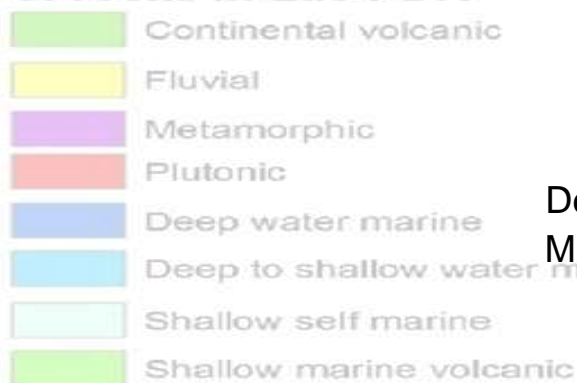


# THE GEOLOGY AND MINERAL RESOURCES OF LAO PDR

## Depositional environments of rocks in Lao PDR



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## Depositional environments of rocks in Lao PDR





## Country overview

Laos, officially the Lao People's Democratic Republic (Lao PDR), is located in Southeast Asia, in the center of the Mekong River region. The country is land-locked; it is bordered by Myanmar and People's Republic of China to the north-west, Vietnam to the east, Cambodia to the south and Thailand to the west. Laos has a population of 6-7 million and a land area of 236,800 km<sup>2</sup>. It has significant natural resources like minerals and hydro-electric power, timber, rubber and agricultural land. It is also a rising power in exporting electricity into the neighboring countries, such as Thailand, China and Vietnam and The Lao economy is accelerating rapidly due to the demands of its metals. The motto of Laos is **"Peace, Independence, Democracy, Unity and Prosperity"**.

Laos is characterized by steep terrain and narrow river valleys. The topography is largely mountainous in the northern part of the country with elevations typically ranging several hundreds of meters excluding the plain of Vientiane and the Plain of Jars in Xiangkhoang Province. The country has a tropical monsoon climate. Rainy season begins in May and continues to October, a dry and cool season is from November through February, and a hot dry season prevailing in March and April. Temperatures range from highs around 40 °C along the Mekong river valley in March and April to lows of 5 °C or less in the highlands. The country's average humidity varies between 87 % in rainy season and 69% in hot dry season.



Map of the Laos. Inset shows the location of the Laos in the southeastern Asia.

Laos has rich cultural history which dates back to hundreds of years. The most famous dynasty ruled in the country was the Lang Xang kingdom from the 14<sup>th</sup> century. In the relatively modern part of its history the country was a colony of France obtaining partial independence in 1949.

Laos has also been dragged into several civil wars and after a period of violence it gained full independence in 1953. This was followed by civil war and political disruption leading to the establishment of the Lao People's Revolutionary Party as the sole legal political party and declaration of the People's Democratic Republic in 1975.

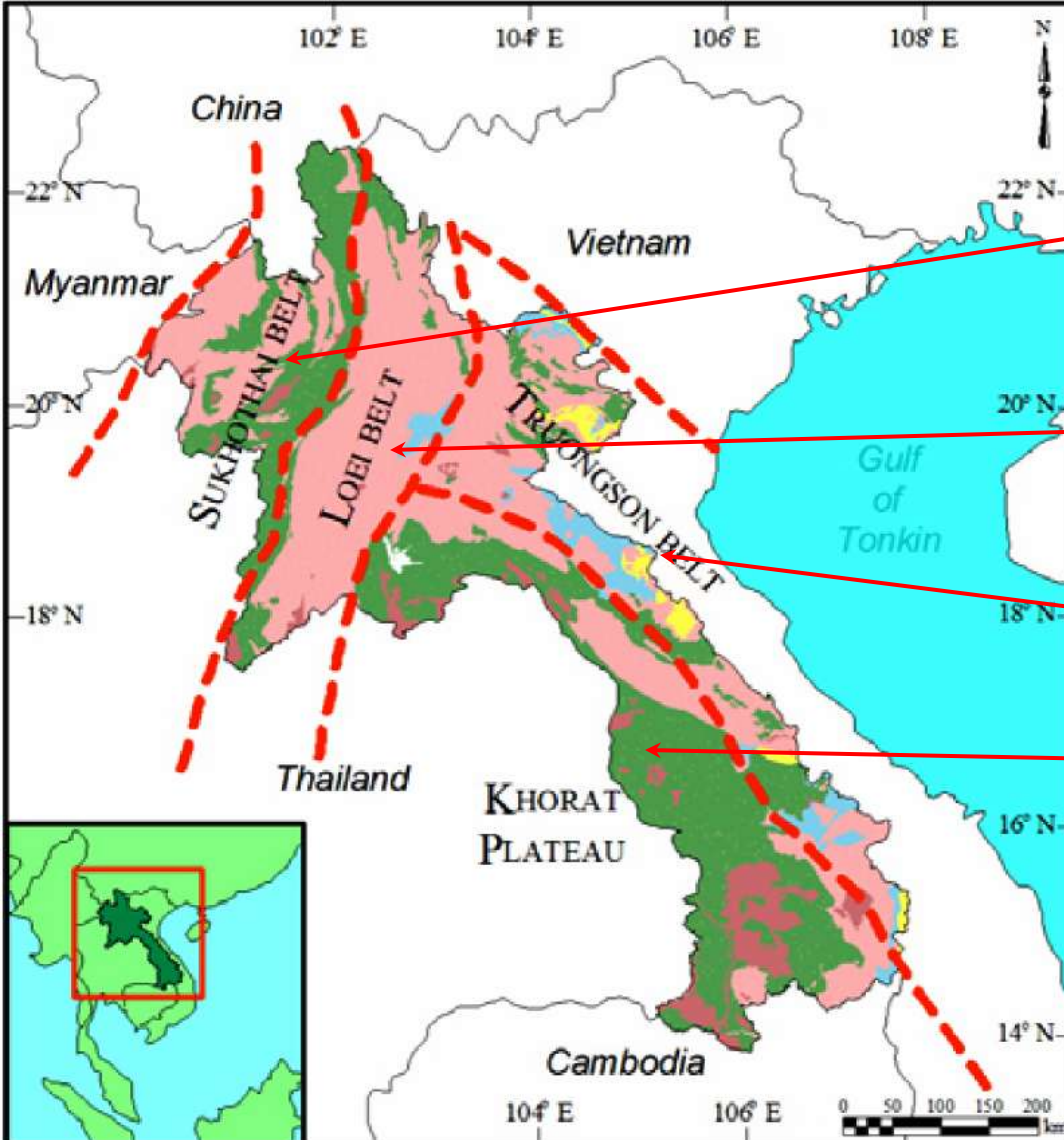
### Laos in a nutshell

Area	236,800 km <sup>2</sup>
Population	6.3 million (Mid 2009)
Population growth rate	1.8 % (2009)
Currency	Kip (LAK); 1 US\$ = 8000 Kip (June 2011)
Inflation	8 % (Aug 2010)
Main exports	Copper, gold, electricity, timber, garments
GDP / Per capita	6.3 US\$ billions / US\$ 984 (2010 estimate)
Economic growth	8.5 % (2010 estimate)



**"Peace, Independence, Democracy, Unity and Prosperity"**

## The Geological Structures



1. Sukhothai fold belt: mainly composed of Middle to Upper Paleozoic system and granitic rocks of the Late Paleozoic era.

2. Loei fold belt: mainly composed of Middle to Upper Paleozoic system, Lower Mesozoic system and granitic rocks of the Late Paleozoic era.

3. Truongson fold belt: mainly composed of Middle to Upper Paleozoic system and granitic rocks of the Late Paleozoic era .

4. Khorat Plateau: mainly Mesozoic group to Paleogene system.

### Legend

Cenozoic  
 Paleogene-Quaternary  
 Mesozoic  
 Triassic-Cretaceous

Paleozoic

Pre-cambrian

Silurian-Permian  
 Cambrian-Ordovician  
 Proterozoic



## Part I: General Geology and Geological History in Lao PDR.



The geological history of the country is briefly summarized and viewed through principal geologic periods

- Neoproterozoic (1000-545 Ma)
- Cambrian-Ordovician (545-440 Ma)
- Silurian-Devonian (440-360 Ma)
- Carboniferous-Permian (360-250 Ma)
- Triassic-Cretaceous (250-65 Ma)
- Paleogene-Quaternary (<65 Ma)

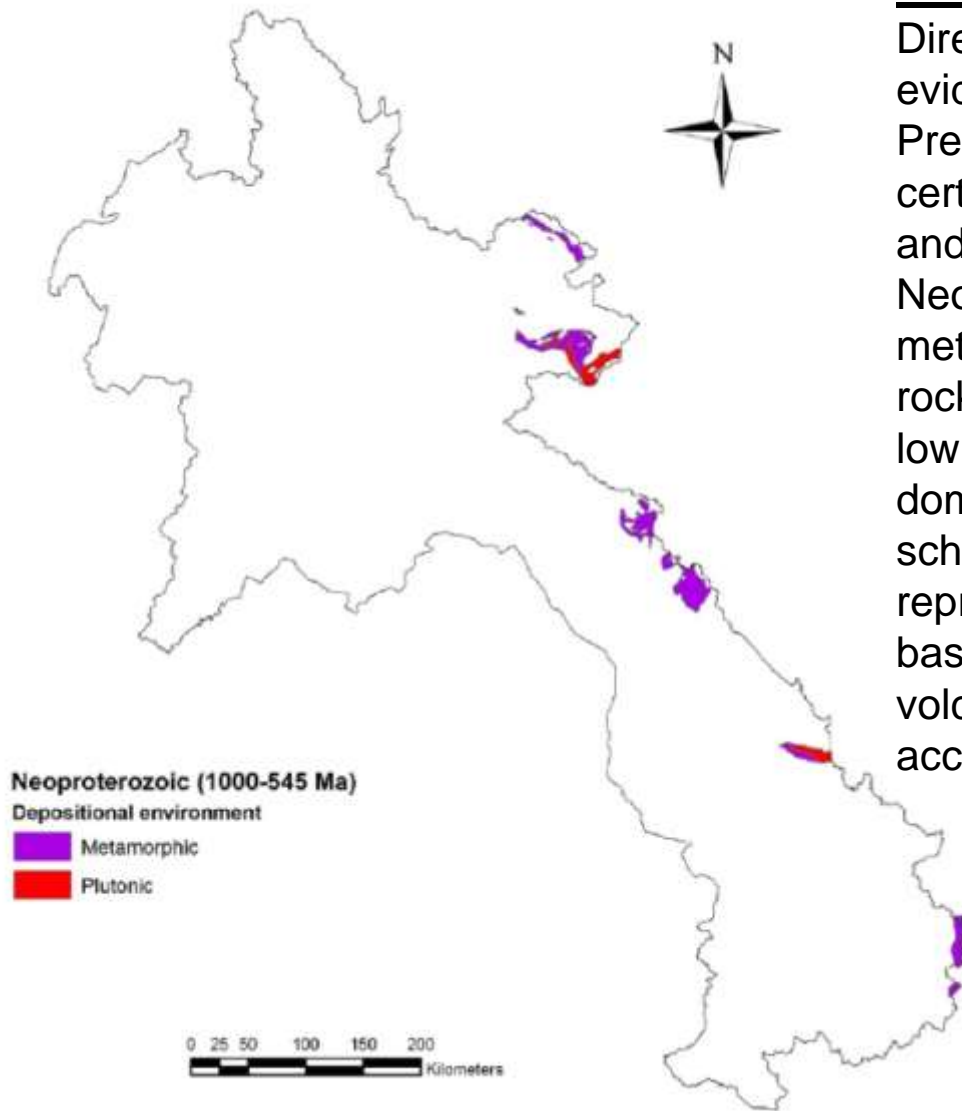
### Depositional environments of rocks in Lao PDR

- Continental volcanic
- Fluvial
- Metamorphic
- Plutonic
- Deep water marine
- Deep to shallow water marine
- Shallow self marine
- Shallow marine volcanic

0 25 50 100 150 200  
Kilometers

## **Neoproterozoic (1000-545 Ma)**

Direct geochronological or stratigraphic evidence of the existence of the Precambrian rocks are missing but certain areas in the northwest, northeast and southeast are believed to be Neoproterozoic (1000-545 Ma) due to metamorphic rocks in these areas. These rocks of Laos consist of gneisses and low to high-grade metasedimentary rocks dominated by porphyroplastic mica schists, arenites and limestones. They represent the older metamorphic basement on which the younger volcanosedimentary rocks have accumulated.



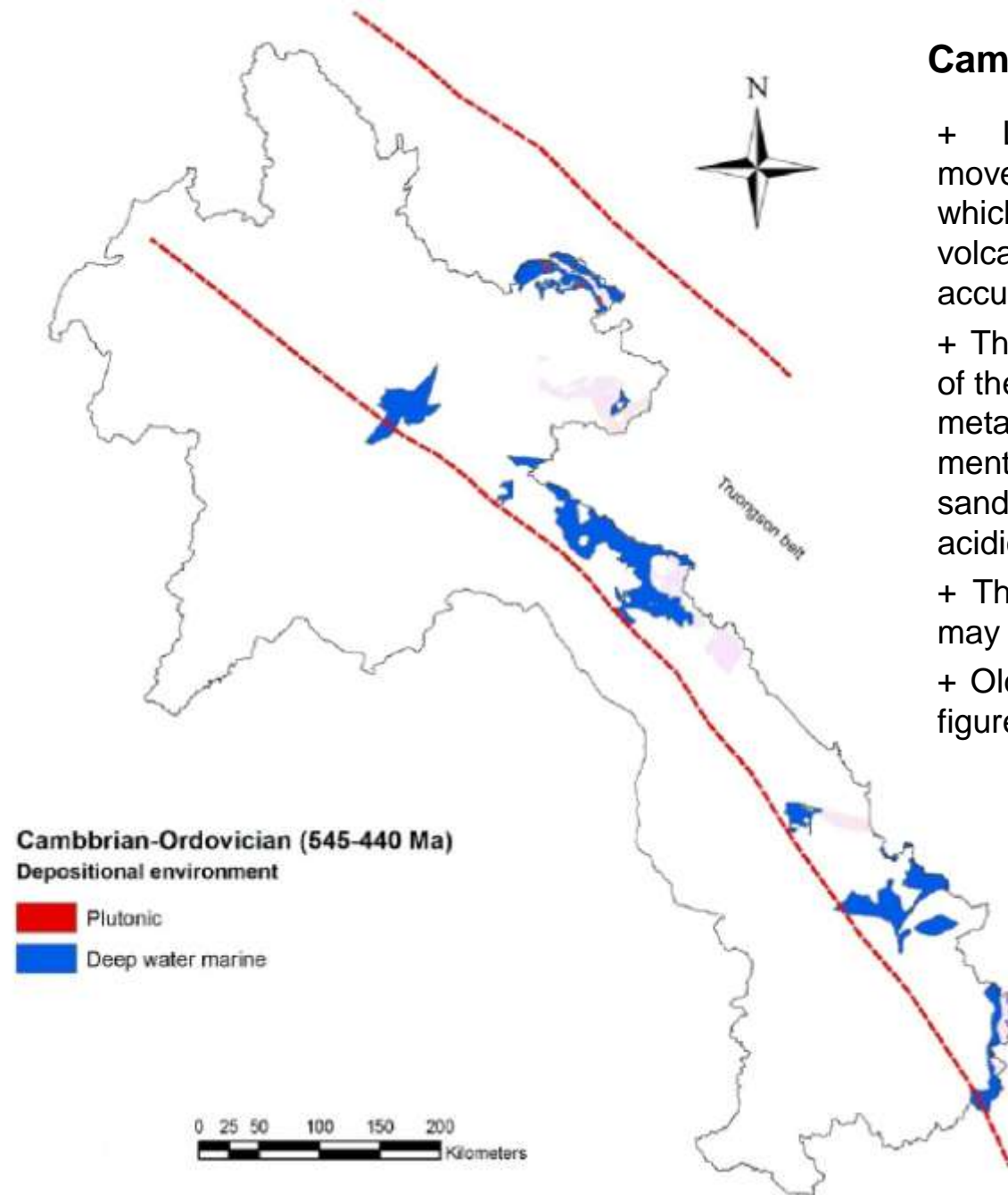
## Cambrian-Ordovician (545-440 Ma)

+ Large-scale NW-SE trending structural movements generated a deep marine basin into which Cambrian-Ordovician (545-440 Ma) volcanic and sedimentary sequences accumulated.

+ These rocks, now representing the lower parts of the Truongson belt, are characterized by slightly meta-morphosed deep marine volcanosedimentary rocks, i.e. mudrocks interbedded with sandstones, wackes, basic to intermediate and acidic lava flows and black limestone.

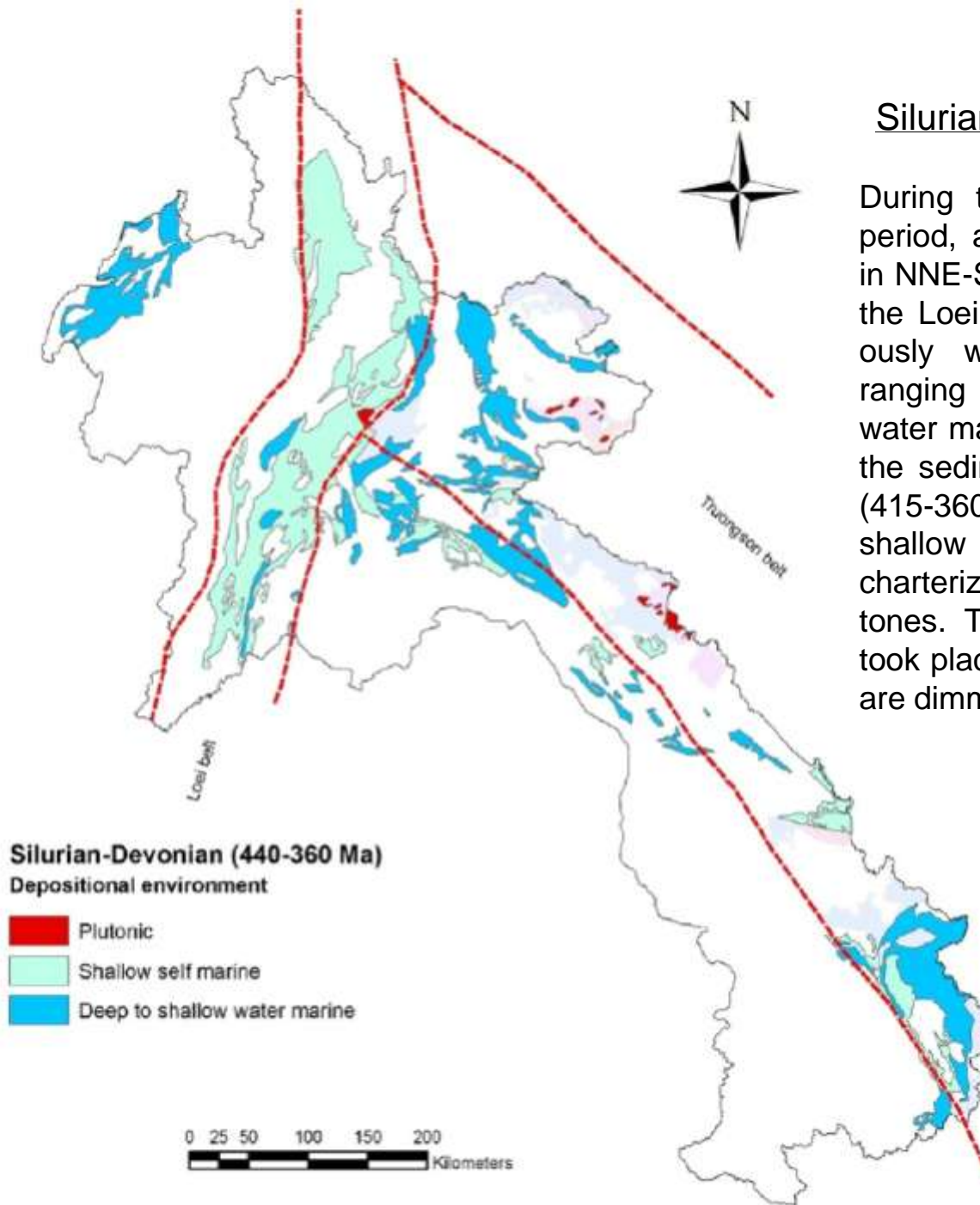
+ The plutonic rocks in the NW part of the belt may represent ophiolite succession.

+ Older Neoproterozoic areas are dimmed in the figure.



## Silurian-Devonian (440-360 Ma)

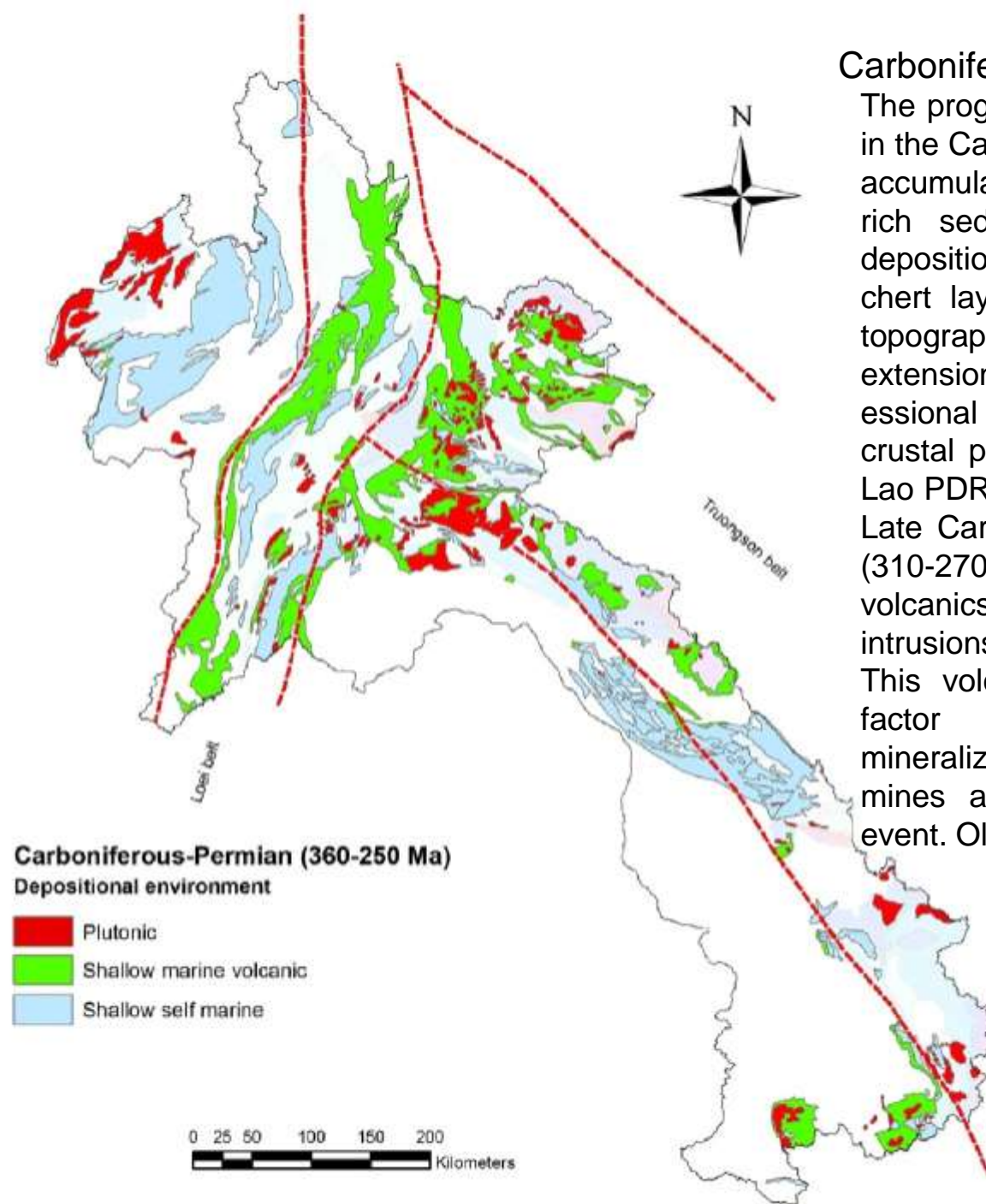
During the Silurian-Devonian (440-360 Ma) period, a major crustal structural movements in NNE-SSW direction led into development of the Loei belt which was first filled simultaneously with Truongson belt by sediments ranging from deep water muds into shallow water marine sandstones. The major phase of the sedimentation occurred during Devonian (415-360 Ma) including the development of shallow self depositional environment characterized by accumulation of muddy limestones. The extensive volcanism in Loei belt took place about 50-100 Ma later. Older areas are dimmed in the figure.





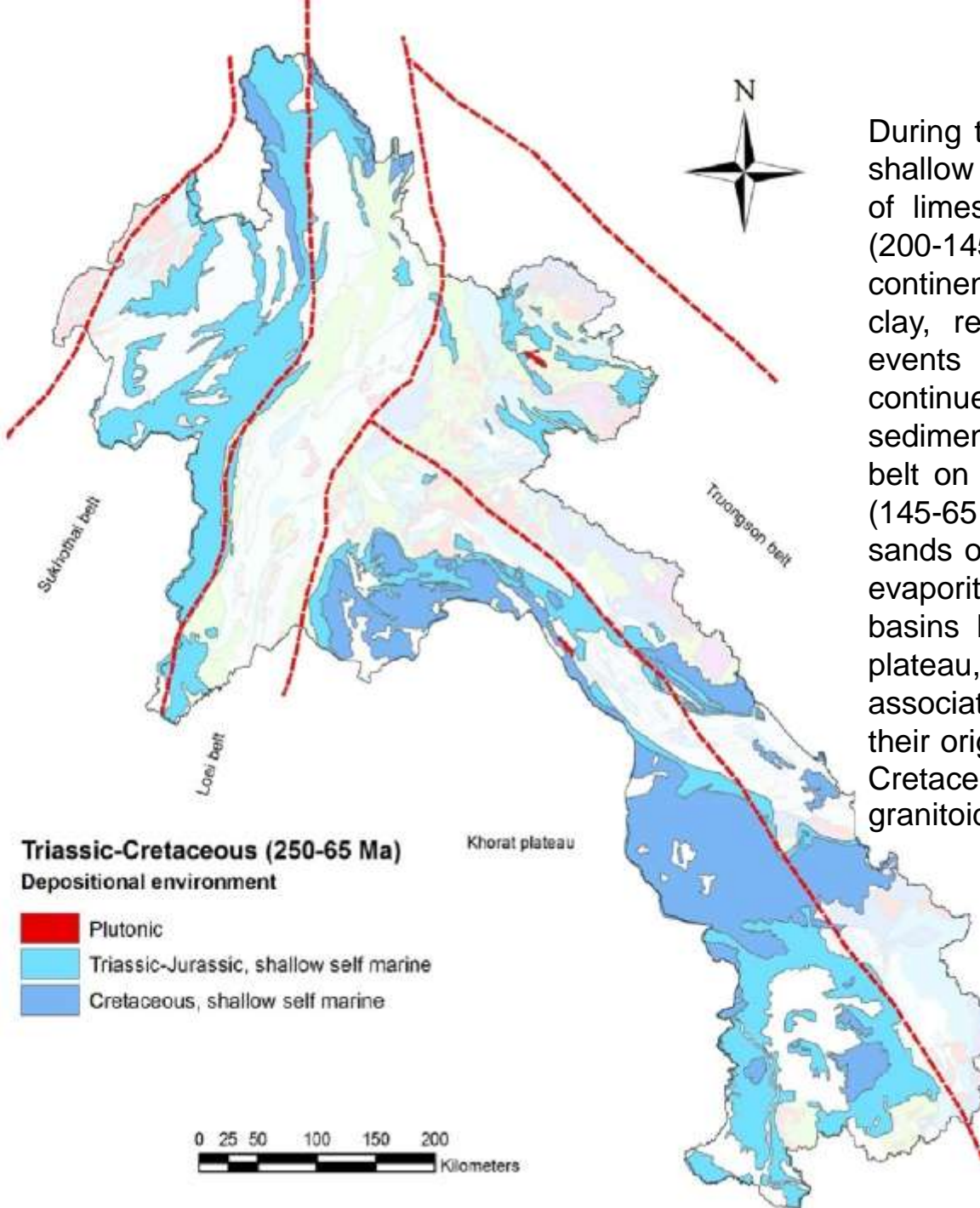
## Carboniferous-Permian (360-250 Ma)

The prograding shallow self sedimentation continued in the Carboniferous-Permian (360-250 Ma) period by accumulation of sands to fine-grained silty or clay-rich sediments with coal interbeds followed by deposition of extensive limestones with interbedded chert layers forming the present outstanding karst topography of the Loie belt. However, soon the extensional stress field was replaced by a compressional one that was related to the movements of crustal platforms in the northern part of the present Lao PDR. The Loie belt is characterized by extensive Late Carboniferous to Early Permian igneous event (310-270 Ma). It included extrusion of andesitic volcanics and formation of granitic subvolcanic intrusions probably related to a subduction episode. This volcano-plutonic event was the most critical factor regarding to the major copper-gold mineralizations in Lao PDR; Phu Kham and Sepon mines are genetically associated to the igneous event. Older areas are dimmed in the figure.



## Triassic-Cretaceous (250-65 Ma)

During the main part of the Triassic (250-200 Ma), shallow sea conditions prevailed with the deposition of limestone, but towards the middle of Jurassic (200-145 Ma) there occurred a gradual change into continental conditions indicated by proportion of clay, red sand and conglomerate. The collision events which had begun in the Late Paleozoic continued during the Mesozoic and caused the sedimentary deposits to fold to form the Sukhothai belt on the west of the Loei belt. The Cretaceous (145-65 Ma) was characterized by deposition of red sands over stable continental area. Mudstones and evaporitic sequences developed in shallow lagoonal basins limited to the cratonic area. In the Khorat plateau, the Mesozoic continental red beds associated with minor basalt fields have retained their original position. The plutonic rocks of Triassic-Cretaceous period are typically megacrystic granitoids. Older areas are dimmed in the figure.



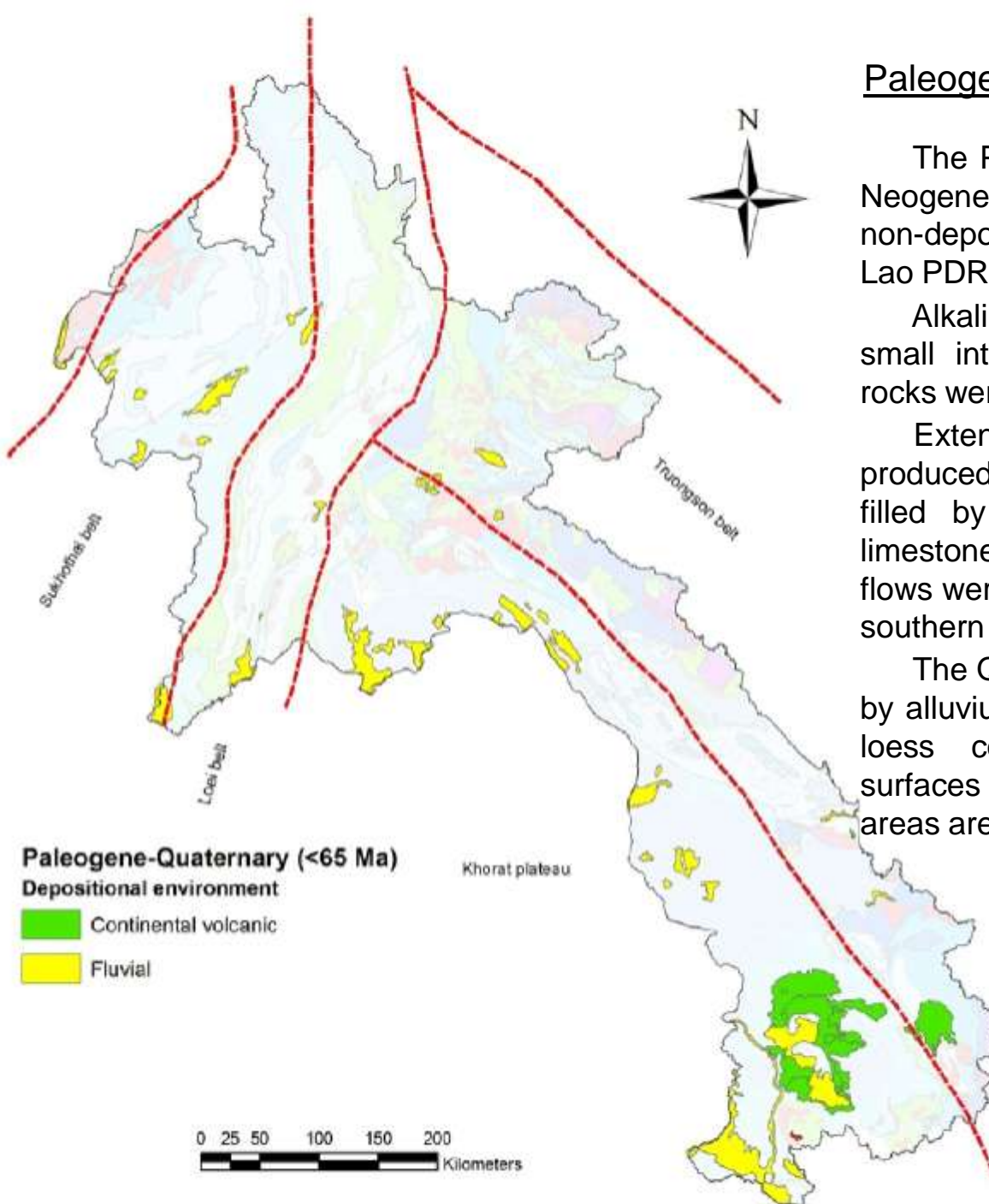
## Paleogene-Quaternary (<65 Ma)

The Paleogene (65-23-Ma) and beginning of the Neogene (23-5,3 Ma) periods were characterised by non-deposition over the entire area of the present Lao PDR.

Alkali basaltic lava flows were extruded, and small intrusions of gabbro, monzonite and acidic rocks were emplaced.

Extensional movements of Late Neogene age produced small "pull-apart" basins which became filled by fresh-water sequences with occasional limestones and lignite beds. Some basaltic lava flows were also extruded at this time especially in the southern part of the present Lao PDR area.

The Quaternary (<5.3 Ma) sequence is presented by alluvium in the present river system and regional loess cover. Lateritic intra-formational erosion surfaces exist within the Quaternary sequence. Older areas are dimmed in the figure,

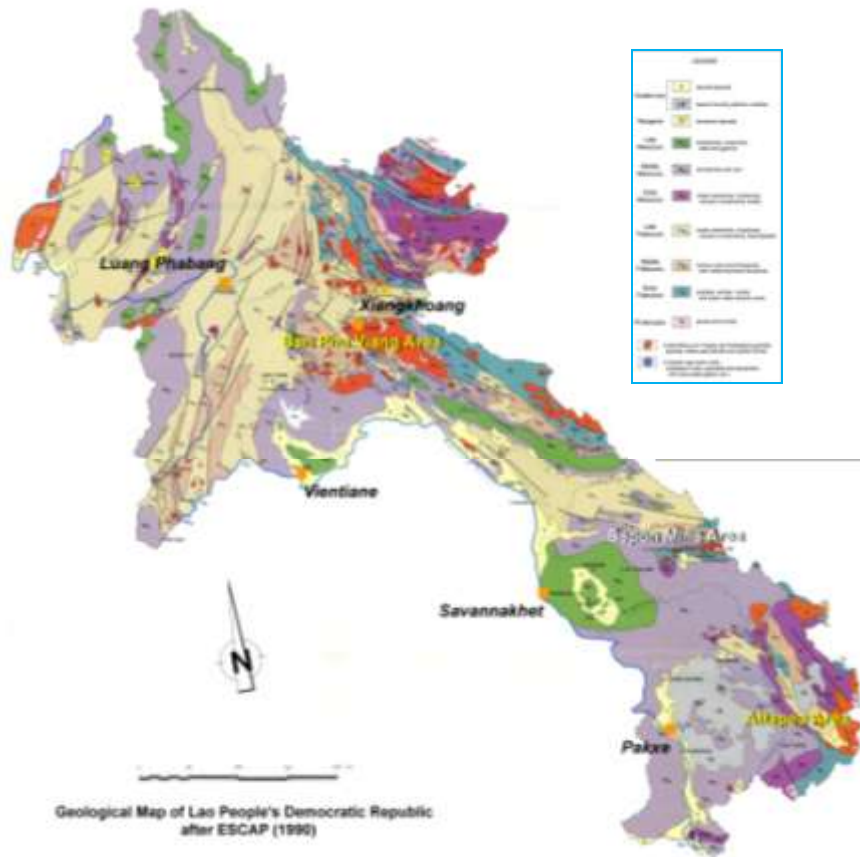




# Part II: Mineral Resources Development

## DATA REVIEW OF GEOLOGY AND MINERAL RESOURCES

### 1. Geological and Mineral resources map:



### Existing 1: 1,000,000 Geological and Mineral Resources Map (BGS 1991)

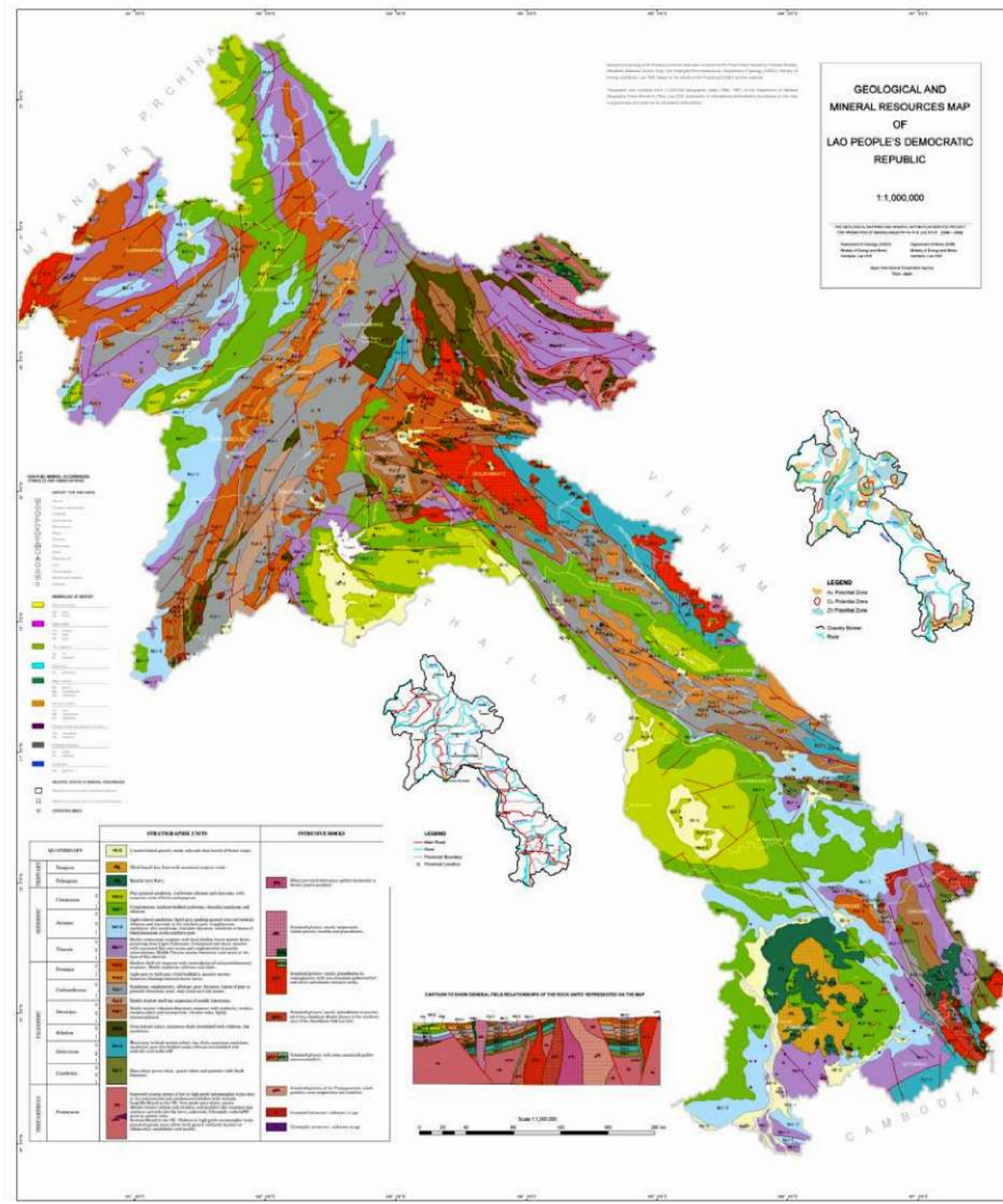
■ The 1:1,000,000 geological and mineral resources map published in 1991 is prepared by British Geological Survey and British Mineral Consultants Ltd., all known mineral occurrences are added on the map. Main source of information for this map is as follows:

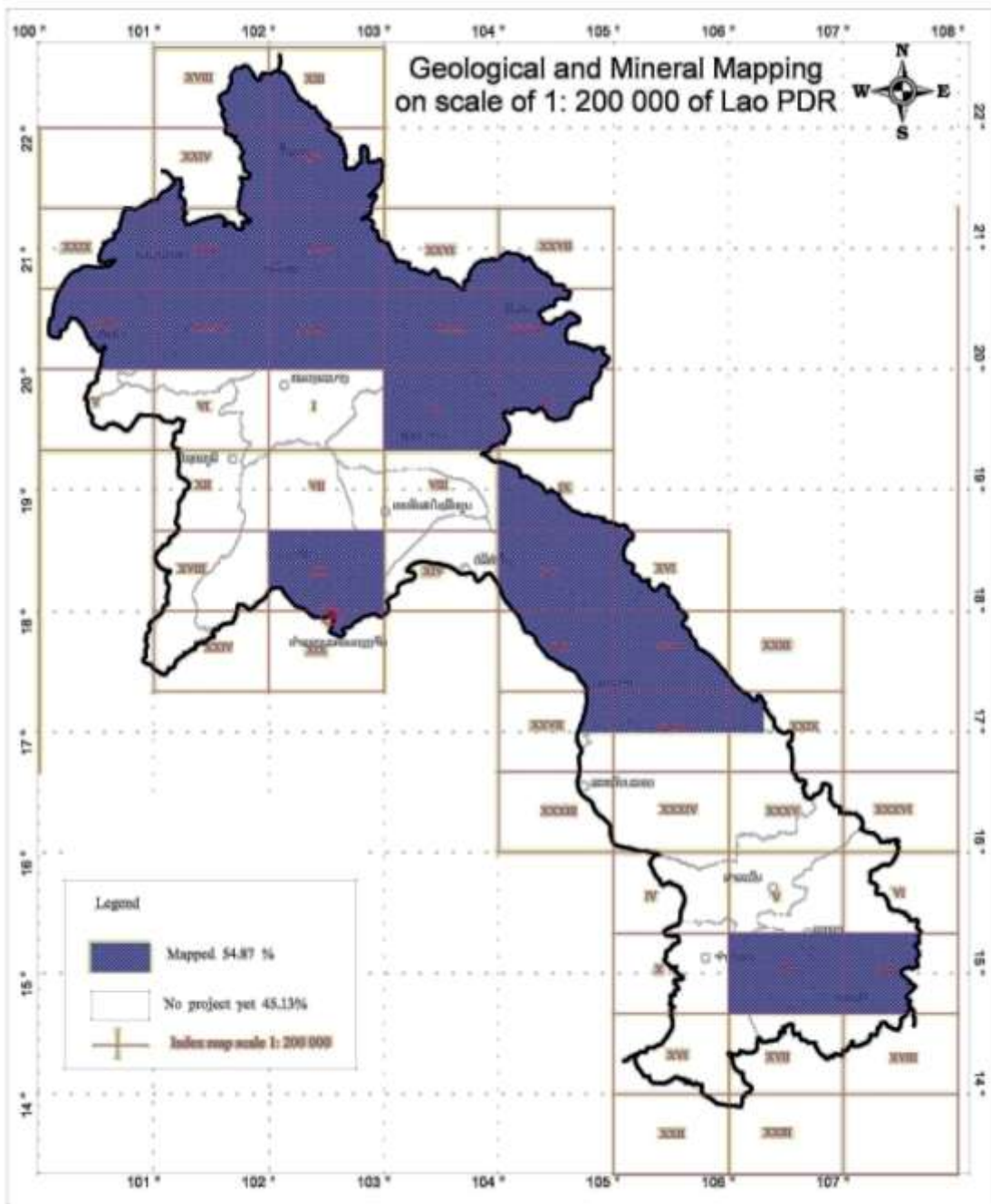
- ✓ Geological map at 1:500,000 over whole Indochina prepared by Service Geologique de l'Indochine, based in Hanoi, Vietnam, in 1930.
- ✓ Geological map of Xam Neua(northeast Lao PDR), Khang Khay(north of Xiengkhouang) and Vientiane area at 1:200,000 prepared by DGMV, in 1975 -1990.
- ✓ Geological map of whole Indochina at 1:1,000,000 prepared by DGMV, in 1988. Second edition was published in 1991.
- ✓ Summary geological map of Lao PDR at 1:1,500,000 prepared by ESCAP, in 1990.

# The 1:1,000,000 geological and mineral resources map (revised by JICA)

## Source of information:

1. 1:1,000,000 Mineral Resources Map of 1991 compiled by BGS showing **479** locations of mineral occurrence.
2. DGMV surveyed over central area and **151** localities were described as "Record Book of Mineral Deposits and Ore Occurrences",
3. Attapu district a **new copper occurrence** was discovered by the JICA Project and
4. In the northern part newly discovered mineral occurrences have been reported by DGMV survey team.

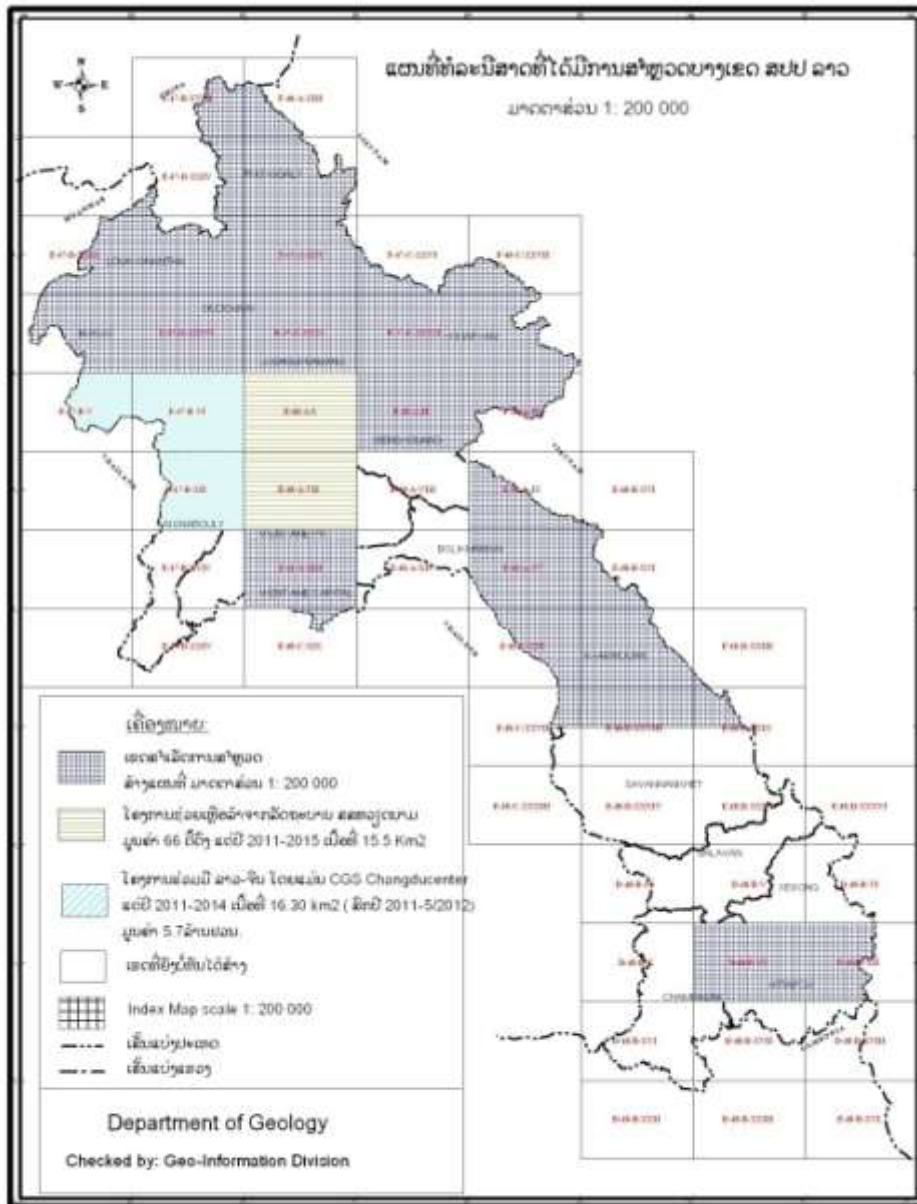




## The Geological and Mineral Resources Map on scale of 1:200,000

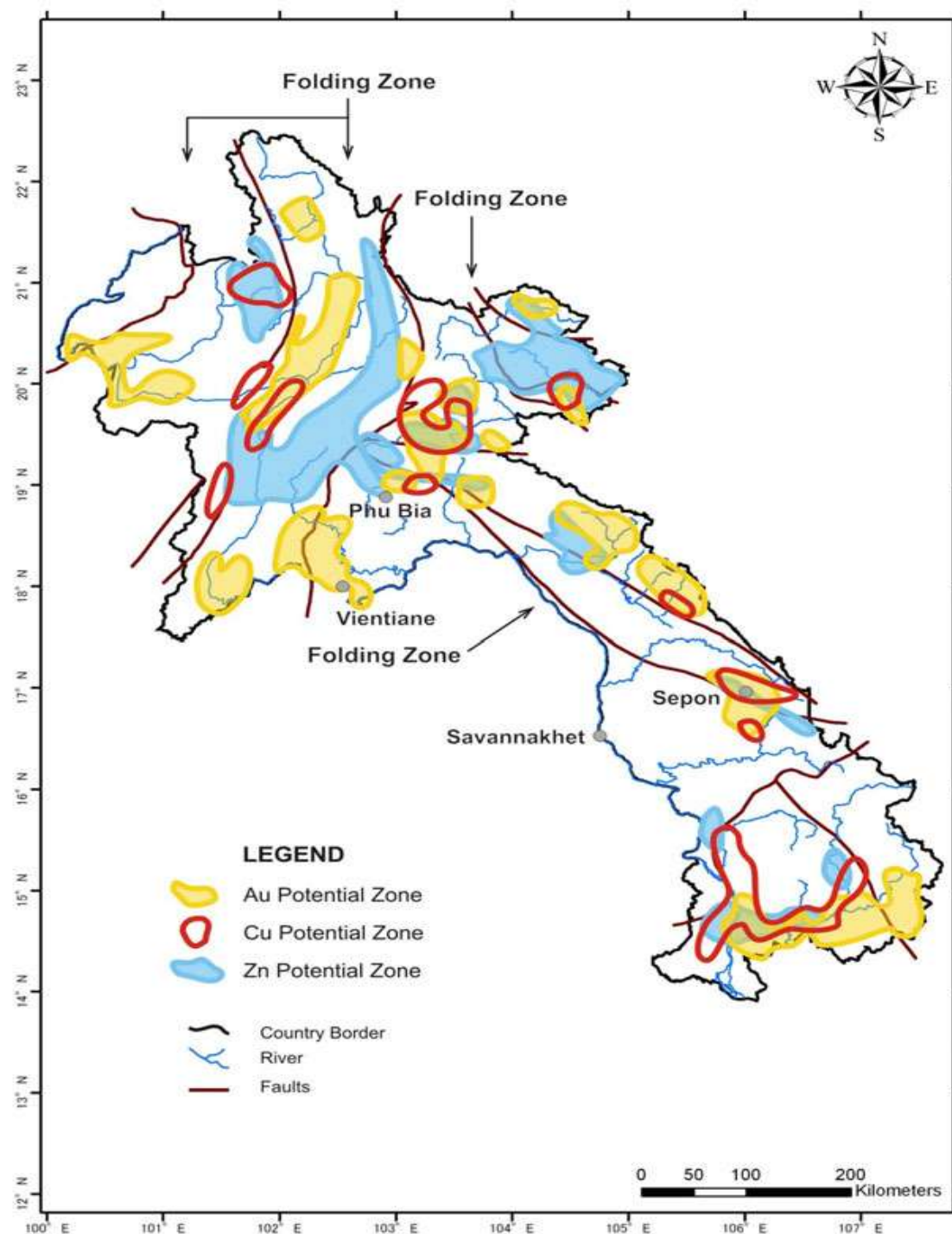
- 4 sheets of geological map in north-eastern part and 1 sheet in Vientiane Province were already prepared by DGMV before 1988.
- 9 sheets of geological and mineral resources map in Central part were already prepared by DGMV before 1999.
- 12 sheets of geological and mineral resources map in Northern area covering by DGMV was completed in 2007.
- 2 sheets geological and mineral resources map over Attapeu area covering by JICA was completed in 2008.





## Geological mapping 1:200,000 in Lao PDR

1. Mapped 55%
2. Under conducting 20%
3. Need to carry out 25%

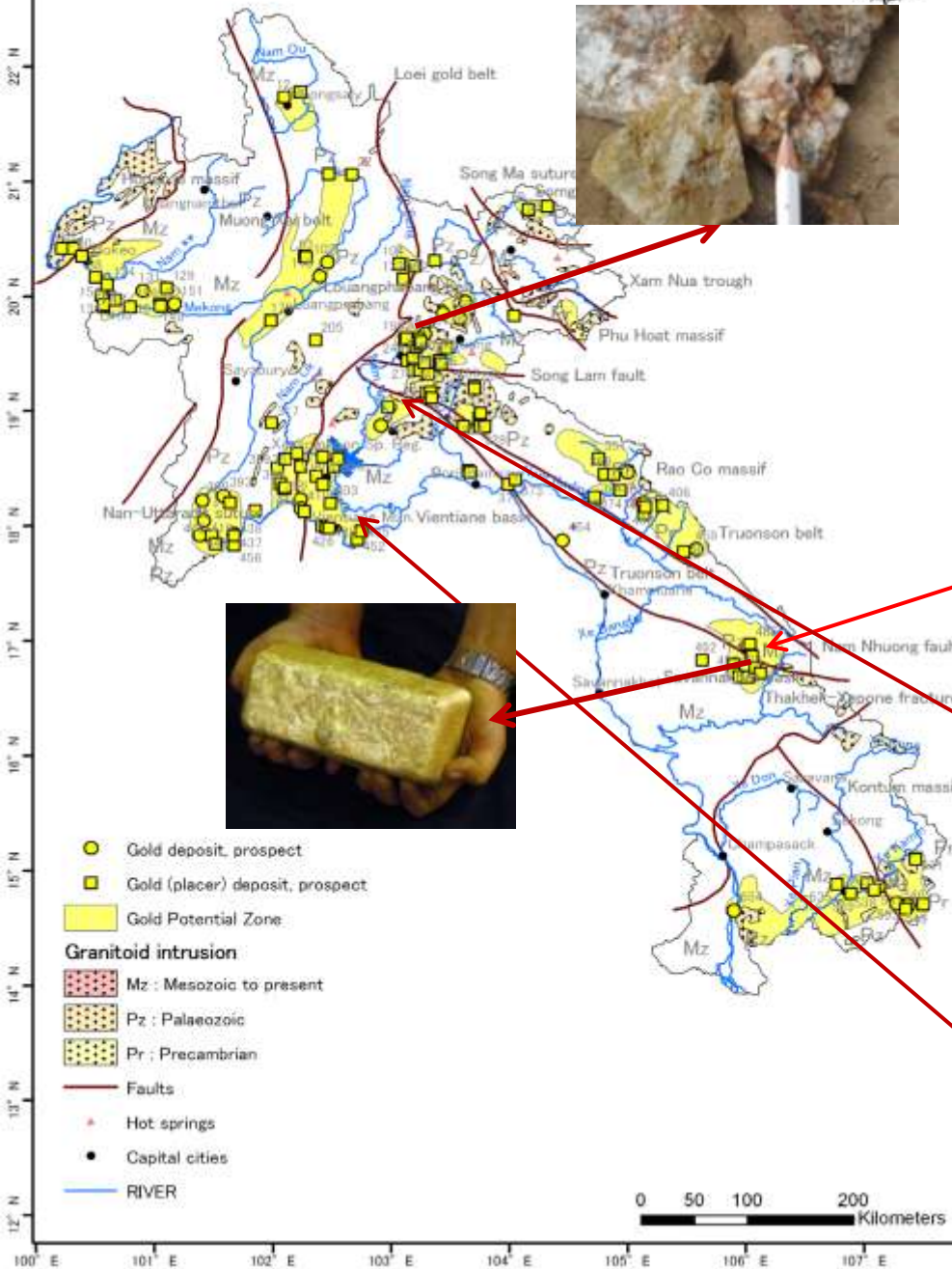


## 2. Mineral resources:

### MINERAL POTENTIAL

The geological potential to develop mineral resources in Laos is good for gold, silver, copper, iron and bauxite, but also for other commodities such as potash, sapphire, gypsum, coal and to a lesser extent tin, lead-zinc and construction materials.

## Mineral Potential Map of Laos (Gold)

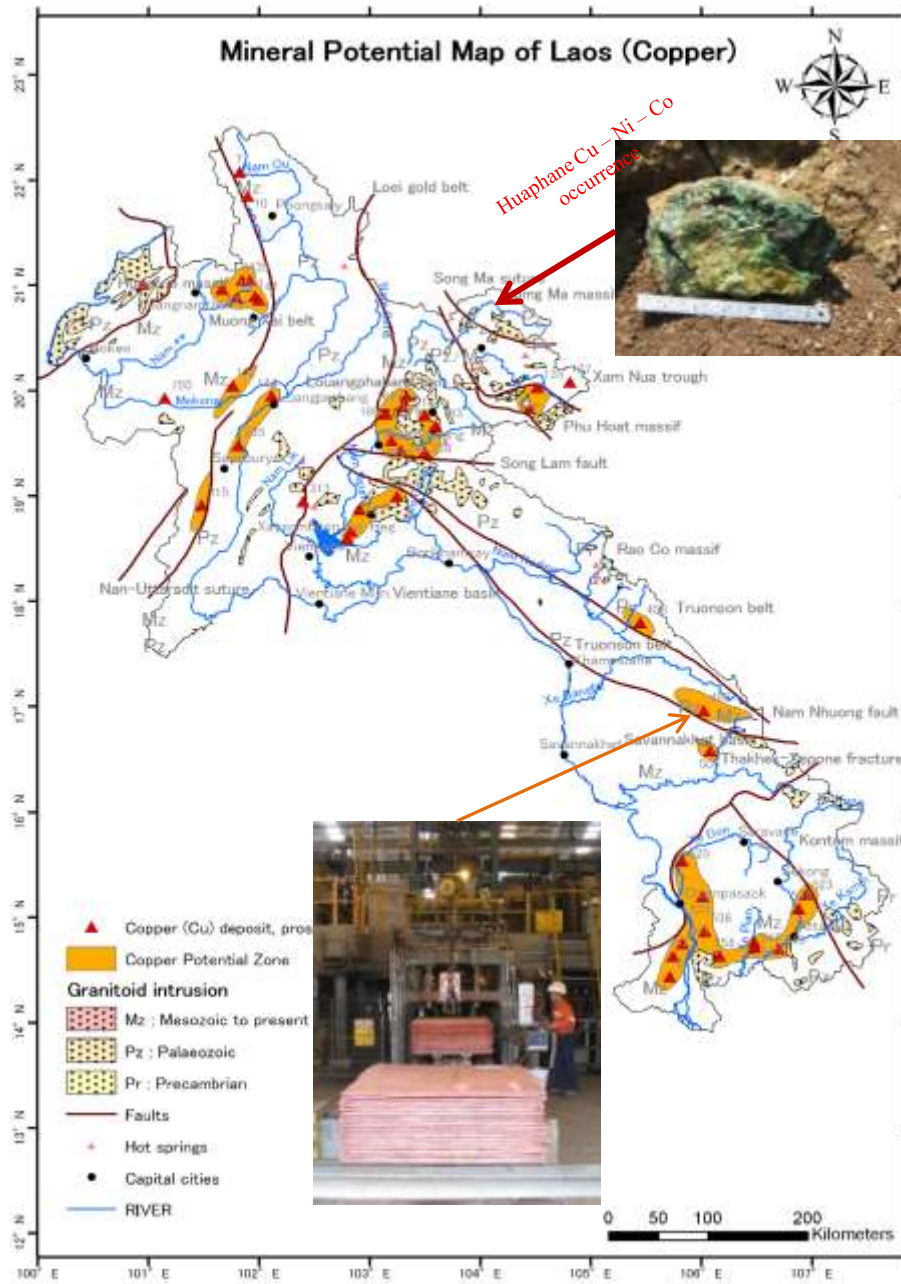


## Gold

- + The Junction between the Loei fold belt and Truongson fold belt hosts a number of deposits.
- + The mineralization style in the Loei belt is comparable to the subduction zone system.
- + Majority gold occurrences in both Truongson and Loei belts are porphyry Cu-Au type stockworks and skarns.
- + Currently there are two mines producing gold : **Sepon Cu-Au mine** and **Phoubia Cu-Au mine**, both deposits are related to near fracture zones along tectonic lines and are thought to be formed by Late Paleozoic granitic igneous activity.
- + The **Sepon Cu-Au mine**, the mineralization is associated to porphyritic intrusions with kilometer scale alteration zone showing indications of Carlin-type deposit for its gold and skarn for its copper mineralization; resource of the Sepon mine amounts to 142 million tons with 3.43g/t Au and 5.68g/t.
- + The **Phu Bia Cu-Au** Project comprises three deposits: the Phu Kham deposit; Long Cheng deposit; and Ban Houayxai deposit. The Phu Kham Cu-Au mine the mineralization is a skarn and stockwork in volcanics above and around porphyritic intrusion and estimate resource 45 million tons.
- + **Gold alluvial deposits** are found in the Khorat plateau near Vientiane city, but place deposits originated in gold deposits in the Loei fold belt.

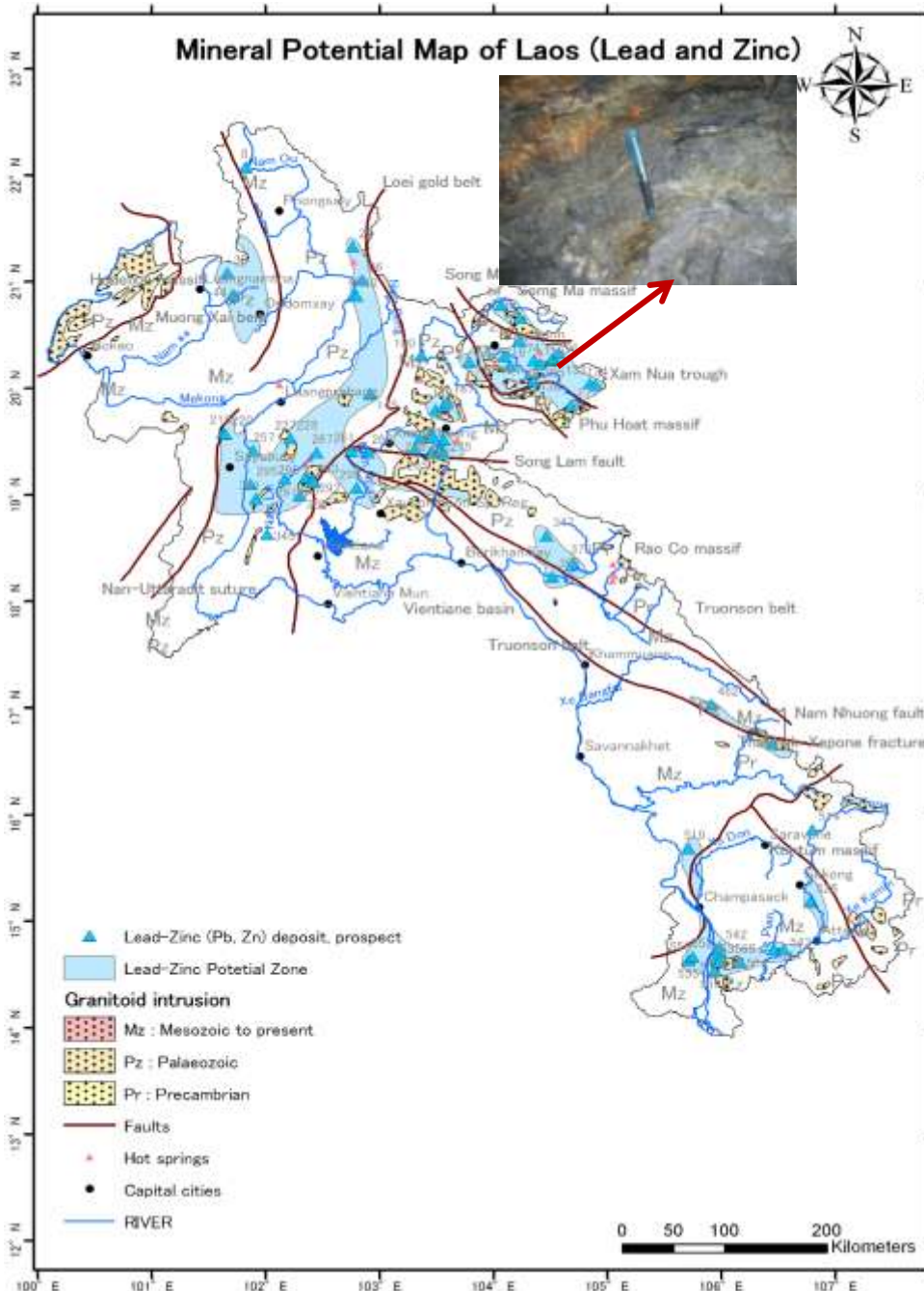
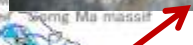
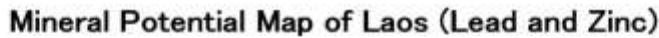


## Copper Potential



- Copper deposits and occurrences are mostly located in Truongson, Loei and Sukhothai fold belt.
- 2 types of copper mineralization: porphyry gold copper deposit forming quartz stockwork in granitic rocks and copper skarn deposit formed around country rocks.
- Khanong copper deposit at Sepon mine skarn type, Cu resources of 1.68 million tons copper.
- Phu Kham copper deposit at Phu Bia mine: porphyry type related to Late Paleozoic granite, Cu resource of 144 millions tons at 0.56 % Cu (or 810,000 tons Cu)
- Cu metal reserves total 2.9 million tons, resources 6 million tons.

# Lead and Zinc Potential



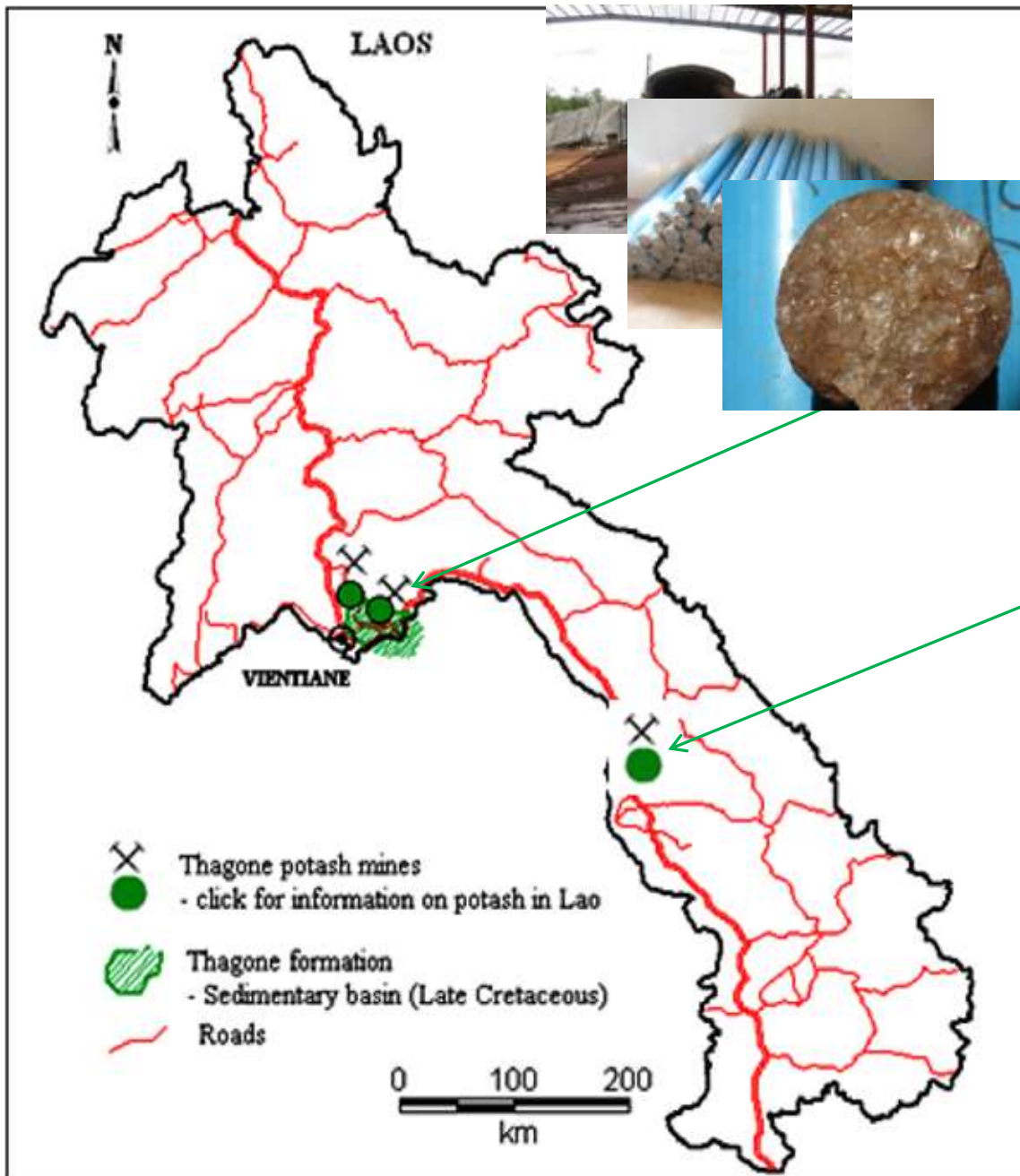
- Numerous lead/zinc deposits and occurrences are distributed in Loei fold belt (Vientiane & Louangprabang) and north of Indosinian fold belt (Xiengkhouang & Houaphan).
- They are divided into skarn type and Mississippi valley type.
- Estimated Pb/Zn ore resources: 0.8 million tons.
- 2 companies are undertaken mining activities and 3 prospecting.



- Tin deposits and prospects are distributed in the northern and southern of Sayphouluang belt.
- Tin deposits are related to granitic rocks of Late Paleozoic era.
- Cassiterite-bearing quartz veins type.
- Quartz network type.
- Placer type.
- Tin resource in Laos amount to 45 million T at present.
- The Tin products are 500 to 600 T/year with a grade of 70% cassiterite







## Potash

+ Potash is found in two sub-basins : Vientiane and Khammouane area. These sedimentary basins continue across the border to Thailand.

+ The **Vientiane potash deposit** near Vientiane Capital has an estimated reserve of 50 million tons with grades up to 15 %  $K_2O$  at depths between 25 and 200 meters and with a thickness of up to 100 meters.

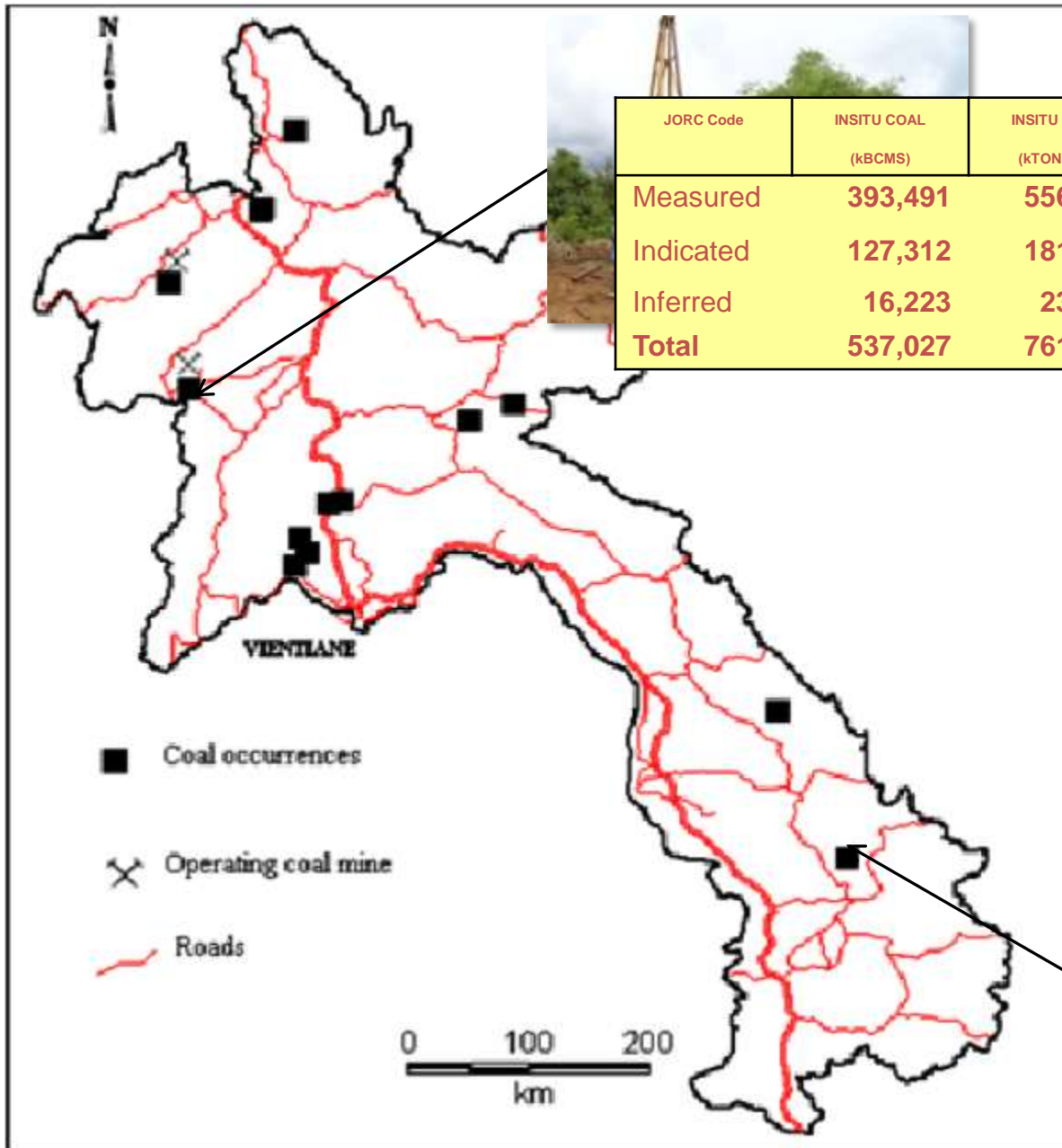
+The **Khammouane potash deposit** (Nonglom potash deposit near Thakhek City) is the second deposit under development. The variation coefficient of thickness of sylvinite - carnallite bodies is 46 meters. Its dip is gentle (5 - 10 degrees). The quality of major compositions of sylvinite, carnallite and halite is rather good. In sylvinite - carnallite, the average content of KCl in this area varies from 14.78 to 29.15% with the variation coefficient of KCl content = 26%, MgCl = 56%. Total estimated reserves and inferred resources in the area of 13,440 km<sup>2</sup> is 450,000 million tons of sylvinite-carnallite.

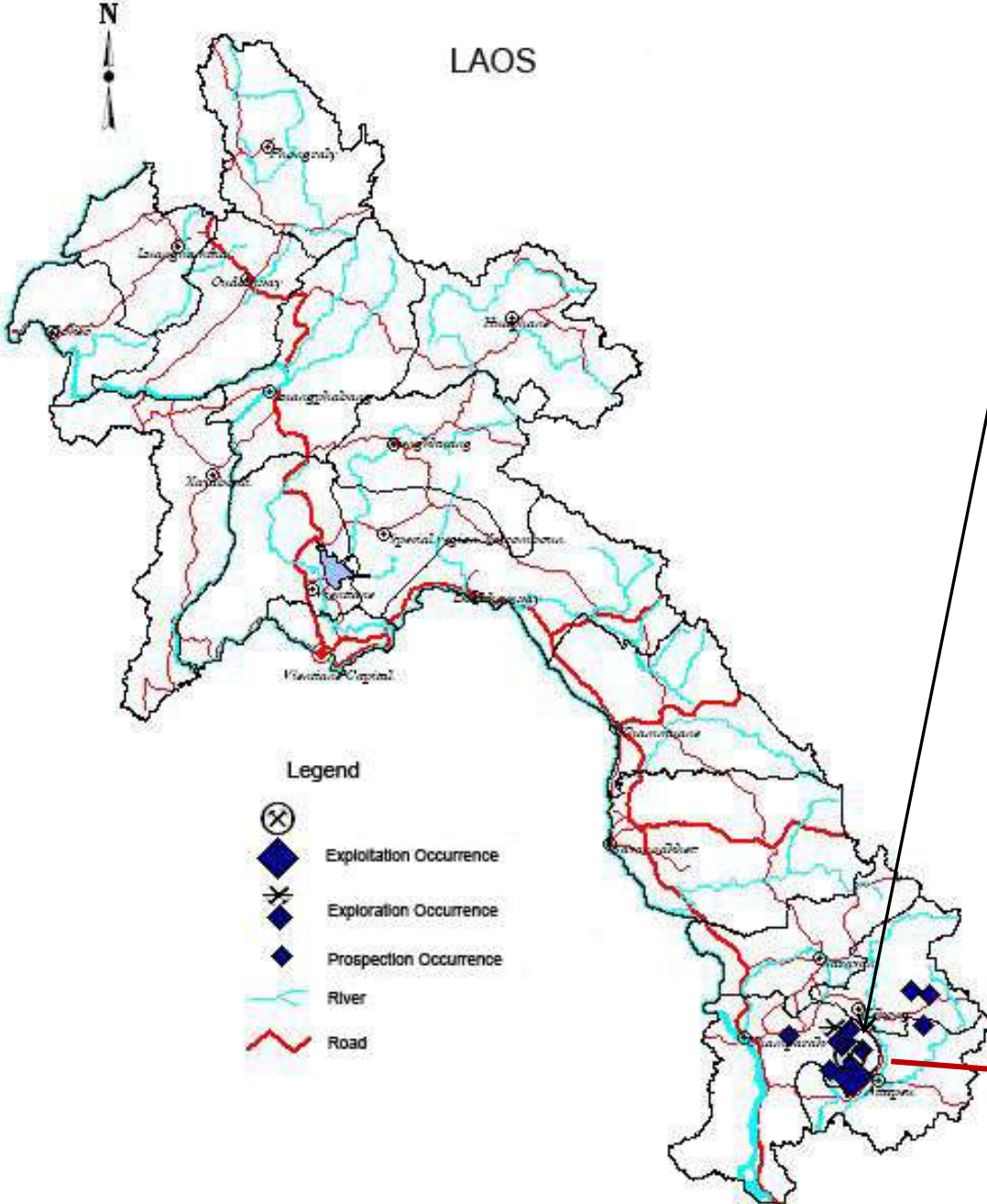
## Coal

Coal occurrences and deposits are found in many locations of Lao PDR.

There are two types of coal: anthracite of Palaeozoic to Mesozoic age and lignite of Tertiary age.

- Currently, lignite (Tertiary) in Hongsa, Viengphoukha and Khangphaniang basin, and anthracite (Paleozoic - Mesozoic) in Saravan and Phongsaly province.
- Total coal resources: about 900 millions tons.
- Hongsa lignite deposit with 700 millions tons is reserved to supply to power plant.





## Bauxite

- Bauxite has good potential for development of medium scale mine.
- Al is found in two plateau (Bolaven and Sanxay plateau) with the weathering alkaline basalt.
- Al deposit in Bolaven plateau has an resource about 1,053 million tons.
- Al deposit in Sanxay plateau is the second deposit under development has an resource about 735 million tons.

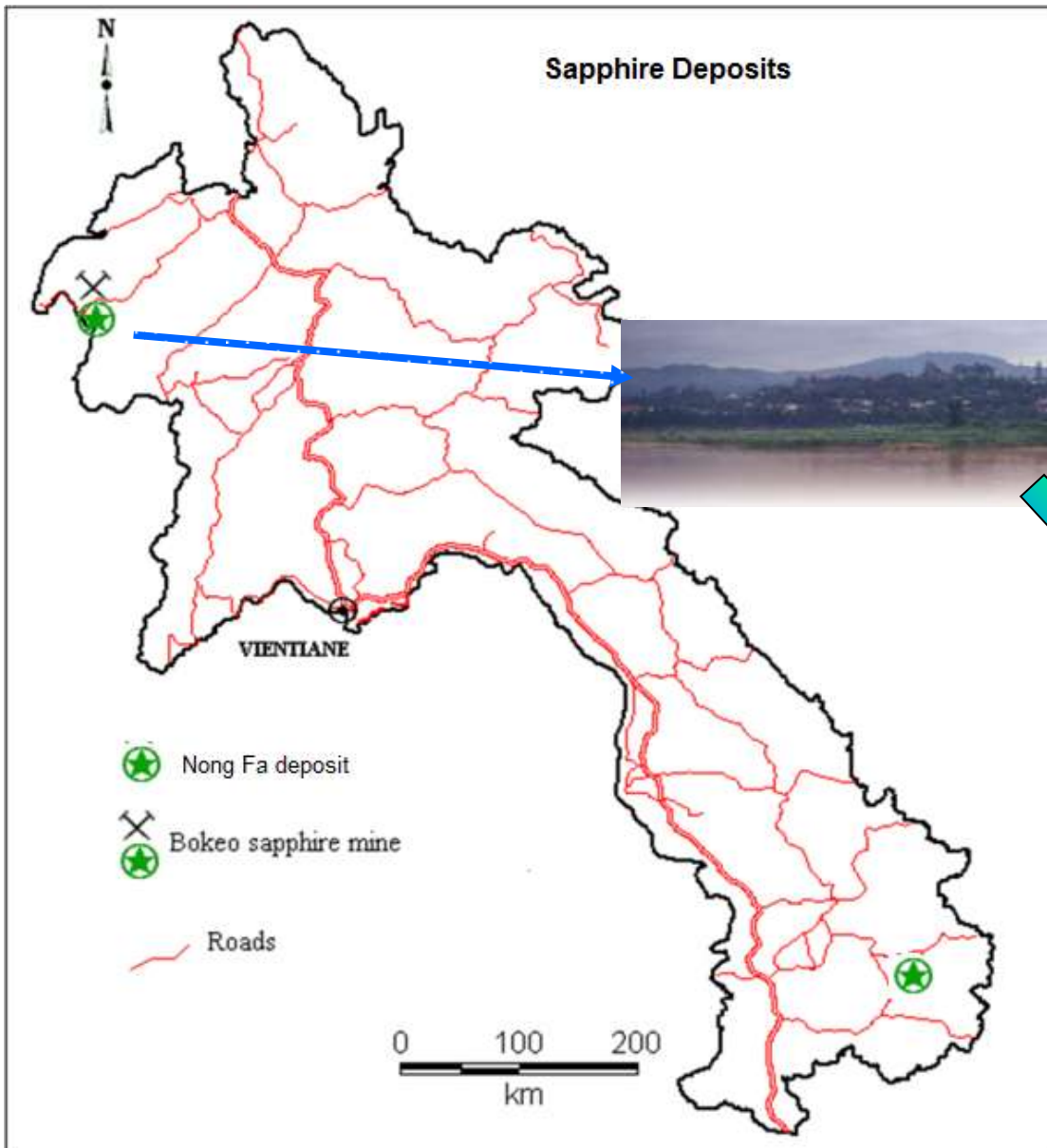


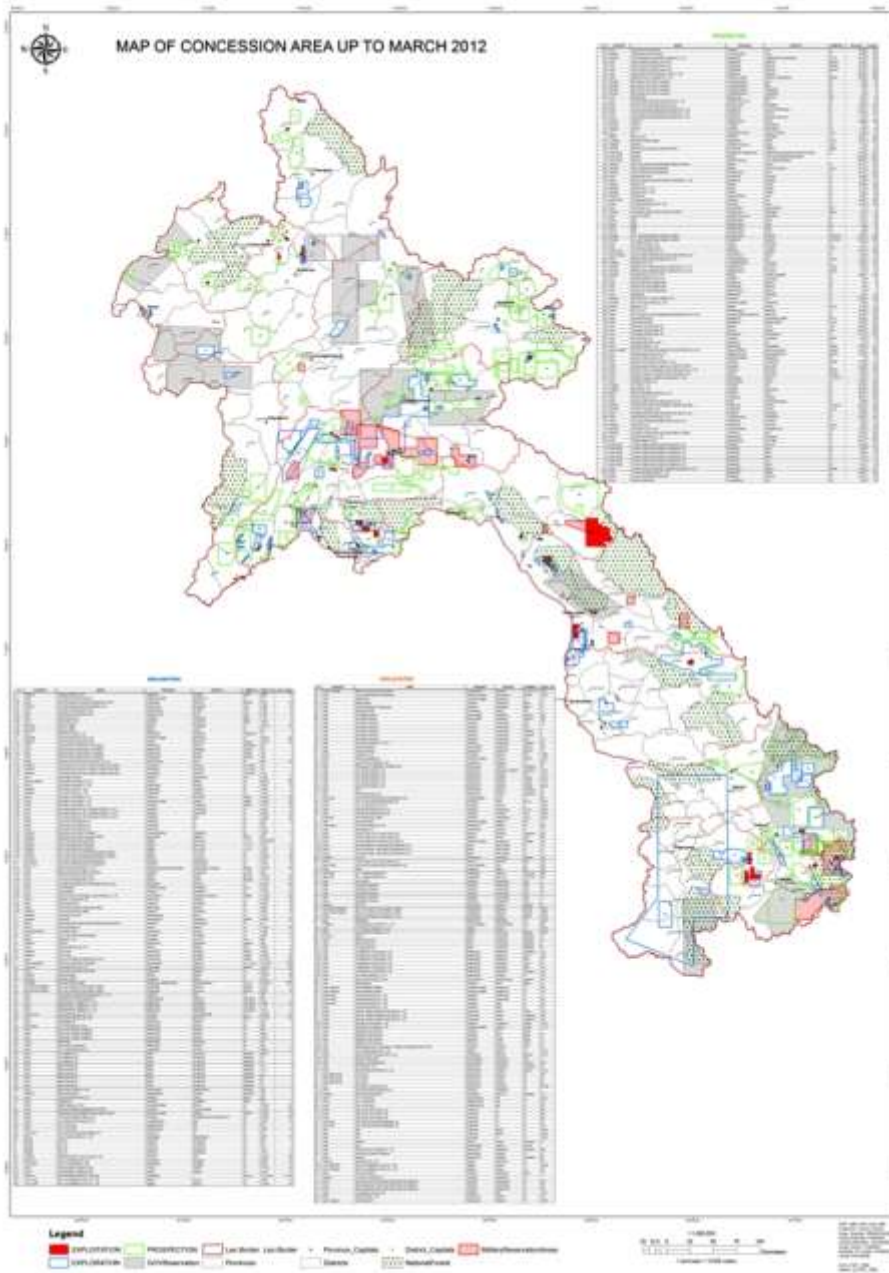


## Sapphire

Sapphire of good quality has recently been mined in Houei Sai area in North-West Laos.

In southern part of Lao PDR the geology may also be highly favourable to sapphire deposits





## Concession map

1. There are 290 projects
2. Prospecting 107 projects
3. Exploration 125 projects
4. Mining 58 projects





# conclusion

- ✓ Rich in mineral resources.
- ✓ Exploration activities not yet have been sufficiently implemented.
- ✓ Mining sector development is important for Lao social economic development.