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## Magmatism of the Earth and related strategic metal deposits



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The mineral deposits of strategic metals are vulnerable to political and economic changes, and their availability is essential for high-technology, green energy, and other applications. The most of them are related to the deep-seated alkaline magmas.

This book offers a collection of papers presented at the 35th International Conference on Magmatism of the Earth and Related Strategic Metal Deposits held from September 3th to 7th 2018 in Moscow, Russia.

The conference articles are focused on the understanding of the geological processes that produce high concentrations of critical metals in geological systems such as the metal transport in the mantle (possibly from the core-mantle boundary) and crust and enrichment processes, hydrothermal and metasomatic processes leading to the formation of such significant deposits. Papers in this book give a representative overview including mineralogy, geochemistry and origin of strategic metals deposits.

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The cover pictures - Sparrow Hills, May. Konstantin Fedorovich Yuon, 1910.

# **Metallogenic mineralization in serpentinites from the Nui Nua Complex (Song Ma, North Vietnam)**

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Song Ma zone is interpreted as a fragment of oceanic lithosphere situated between the Indochina and South China blocks (Hutchison, 1975; Findlay and Trinh, 1997). Serpentinized ultramafic rocks of the lowest part of an ophiolitic suite dated at Middle Cambrian, occur as small bodies at the Nui Nua, Hon Vang, Chieng Khuong and Bo Xinh regions. The biggest outcrop of serpentinites is exposed in Thanh Hoa Province called the Nui Nua Complex (NNC) – Fig. 1.



Fig. 1. Simplified structural sketch of Vietnam showing localization of Nui Nua Complex (blue square). The positions of main faults and continental blocks are marked according to Lepvrier et al., (2004). ASF: Ailao Shan Fault; RF: Ranong Fault; RRF: Red River Fault;



SMEZ: Song Ma Fault Zone; TPF: Three Pagodas Fault; WCF: Wang Chao Fault (modified after Trung et al., 2006).

The Nui Nua Complex from Song Ma zone, is overlain by Triassic sedimentary rocks to the south and southwest, and covered with Quaternary sediments on north and north-east. The chromite-bearing serpentinized peridotites occur in NNC unit, together with dunites, harzburgites, gabbros and diabbases. The age of those rocks is considered as Cambrian and Ordovician (Chien, 1964; Vuong et al., 2006,). All of primary silicates have been replaced by serpentine-group minerals or converted into actinolite-bearing and talc-actinolite schists (Son, 1975)

The preliminary mineralogical studies of serpentinites from Nui Nua Complex (Thanh Hoa Province) were conducted by Halpin et al. (2016) for recognizing the types of its metallogenic mineralization. Our microscopic observations in transmitted light have indicated that serpentine minerals often occur in two forms: (1) small cell-shaped lizardite filling the whole rock background and (2) flattened and disturbed chrysotile veins. Sometimes, serpentinites contain small, sharp-edged and fragmented primary olivine and pyroxene (diplage) relics. Magnesiochromite and andradite often occur as sharp-edged, strongly cracked, irregular forms, rarely forming small aggregates.

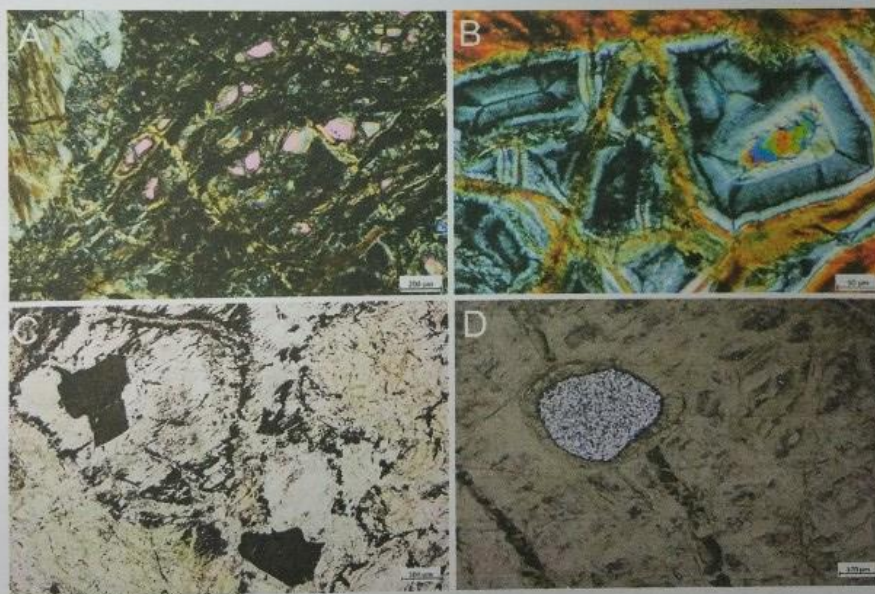


Fig. 2. A) The small sharp-edged relics of primary olivine surrounded by mesh-structure of serpentinite (transmitted light, NX). B) Cell-shaped banded lizardite (transmitted light, NX);

C) The garnet-andradite grains including translucent brownish chromian spinels (transmitted light, NX); D) magnesiochromite grain in serpentine background (in reflected light)

The SEM-EDS observations have shown that magnesiochromites are main accessory component of those rocks. They form "grains" about 1 mm in size, which are randomly distributed within the rock mass. The Raman bands at 735 ( $A_{1g}$  mode), 689 ( $A_{1g}$  mode) and 606  $\text{cm}^{-1}$  ( $F_{2g}$  mode) registered for magnesiochromite well correspond, with previously published data (e.g. Wang et al., 2002; Lenaz and Lughi, 2013; D'Ippolito et al., 2015).

Andradite found in these serpentinites most often forms large, oval-shaped, isometric grains up to 0.5 mm in diameter with characteristic rims composed of magnetite. Its Raman spectrum shows the most intensive peaks (see Mingsheng et al., 1994) at 875  $\text{cm}^{-1}$  ( $A_{1g}$ ), 516 ( $T_{2g}$ ), 370  $\text{cm}^{-1}$  ( $E_g$ ) and 353 ( $E_g$ )  $\text{cm}^{-1}$ .

Magnetite occurs in two forms there: (1) narrow rims around magnesiochromites crystals and (2) small individual grains in the serpentinite background. Its presence is proved by three marker bands at 668 ( $A_{1g}$ ) and 547 ( $T_{2g}$ ) and 313 ( $E_g$ )  $\text{cm}^{-1}$  (de Faria et al., 1997; Hanesch, 2009). The accessory ilmenite was evidenced also by the strongest band at 696  $\text{cm}^{-1}$  (Wang et al., 2004).

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# Metallogenic mineralization in serpentinites from the Nui Nua Massif (Song Ma, North Vietnam)

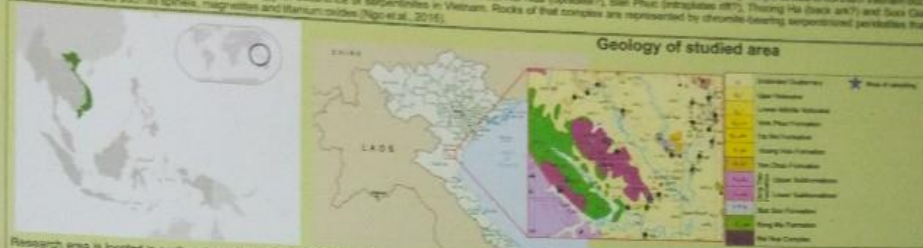
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## Introduction:

In Vietnam serpentinites are found in many places, such as in central (the Kon Tum Massif) and northern (the Song Ma fault zone) parts of the country. Serpentinites of northern Vietnam occur mostly as small isolated bodies surrounded by younger rocks, they also exhibit various origins and protoliths (i.e. Nui Nua (ophiolite?), Ban Phuoc (metagabbro?), Thuan Hoa (basalt and?) and Suoi Giang (hyaloclastite?)). Nui Nua Complex form the biggest occurrence of serpentinites in Vietnam. Rocks of that complex are represented by chrome-bearing serpentinites peridotites that contain various accessory minerals such as spinels, magnetite and titanium oxides (Ngu et al., 2016).



Research area is located in northern part of Vietnam in Thanh Hoa Province. The Nui Nua Complex is a part of the Song Ma suture zone (Chuong et al., 2007). This formation mostly consists of rocks Cambrian and Ordovician ages (Chen, 1984). Locally, dykes of gabbro-diorite occur as thick veins in sheared contacts with the serpentinites. Along the eastern and western margins of Nui Nua Complex there are chromite deposits as well as veins and pockets of primary magnetite-chromite occurring within the ultramafic rocks and representing its main mineralizations. The Nui Nua Complex is surrounded by Triassic sedimentary formations (i.e. shale, marly shale, clay limestones, limestones) in the S-SW and Quaternary sediments (i.e. clay, sand, gravel, all) in the N-NE parts.

## Results of research

### Polarizing microscopy in transmitted light



Fig. 1. A - The small sharp-edged relics of primary olivine surrounded by mesh microstructure of serpentinite (transmitted light, NX). B - Cell-shaped banded lizardite (transmitted light, NX). C - primary and serpentine minerals surrounding and crosscutting opaque, ore mineral (transmitted light, NX). D - Vein cutting the rock filled with siliceous minerals (transmitted light, NX).

### SEM-BSE and reflected light images with Raman spectra

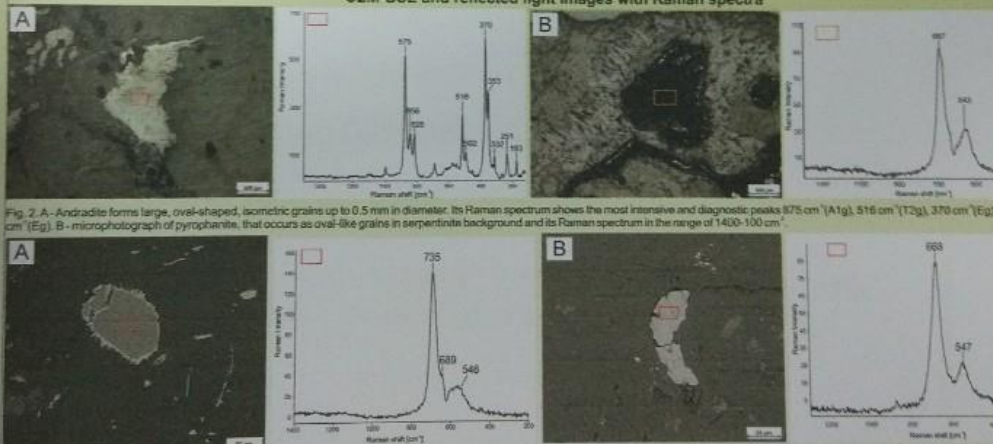


Fig. 2. A - Andradite forms large, oval-shaped, isometric grains up to 0.5 mm in diameter. Its Raman spectrum shows the most intensive and diagnostic peaks 875 cm<sup>-1</sup> (A1g), 516 cm<sup>-1</sup> (T2g), 370 cm<sup>-1</sup> (Eg) and 140 cm<sup>-1</sup> (Eg). B - microphotograph of pyrophanite, that occurs as oval-like grains in serpentinite background and its Raman spectrum in the range of 1400-100 cm<sup>-1</sup>.

Fig. 3. A - BSE image of magnesiochromite with narrow rim built of magnetite and its Raman spectrum in the spectral range of 1400-200 cm<sup>-1</sup>. B - small individual grains of magnesiochromite in the serpentinite background and its Raman spectrum in the range of 1300-200 cm<sup>-1</sup>.

## Conclusions:

1. The preliminary research of serpentinites from the Nui Nua Complex has confirmed the primary ultramafic character of their protolith.

2. Serpentinites are very interesting in terms of content of various accessory minerals.

3. Besides spinels such as magnetite and titanium oxide the rocks consist of significant amounts of garnets.

4. Further investigations of garnets chemistry will help to determinate P-T conditions of metamorphism of rocks from Nui Nua Complex.

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