup> Department of Geological Sciences, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand  
 \*vimoltipst@gmail.com, vimosi@kku.ac.th \*\*buraphaphj3@gmail.com

### INTRODUCTION

Phu Wiang Valley is an area rich in natural resources, both biological and physical features, which is located in Wiang Kao District of Khon Kaen Province and a part of Phu Wiang National Park and Khon Kaen Geopark. The area exhibits a special topographic feature where the folding is the main geological structure that creates high mountains surrounding the basin in the middle and consists of sandstone of Korat Group (Nam Phong, Phu Kraueang, Phra Wihan, Sao Khrua, Phu Phan, and Khok Kruat Formations) as shown in Fig. 1. According to the conservation legislations of the Department of National Parks, Wildlife and Plant Conservation, studying vegetation at different heights and lithological characteristics is therefore interesting because the factors can be controlled, especially agricultural activities.

### PREVIOUS FORESTRY STUDIES

According to studying the flora and fauna in the Phu Wiang National Park of Thitimetharoch (1998), the work set up 6 experimental plots, sizes 40x40 m<sup>2</sup>, at altitudes of 300, 400, 500, 600, 700, and 800 MSL (1 plot at each level, a total area of approximately 6 rai) in a perfect forest condition with evenness of the vegetations [1] as shown in Figure 1. A detailed botanical study from May 1995 to 1997 shows that plots 1 and 2 show dry dipterocarp forest and plot 3 shows mixed deciduous forest. Meanwhile, plot 4, plot 5 and plot 6 show dry evergreen forests. The dry dipterocarp forest was found to cover 50% of the total area and abundant at 200-500 MSL. In addition, deciduous forest covered 35% at 400-600 MSL and dry evergreen forest covered 15% at 500-844 MSL.

### RESULTS

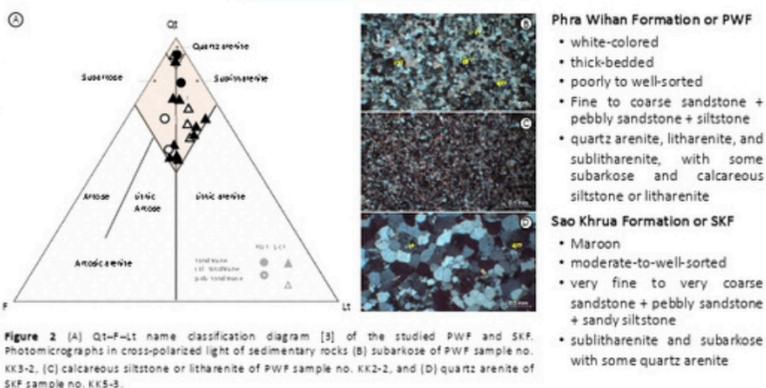


Figure 2 (A) Q1-F-Lt name classification diagram [3] of the studied PWF and SKF. Photomicrographs in cross-polarized light of sedimentary rocks (B) subarkose of PWF sample no. KK3-2, (C) calcareous siltstone or litharenite of PWF sample no. KK2-2, and (D) quartz arenite of SKF sample no. KK5-3.

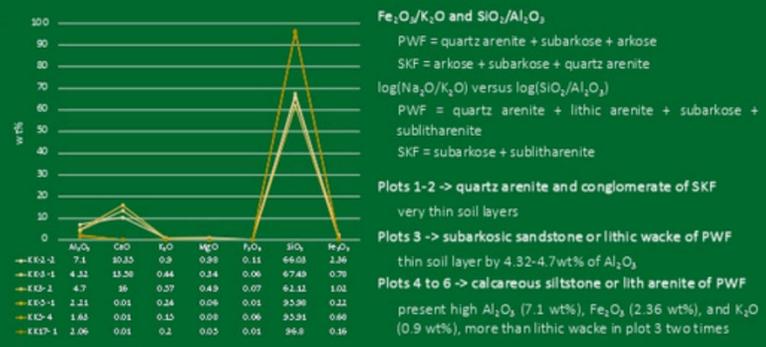
# Ecosystem Restoration Geo-Cultural Research

## Vegetation distribution in the Phu Wiang Valley

- SKF (Plots 1-2): Quartz arenite and conglomeratic sandstone with thin, dry soils → **dry dipterocarp forest.**
- PWF (Plot 3): Subarkosic sandstone (lithic wacke) with moderate Al<sub>2</sub>O<sub>3</sub> (≈4.5 wt%) → **deciduous forest.**
- PWF (Plots 4-6): Calcareous siltstone and litharenite with higher Al<sub>2</sub>O<sub>3</sub> (7.1 wt%), Fe<sub>2</sub>O<sub>3</sub> (2.36 wt%), and K<sub>2</sub>O (0.9 wt%) → **dry evergreen forest.**
- Forest distribution is controlled by lithology and soil composition, not elevation alone.

### DISCUSSION & CONCLUSION

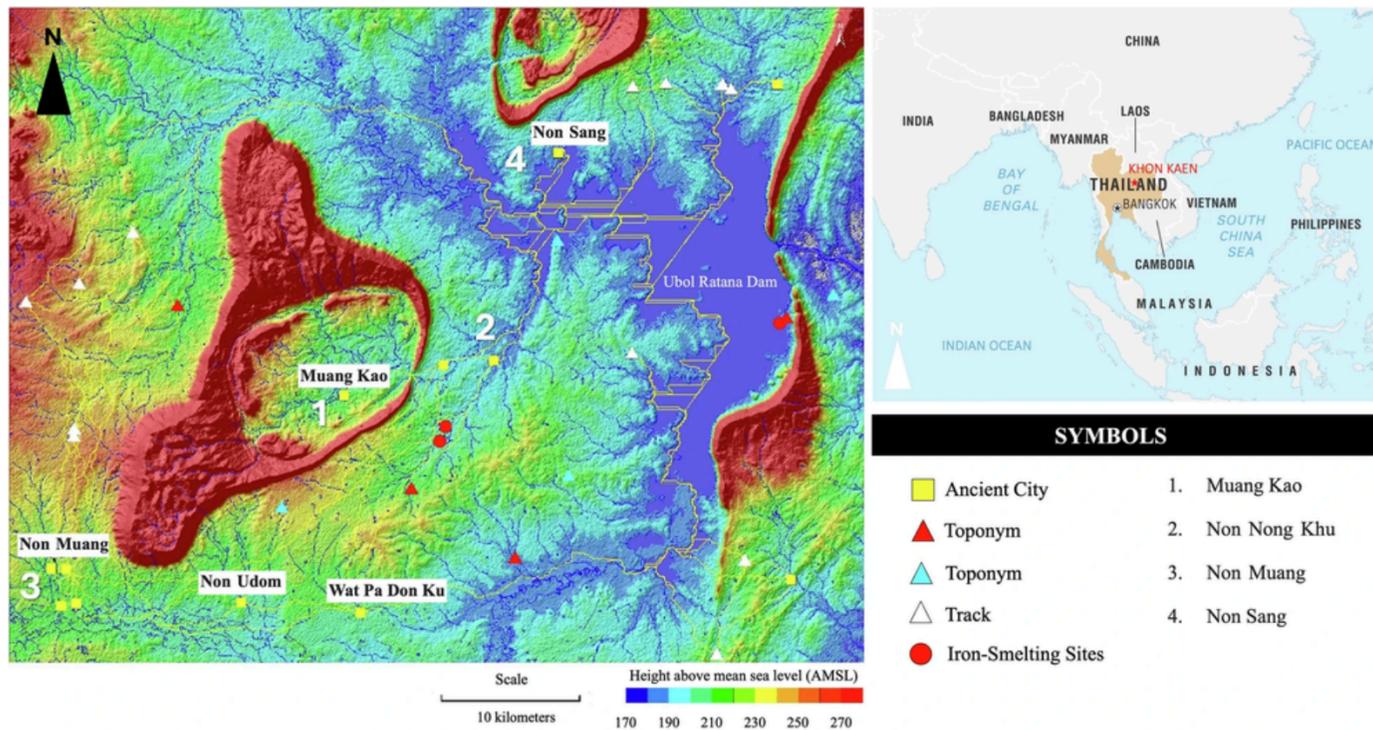
The botanical and forestry data describe that all three types of forest can occur at any height in the experimental plot. The discovery of trees in forest families that are clearly different according to the height above sea level is a result of different geological characteristics, especially lithology. Therefore, this work links the previous forestry studies of sandstones in the area. The dry dipterocarp forest (plots 1-2) grows well in areas with very dry and shallow soil layers corresponding to the quartz arenite of SKF. In the Phra Wihan Formation, there are two types: (1) the deciduous forest of plot 3 - subarkose (lithic wacke) producing a high amount of soil and (2) a dry evergreen forest of plots 4 to 6 - highly weathered litharenite (siltstone) or arkose producing large quantities and retaining higher moisture than subarkose. Thus, the subarkose are effective for deciduous forest growth, while arkoses are suitable for the growth of trees in dry evergreen forests that need moisture over the year. To summarize, the factors of vegetation growing are not only elevation and humidity but also linked to geological characteristics, affecting soil minerals that are important to plant nutrients. However, some flora in the area covered by sedimentary rocks may be heterogeneous forests at the same elevation linked with non-homogeneous geological characteristics of sedimentary strata similar to this area, which presents many kinds of rocks in each formation.



# Ecosystem Restoration Geo-Cultural Research

## Ancient Sīma stone heritage

- Sandstone artifacts and Sīma stones in Khon Kaen Geopark show diverse lithologies: Ban Ruea sandstones → sublitharenite. Tham Phra Kho Khat → quartz arenite and sublitharenite. Sop Nam, Ban Kut Kaen, Wat Pa Don Ku → litharenite.
- $\text{SiO}_2/\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3/\text{K}_2\text{O}$  classify rocks as Fe-sandstone, quartz arenite, litharenite, sublitharenite, arkose, wacke, Fe-siltstone, and siltstone.
- Rb/Sr links Ban Ruea and Wat Pa Don Ku to the Nam Phong Formation, while Tham Phra Kho Khat aligns with the Phra Wihan Formation.
- Findings reveal multiple sandstone sources and enhance understanding of ancient quarrying and heritage conservation.



# GEOLOGICAL INSIGHTS INTO ORE GENESIS AND ANCIENT METALLURGY IN KHON KAEN GEOPARK, THAILAND: GEOCHEMICAL AND PETROGRAPHIC EVIDENCE FROM SLAG, LATERITES, AND HOST ROCKS

Vimoltip Singtuen,<sup>1\*</sup> Ajcharanan Nakdee,<sup>1</sup> Burapha Phajuy,<sup>2</sup>

<sup>1</sup> Department of Geotechnology, Faculty of Technology, Khon Kaen University, Khon Kaen 40002 Thailand  
<sup>2</sup> Department of Geological Sciences, Faculty of Science, Chiang Mai University, Chiang Mai 50200 Thailand  
 \*vimoltipst@gmail.com, vimosi@kku.ac.th



# Ecosystem Restoration Geo-Cultural Research

## Reddish Sandstone to the Iron ore genesis

- Laterite samples contain 36–41 wt% Fe<sub>2</sub>O<sub>3</sub>, 12–18 wt% Al<sub>2</sub>O<sub>3</sub>, and 0.6–1.4 wt% TiO<sub>2</sub>, indicating iron enrichment through tropical weathering.
- Geochemical data reveal kaolinite formation, Fe–Mn enrichment, and variable ferritic–kaolinitic compositions.
- REE and major oxide patterns suggest sources from sedimentary, volcanic, and metamorphic rocks.
- Field and chemical evidence confirm ancient smelting activity, with slag derived from Fe-rich laterites and residual weathering of arkosic sandstone in oxidizing conditions.

Associate Professor Vimoltip Singtuen, Ph.D. | Khon Kaen University



### INTRODUCTION

Khon Kaen Geopark (KKGp), or "Phu Wiang," located in northeastern Thailand, exhibits a distinctive basin-like geomorphology surrounded by concentric mountain ranges on the Khorat Plateau. The geological framework of the area is dominated by Mesozoic continental sedimentary rocks of the Khorat Group, encompassing the Nam Phong, Phu Kradung, Phra Wihan, Sao Khua, Phu Phan, Khok Kruat, and Mahasarakham Formations as well as Quaternary sediments. These units collectively represent a succession of Triassic to Cretaceous fluvial-lacustrine deposits, composed primarily of red sandstones, siltstones, mudstones, and occasional conglomerates. Recent surveys have revealed extensive accumulations of ancient iron slag along the eastern margin of Phu Wiang District, indicating prehistoric metallurgical activities. However, the provenance and formation processes of these materials remain poorly constrained.

### OBJECTIVE & METHODOLOGY

This study investigates the geochemical and mineralogical composition, as well as the genesis, of lateritic soils and associated materials to assess their potential as ancient iron ore sources.

The results will provide insight into the regional georesource and ancient smelting technologies, contributing valuable scientific data/evidence to support Khon Kaen Geopark's nomination for UNESCO Global Geopark recognition.



### PETROGRAPHY

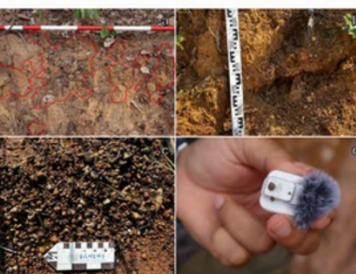
Macroscopic analysis identified two **laterite types—nodular and recemented**—with physical and textural variations among **slag samples**, including **vesicular, flow-banded, and glassy** textures. These features, together with weak magnetism and dense structures, indicate high-temp. pyrometallurgical processes associated with ancient smelting activities.

Sandstone samples from Site 2, located near the **Nam Phong-Phu Kradung boundary** within Khon Kaen Geopark, are primarily arkosic sandstones, classified as **arkose** and **lithic arkose** according to Pettijohn (1974). These rocks consist of quartz, feldspar, and lithic fragments with siliceous, calcareous, and ferruginous cement. Sample KK3-1 represents fine- to medium-grained arkose with 14–30% quartz and 10–20% feldspar, while samples KK3-2 and KK3-3 are lithic arkoses containing 40–54% lithic fragments and lower feldspar. The mineralogy, which includes tourmaline and chlorite, indicates a mixed source of sedimentary, volcanic, and metamorphic terrains.

### FIELD OBSERVATION

Fieldwork in Phu Wiang District focused on stream terraces containing archaeometallurgical slag overlying sandstone and siltstone of the Nam Phong and Phu Kradung Formations.

Site 1 showed scattered slag and lateritic nodules, Site 2 displayed a complete soil profile with slag-rich upper layers and lateritic nodules above a sandstone base, Site 3 was linked to an ancient settlement with sandstone artifacts and limited slag, and Site 4 contained abundant slag and furnace remains.



Field observations at coordinates 48Q 226253E 1849328N: (a) distribution of slag fragments and kiln remains within the soil profile; (b) soil profile exhibiting lateritic nodules; (c) lateritic nodules exposed at the ground surface; and (d) some lateritic nodules exhibiting magnetic properties.

### CONCLUSION

The Khon Kaen Geopark in Phu Wiang District contains abundant metallic slag deposits near fluvial terraces underlain by iron-rich red sandstones. Slag samples exhibit dense, porous, and glassy pyrometallurgical textures, confirming ancient high-temperature smelting. Two main laterite types—nodular and recemented—were identified. Integrated petrographic and geochemical analyses reveal progressive lateritization, strongest in saprolitic horizons (B and C) with high Fe<sub>2</sub>O<sub>3</sub> and kaolinite contents. Sites 1–2 show moderate alteration and bauxitization trends, while Site 3 exhibits advanced ferric enrichment. Vertical profiles indicate Fe, Mg, K, and Mn accumulation in lateritic zones and leaching of Si and Ca. Parent arkosic sandstones of the Phu Kradung Formation, composed mainly of quartz and feldspar, underwent oxidation of Fe-bearing minerals and sulfate interaction, producing goethite, gypsum, and kaolinite. The close association of slag and lateritic nodules near archaeological areas supports evidence of ancient local iron smelting using lateritic ores, linking geological processes with historical metallurgical activity in the geopark.

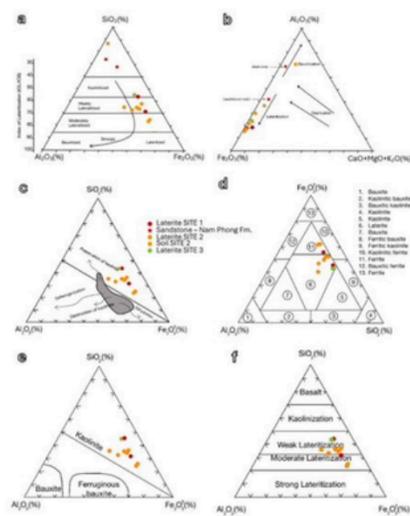
### GEOCHEMISTRY

Geochemical analysis reveals that laterites contain 36–61 wt% Fe<sub>2</sub>O<sub>3</sub>, 11–23 wt% Al<sub>2</sub>O<sub>3</sub>, and 20–40 wt% SiO<sub>2</sub>, while iron slags are richer in Fe<sub>2</sub>O<sub>3</sub> (52–69 wt%) and lower in silica (16–30 wt%). Sandstones show high SiO<sub>2</sub> (65–72 wt%) and moderate Al<sub>2</sub>O<sub>3</sub> (14–18 wt%), whereas soils are silica-rich (85 wt%) with low Fe<sub>2</sub>O<sub>3</sub> (2.6 wt%).

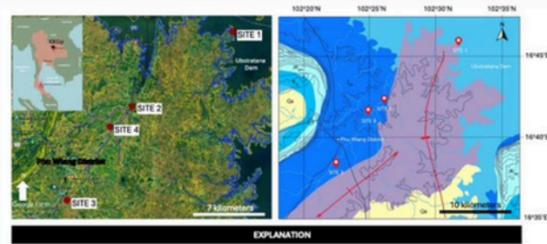
Ternary diagrams (SiO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub>-Fe<sub>2</sub>O<sub>3</sub>) demonstrate variable lateritization intensity among sites, ranging from weak to strong.

Samples from Sites 2 and 3 indicate kaolinite formation and aluminium (Al) enrichment, signifying bauxitization and laterite alteration.

Laterites from Sites 1 and 2 display mixed laterite–ferrite characteristics, while Site 3 is ferritic (Fe) and kaolinite-rich, confirming progressive weathering and Fe-enrichment during laterite formation.

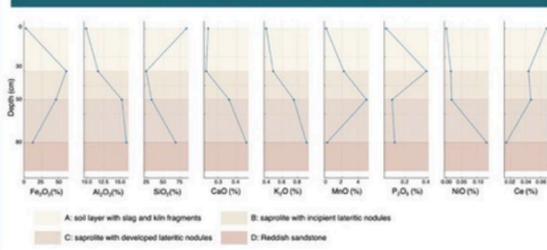


Geochemical classification and lateritization trends of lateritic samples, sandstones, and soils based on modified ternary diagrams: (a) SiO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub>-Fe<sub>2</sub>O<sub>3</sub> diagram illustrating lateritization trends and laterite development index, modified from Scheilermann (1981,1986); (b) Al<sub>2</sub>O<sub>3</sub>-(CaO+Na<sub>2</sub>O+K<sub>2</sub>O)-Fe<sub>2</sub>O<sub>3</sub> (A-L-F) diagram showing chemical concentration trends in lateritic samples, modified from Baboobak et al. (2004); (c) SiO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub>-Fe<sub>2</sub>O<sub>3</sub> ternary diagram illustrating geochemical evolution during bauxitization, modified from Bauvaux (1991); (d) Fe<sub>2</sub>O<sub>3</sub>-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> diagram for bauxite classification, modified from Aleva (1994); (e) SiO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub>-Fe<sub>2</sub>O<sub>3</sub> ternary diagram for bauxite classification, modified from Bouange et al. (1996); (f) SiO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub>-Fe<sub>2</sub>O<sub>3</sub> diagram highlighting lateritization trends and indices in the study area, modified from Scheilermann (1986).



### LATERITIC PROCESS

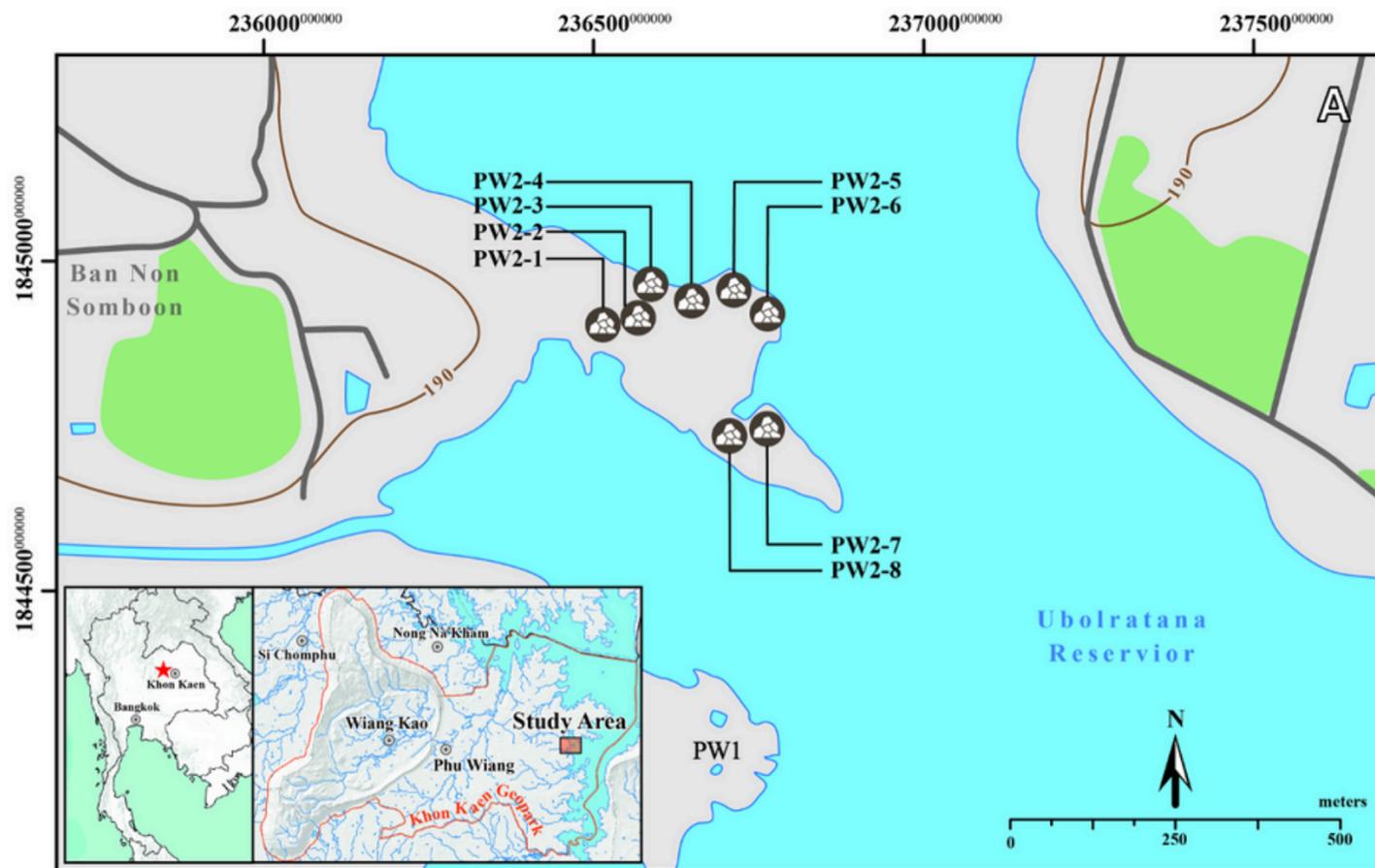
At Site 2, near the confluence of the Huai Nam Yang and Huai Nam Bong streams, the stratigraphy comprises four horizons: (A) loamy soil, (B–C) saprolitic layers rich in laterite, and (D) unweathered sandstone of the Nam Phong Formation. Laterite predominates in Horizons B and C, where Fe<sub>2</sub>O<sub>3</sub>, MgO, and K<sub>2</sub>O concentrations are highest, while SiO<sub>2</sub> decreases with depth. These geochemical patterns suggest iron enrichment through groundwater leaching and downward transport from upper layers, consistent with gossan and supergene processes. Feldspar weathering produced kaolinite, while oxidation of Fe-bearing minerals in arkosic sandstone generated limonite, gypsum, and kaolinite. The occurrence of iron nodules likely reflects ancient smelting activity, paralleling evidence from other Khorat Plateau archaeological sites.



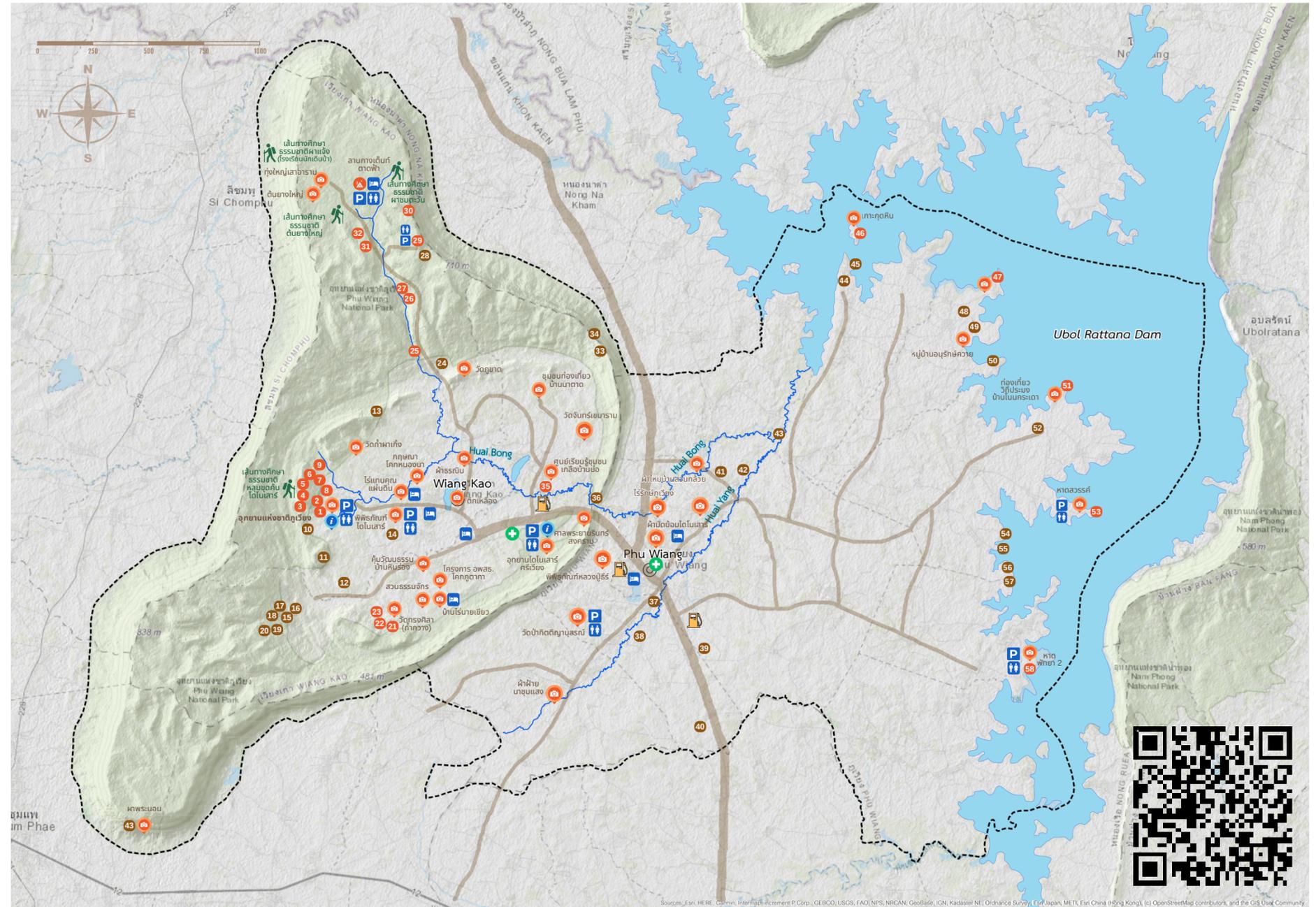
# Ecosystem Restoration Geo-Cultural Research

🔥 Archaeometallurgical study of Late Iron Age smelting

- Large slag mounds and vitrified furnace debris
- Glassy slag matrices with skeletal olivine, plagioclase, spinel oxides, and metallic prills, indicating high-temp. reduction and rapid cooling.
- 3 slag types: Fe-rich slags, Si-rich slags, and Mixed slags.
- High Al<sub>2</sub>O<sub>3</sub> contents (15–36 wt%) caused viscous slags requiring adaptive furnace control. Lateritic nodules (up to 68 wt% Fe<sub>2</sub>O<sub>3</sub>) confirm local laterite as ore source.
- Thermoluminescence dating (1,425–1,956 cal yr BP) indicates prehistoric iron production with advanced smelting adaptation to Fe-rich laterites.



# Community Engagement & Empowerment



## แผนที่แหล่งท่องเที่ยว/เรียนรู้อุทยานธรณีขอนแก่น

Geotourism Map Khon Kaen Geopark Map

สัญลักษณ์และชื่อแหล่งธรณีวิทยา Legend & Geosites Name

-  เส้นขอบเขตอุทยานธรณีขอนแก่น  
Khon Kaen Geopark Borderline
-  แหล่งธรณีวิทยา (เปิดให้ท่องเที่ยว)  
Geosites (Open for Tourism)
-  แหล่งธรณีวิทยา  
Geosites
-  สถานที่ท่องเที่ยว  
Tourist Attraction
-  ศูนย์บริการข้อมูล  
Information Center
-  ที่จอดรถ  
Parking Area
-  สุขาสาธารณะ  
Public Toilet
-  ที่พักแรม  
Accommodation

# Community Engagement & Empowerment

## 01 Local Enterprises: “Phu Wiang Dinosaur Valley Learning Community”

A collaborative network of local guides, artisans, and entrepreneurs promoting community-based geotourism through hands-on learning activities. The initiative strengthens local identity by integrating geological heritage with cultural and educational experiences, fostering sustainable income and stewardship of the Phu Wiang Geosite.

## 02 Geofood/Product Development – Linking Goods Identity to Local Geology

Local products such as salt, clay-seasoned dishes, and mineral-inspired snacks are developed under the Geofood concept, connecting cuisine to the area’s unique geological environment. This initiative supports circular economy models, enhances local branding, and demonstrates the direct relationship between geology, soil composition, and agricultural productivity.

## 03 Geotrails and geo-education programs fostering inclusive participation

The geopark’s geotrails and educational activities are designed to engage schools, tourists, and community members in geological interpretation and conservation. Through field learning, storytelling, and guided tours, participants gain appreciation of earth processes and local heritage—promoting inclusive education, accessibility, and community pride.

# Community Engagement & Empowerment

## Local Enterprises: “Phu Wiang Dinosaur Valley Learning Community”



# Community Engagement & Empowerment

## Geofood/Product Development – Linking Goods Identity to Local Geology



# Community Engagement & Empowerment

## Geofood/Product Development – Linking Goods Identity to Local Geology



# Community Engagement & Empowerment

## Geofood/Product Development – Linking Goods Identity to Local Geology

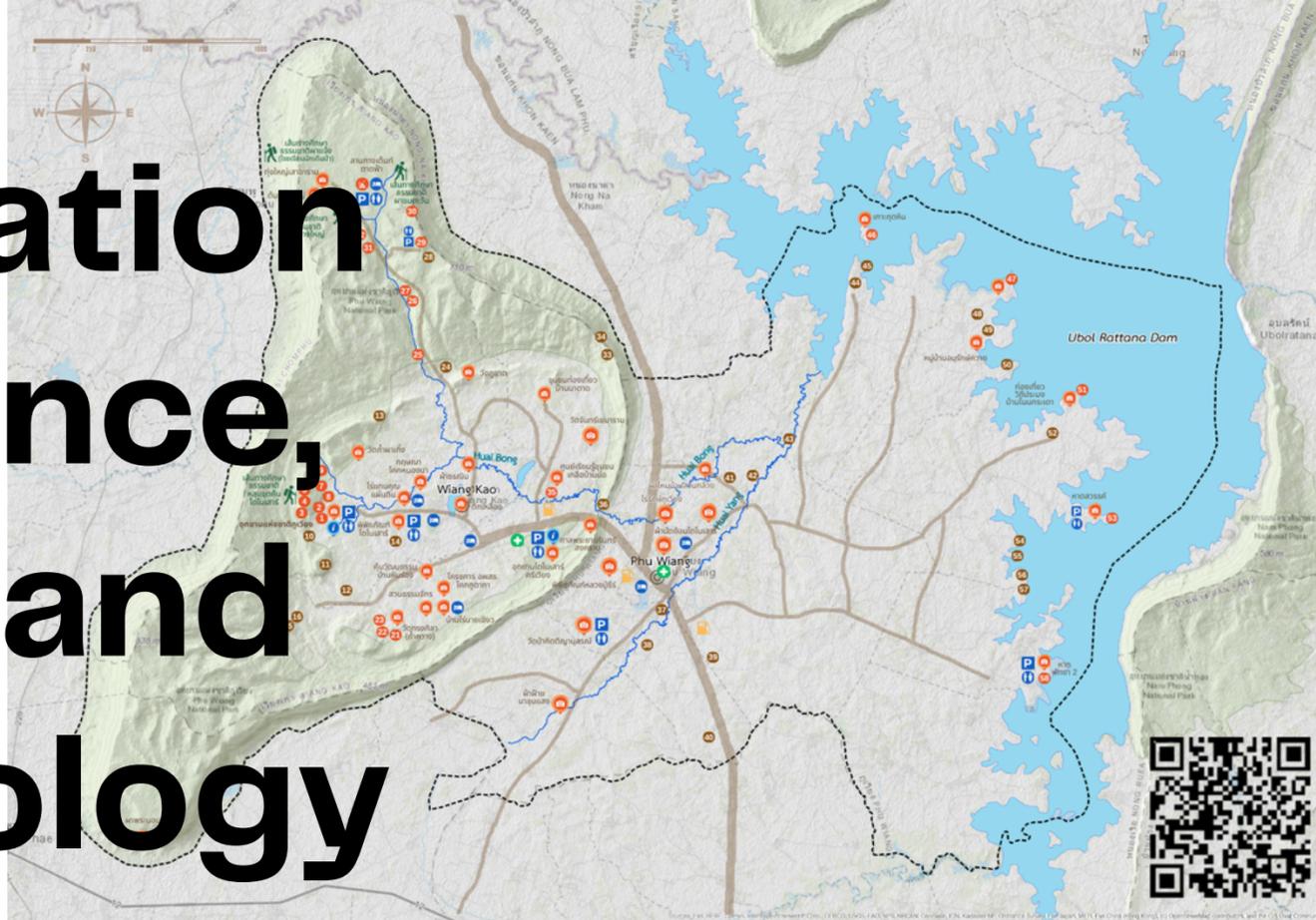


# Community Engagement & Empowerment

Geotrails and geo-education programs fostering inclusive participation



# Integration of Science, Policy, and Technology



## แผนที่อุทยานธรณีขอนแก่น Khon Kaen Geopark Map

### สัญลักษณ์และชื่อแหล่งธรณีวิทยา Legend & Geosites Name

- เส้นขอบเขตอุทยานธรณีขอนแก่น Khon Kaen Geopark Borderline
- แหล่งธรณีวิทยา (เปิดให้ท่องเที่ยว) Geosites (Open for Tourism)
- แหล่งธรณีวิทยา Geosites
- สถานที่ท่องเที่ยว Tourist Attraction
- ศูนย์บริการข้อมูล Information Center
- ที่จอดรถ Parking Area
- สุขาสาธารณะ Public Toilet
- ที่พักแรม Accommodation

- 1 ลานยูเรเนียม Uranium Field
- 2 หลุมขุดค้นที่ 3 : ห้วยประตูตีหมา Excavation Site 3 : Huai Pratu Tee Ma
- 3 ผากาลเวลา Kan Wela Cliff (Chrono Cliff)
- 4 หลุมขุดค้นที่ 1 : ภูประตูตีหมา Excavation Site 1 : Phu Pratu Tee Ma
- 5 สุสานหอย 130 ล้านปี 130-million-year Shell Bed
- 6 หลุมขุดค้นที่ 2 : ท่าเจ็ย Excavation Site 2 : Tham Jia
- 7 ท่าเจ็ย Tham Jia (Bat Sandstone Cave)
- 8 หินตารางหมากรุก Chessboard Rock
- 9 หลุมขุดค้นที่ 9 : หินลาดยาว Excavation Site 9 : Hin Lad Yao
- 10 หลุมขุดค้นที่ 5 : ข่าหญาคา Excavation Site 5 : Sam Ya Kha
- 11 หลุมขุดค้นที่ 6 : ตงเค็ง Excavation Site 6 : Dong Keng
- 12 หลุมขุดค้นที่ 7 : ภูน้อย Excavation Site 7 : Phu Noi
- 13 หลุมขุดค้นที่ 4 : โนนสาวเอ้ Excavation Site 4 : Non Sao Ae
- 14 หินลาดพระบาท Hin Lat Phra Bot
- 15 ลานหินปุ่ม Lan Hin Pum (Nodule Rock Field)
- 16 ประติมากรรมหินเสาเจียง Sao Chaliang (Rock Pillar)
- 17 น้ำตกทับพญาเสือ Thap Phaya Seu Waterfall
- 18 ถ้ำหินลาดหัวเมย Tham Hin Lad Hua Mei Rock Shelter
- 19 ถ้ำประทุนเขวียน Tham Praturon Gwian Rock Shelter
- 20 ถ้ำฝ่ามือแดง Tham Fah Mue Daeng (Red Handprint Rock Shelter)
- 21 ถ้ำกวาง Tham Kwang Temple Rock Shelter
- 22 หินร่อง Hin Rong (Large Rock Channel)
- 23 ลานตากหมอก Lan Tak Mok (Mist Viewpoint Rock Terrace)
- 24 น้ำตกตาดอ่างริน Tat Hang Rin Waterfall
- 25 น้ำตกวังสักสัว Wang Sak Siw Waterfall
- 26 หลุมขุดค้นที่ 8 : รอยตีนไดโนเสาร์ Excavation Site 8 : Dinosaur Footprints
- 27 หินหัวใจไดโนเสาร์ Dinosaur Heart Rock
- 28 กุมภลักษณ์หินลาดอ่างทง Hin Lad Ang Kop Potholes
- 29 ผาขมตะวัน Chom Tawan Cliff (Sunrise Cliff)
- 30 ถ้ำสุริยันจันทร์ Suriyan-Chanthra Cave (Sun - Moon Cave)
- 31 น้ำตกตาดฟ้า Tat Fa Waterfall
- 32 น้ำตกแก่งม่วง Kaeng Muang Waterfall
- 33 ผาน้ำเที่ยง Pha Nam Thiang
- 34 ถ้ำแมงป่อง Tham Maeng Pong (Scorpion Rock Shelter)
- 35 เกลือไดโนเสาร์บ้านบ่อ Ban Bo Dino Rock Salt
- 36 ปากช่องภูเวียง Phu Wiang Water Gap
- 37 ตะกรันเหล็กโบราณบ้านกลางหวา Ban Klang Hao Ancient Iron Slag
- 38 ภูขี้เถ้า Phu Khi Bao Ancient Iron Slag
- 39 ลานหินแตกบ้านอ่างศิลา Ban Ang Sila Cracky Rock Terrace
- 40 สระน้ำท่าแม่ Tham Khae (Crocodile) Pond
- 41 บ่อหินบ้านเรือ Ban Ruea Quarry
- 42 เมืองโบราณบ้านเรือ Ban Ruea Ancient City
- 43 สบห้วยบอง Huai Bong Confluence
- 44 ธรณีโครงสร้างบ้านโป่งสังข์ Ban Pong Sang Geological Structures
- 45 แหล่งหินบ้านโป่งสังข์ Pong Sang Quarry
- 46 เกาะกุดหิน Ko Kut Hin
- 47 จุดชมวิวกู่ขมพู Thung Chom Phu Viewpoint
- 48 แหล่งหินกรวดมดดอนตู Don Du Conglomerate Quarry
- 49 ภูหินเหล็กไฟ Phu Hin Lek Fai
- 50 โรงสูบน้ำห้วยขี้หนู Huai Khi Nu Pumping Station
- 51 จุดชมวิวน้ำโนนกระเตา Ban Non Kradao Viewpoint
- 52 แหล่งลูกธัญบ้านโนนกระเตา Ban Non Kradao Laterite
- 53 หาดสวรรค์ Had Sawan (Paradise Beach)
- 54 เหมันพระธาตุ Noen Phra That Ancient Iron Slag
- 55 ตะกรันเหล็กโบราณบ้านโนนสนมบูรณ์ Ban Non Somboon Ancient Iron Slag
- 56 แหล่งศิลาแลงแบบมวลพอก Lateritic Iron Nodules Site
- 57 โรงสูบน้ำหนองกุงเขิน Nong Kung Soen Pumping Station
- 58 หาดพัทยา 2 Had Pattaya 2 (Pattaya-like Beach)

Associate Professor Vimoltip Singtuen, Ph.D.  
Khon Kaen University



## การท่องเที่ยวเชิงธรณีในอุทยานธรณีขอนแก่นด้วย AI CHATBOT Geotourism in Khon Kaen Geopark Empowered by AI CHATBOT

ภายใต้โครงการหน่วยขับเคลื่อนนวัตกรรมเพื่อสังคม (Social Innovation Driving unit) ประจำปีพื้นที่ภาคตะวันออกเฉียงเหนือตอนกลาง (SID-ESAN) ประจำปี พ.ศ. 2568

โดย รศ.ดร.วิมลทิพย์ สิงห์ทอง<sup>1</sup> คุณพลาสวรรค์ ปรัชญกุลปต์<sup>2</sup> คุณอดุลยวิทย์ กาวีระ<sup>3</sup> คุณเพชรสายฟ้า พงษ์พาณิชย์<sup>2</sup>  
<sup>1</sup>สาขาวิชาเทคโนโลยีธรณี คณะเทคโนโลยี ภาควิชาลัยขอนแก่น <sup>2</sup>อุทยานธรณีขอนแก่น <sup>3</sup>ศูนย์ศึกษาวิจัยและพิพิธภัณฑ์ไดโนเสาร์ จังหัดขอนแก่น



ONLINE TOOL FOR GEO-GUIDE

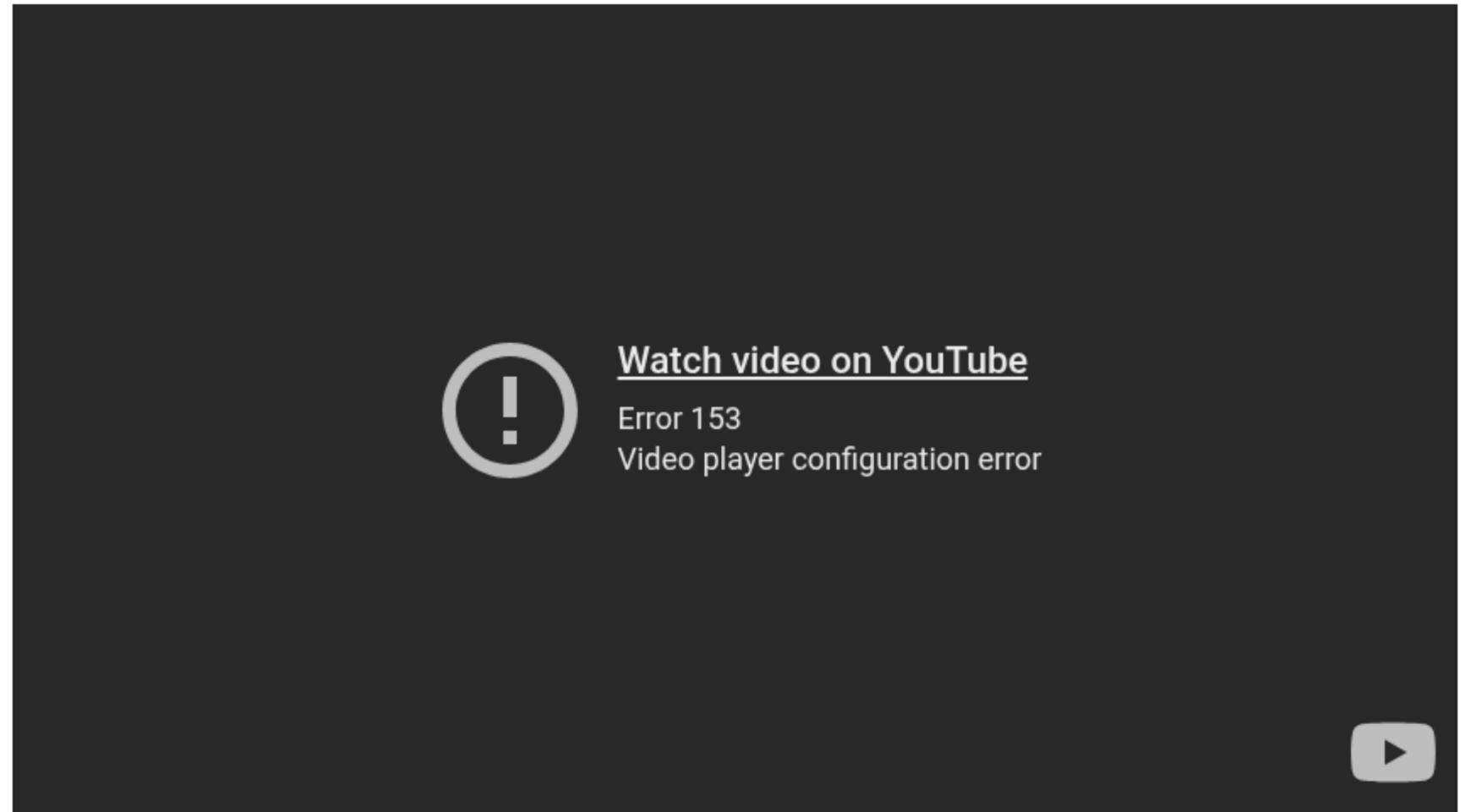
100% GEOLOGY FOR TOURISM



GEOLOGY AI CHATBOT

- Culture**  
Traditional agriculture, fisheries, and textile crafts
- Archaeology**  
Ancient Sima stones and metal slag remains
- Biodiversity**  
Rich flora and fauna adapted to sandstone terrain
- Mineralogy**  
Uranium and iron-laterite ore deposits
- Hydrology**  
Sandstone-controlled streams and waterfalls
- Paleontology**  
Dinosaur fossils and footprints discovery site
- Geodiversity**  
Mesozoic formations and sandstone landforms

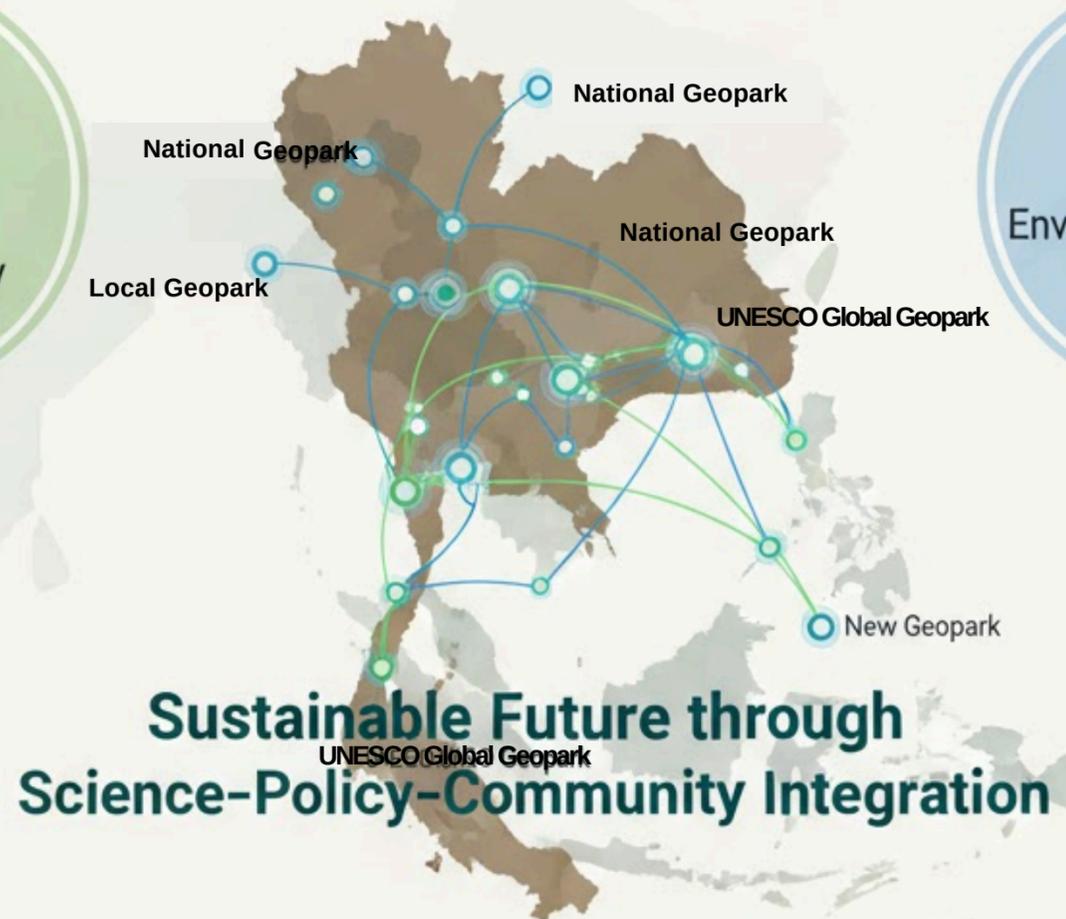
# Integration of Science, Policy, and Technology



# VISION 2030: Expanding Regional Geopark Networks under BCG/ESG Frameworks

**BCG:**  
Bio-Circular-Green Economy

**ESG:**  
Environmental, Social, Governance



**Environment:** Geoconservation, Biodiversity, Climate Action

**Social:** Education, Livelihoods, Community Engagement

**Governance:** Policy, Cooperation, Global Standards

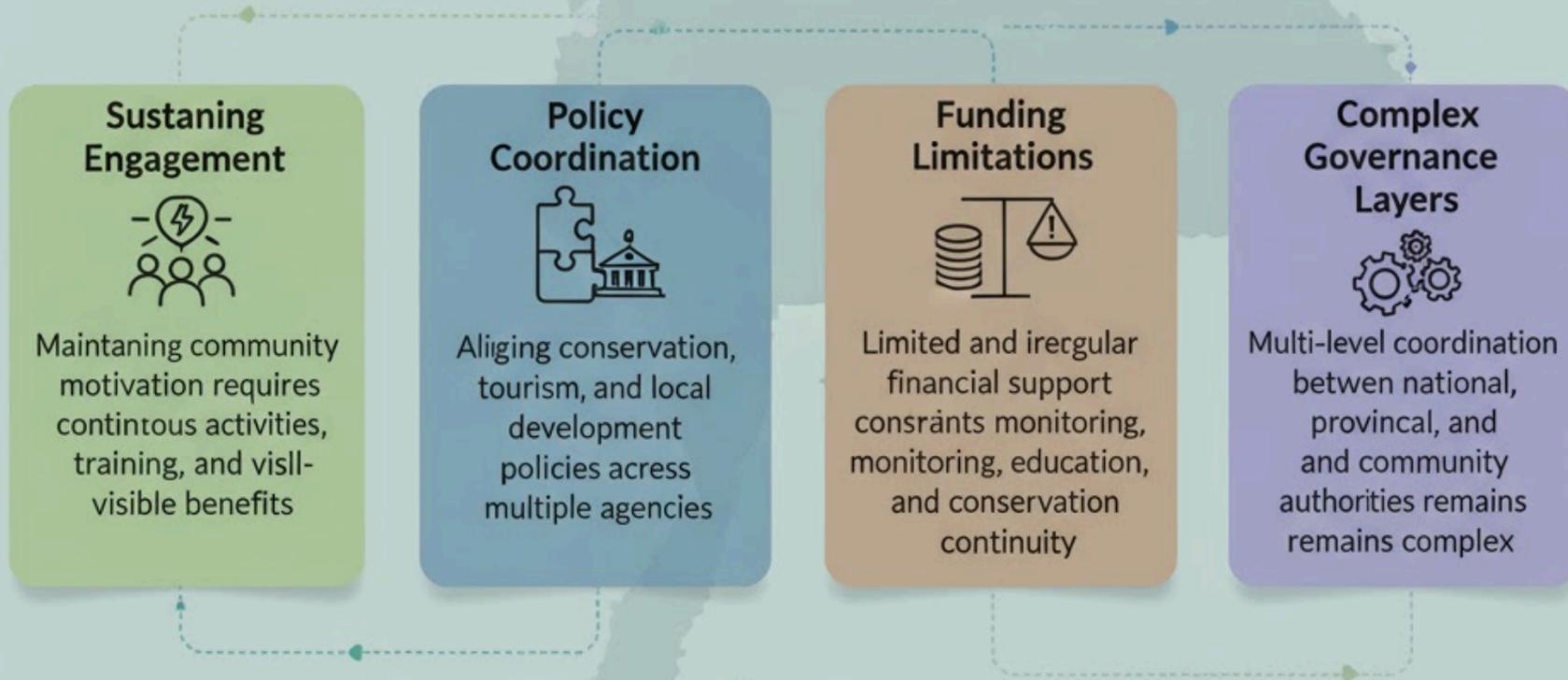
## REFLECTIONS & KEY MESSAGES

### Lessons learned

- **Collaboration:** Strong partnerships among communities, universities, local government, and private sectors ensure shared ownership and effective implementation of geopark initiatives.
  - Khon Kaen Provincial Administrative Organization
  - Department of Mineral Resources
  - Khon Kaen University
  - Department of National Parks, Wildlife and Plant Conservation
  - Fine Arts Department
  - Community Enterprise
  - Local Schools
- **Communication:** Continuous dialogue and information exchange build understanding, transparency, and trust among stakeholders.
- **Continuity:** Long-term commitment and consistent follow-up beyond short-term projects sustain impact and strengthen local engagement.

# Challenges

## Challenges in Sustaining Geopark Management and Ecosystem Restoration



- Paleontological Resource Protection
- Wildlife and Plant Conservation Act - Department of National Museums Act  
Wildlife and National Parks - Wildlife, and Plant Protection  
Fine Arts Department
- Antiquity, Antiques, and National Museums - Department of Culture
- Tourism Licensing Regulations - Department of Tourism
- Food Safety Standards - Ministry of Public Health

Addressing these challenges requires Science-Policy-Community synergy

## REFLECTIONS & KEY MESSAGES

### Challenges

- **Sustaining Engagement:** Maintaining community motivation requires ongoing activities, training, and visible benefits.
- **Policy Coordination:** Aligning conservation, tourism, and local development policies across multiple government levels remains complex.
- **Funding:** Limited and irregular financial support constrains monitoring, education, and conservation continuity.

# Conclusion

- **SDG 4:** Promotes geo-education and lifelong learning through schools and community programs.
- **SDG 8:** Creates local jobs via community-based geotourism and Geofood enterprises.
- **SDG 11:** Strengthens sustainable communities and cultural identity through heritage tourism.
- **SDG 12:** Encourages responsible production using local materials and sustainable practices.
- **SDG 13:** Raises awareness on climate resilience through education and conservation.
- **SDG 15:** Protects geoheritage, ecosystems, and biodiversity.
- **SDG 17:** Builds partnerships among communities, universities, and UNESCO networks.



# Conclusion



## Geopark as a Bridge for Sustainability

- The Khon Kaen Geopark exemplifies how **geoscience, culture, and community engagement** can be harmonized to restore ecosystems and strengthen local resilience.
- It demonstrates that **conservation and development** are not conflicting goals but complementary pathways toward sustainability.

## Integration is the Key

- Effective restoration depends on **integrating science, policy, and local wisdom** – ensuring that knowledge translates into action.
- **Multidisciplinary collaboration** among universities, government agencies, and communities enables a more adaptive and inclusive management model.

## Empowering People through Knowledge and Innovation

- Tools like **Geoeducation, Geofood/Geoproduct entrepreneurship, and AI-based digital platforms (Geo-HOO)** empower communities to take part in sustainable management.
- Science becomes meaningful when it is **localized, communicated, and co-owned** by the people.

## The Way Forward

- Sustaining engagement, improving policy coordination, and securing long-term funding remain ongoing challenges.
- Yet, with strong partnerships and the **BCG–ESG frameworks**, regional Geopark networks can evolve into powerful platforms for **ecosystem restoration and sustainable landscape governance**.



# Acknowledgements

This research was financially supported by

- National Science Research and Innovation Fund (NSRF)
- National Research Council of Thailand (NRCT)
- National Innovation Agency (NIA)

The authors sincerely thank the Department of Mineral Resources, Khon Kaen Geopark Office, and the Department of National Parks, Wildlife and Plant Conservation for their kind cooperation and field assistance. Appreciation is also extended to the Fine Arts Department for heritage coordination and to the local community enterprises of Phu Wiang Dinosaur Valley Learning Community for their active participation and knowledge sharing. Special thanks are given to Khon Kaen University and Chiang Mai University for laboratory facilities and technical support, and to all students and local guides who contributed to fieldwork and educational outreach activities.



# Acknowledgements

The authors and the Khon Kaen Geopark research team humbly express our deepest condolences on the passing of Her Majesty Queen Sirikit The Queen Mother, the beloved Queen Mother of Thailand.

We pay our highest tribute to Her Majesty's lifelong devotion to the Thai people, her dedication to nature conservation, cultural heritage preservation, and sustainable development—values that continue to inspire our work in geoconservation and community engagement.

May Her Majesty's benevolence and legacy live on forever in the hearts of the Thai people.