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Metallogeny of the Hoang Lien Son subduction zone

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Abstract: Located at the southwestern margin of the South China plate, the Hoang Lien Son zone is one of the most important structural and metallogenic units in North Vietnam.

Along this elongated NW–SE zone, extending from the coastline in the southeast, through North Vietnam to the boundary with China in the northwest, are many mafic, ultramafic, alkaline and acid volcanics as well as intrusive rocks.The evidence of the mafic, tectonic, metamorphic and metallogenic activities shows that a subducting plate margin was very active from the Jurassic to the end of the Palaeogene. During that period of time the zone appeared to have been a volcanic arc at the edge of the South China continental plate.

Sulphide mineralization occurs abundantly along this zone, especially that of copper, iron, lead and zinc. Deposits and occurrences of rare earth elements related to alkaline rocks and molybdenum related to granite are also found.

INTRODUCTION

Since 1978 the author has considered the Hoang Lien Son zone to be a structural unit of the active margin of the South China plate throughout the period Jurassic–Palaeogene (Xinh, 1978). Fromaget (1941) considered it to be the marginal unit of the "Haut Tokin" which was separated from the rest of the Indochina Massif by the Da River geosyncline. More recently, geologists belonging to the geosyncline school considered the zone as one of the units of the northwestern Vietnam folded region (Dovjikov, 1965; Luong, 1977; Tri, 1976)

The southwestern boundary of the South China plate has been differently interpreted by various authors as being along the Ma River fault (Tri, 1976), the Da River fault (Xinh and Tinh, 1975), Hong River fault (Vinh, N. 1971), and the Chay River fault (Dovjikov, 1965).

It is believed that the northwestern Vietnam folded region was a mobile belt during the whole of Phanerozoic time, caused by the interaction of the two neighbouring continental plates – South China and Indochina. The mobile margin of the South China plate had left records of a very active period and its boundary seems to have moved northeastward by the breaking off of the margin of the plate from time to time.

The first collision between the two plates seems to have taken place in Early Palaeozoic along the suture zone of the Ma River where ophiolite is seen (the Ma River Suture of Hutchison,1975). Later during the Late Palaeozoic to Middle Triassic, a deep seated rift zone occurred along the Da River zone where mafic and ultramafic volcanic and intrusive rocks are seen intercalating within Upper Palaeozoic and Triassic formations. Following this , the new boundary appeared along that rift zone. From Late Triassic to Palaeogene the passive margin of the South China plate was turning into an active one by a new subduction zone dipping northeastward below the Hoang Lien Son zone. Evidence for these activities will be

presented in this paper. Since Neogene, a continental rift zone has been taking place along the Hong River valley. This activity is related to the opening of the East Sea and Hong River strike-slip fault, considered to be the new boundary of the South China block.

LOCATION OF THE HOANG LIEN SON ZONE IN TIME AND SPACE

The Hoang Lien Son zone as defined here is mainly located between the Hong River fault in the northeast and the Da River fault in the southwest and it trends NW–SE. Its length within Vietnam territory is about 450 km (fig.1). The maximum width is 90 km. Morphologically the Hoang Lien Son mountain chain is the youngest and highest in Indochina, with the peaks ranging from 2000 to 3140 m in elevation. However the average elevation of the Hong River and Da River valleys does not exceed 100 m. In general the heights of the mountain chain decreases toward the sea.

In terms of time, this zone obviously appeared as an active overriding margin of the South China plate during the Jurassic-Palaeogene period following the rift epoch of the Da River belt that lasted from the Late Carboniferous to Middle Triassic (Xinh,1975,1979,1981). The conversion from a rifting regime into a subduction regime most likely happened in Late Triassic time.

Active erosion has been taking place on the mountain chain removing the primary cover and the upper part of the granite batholith which is now exposed in an area 20 km wide and 150 km long.

GEOLOGICAL SETTING

The Hoang Lien Son zone is seen as an asymmetric anticlinorium where Proterozoic metasediments, orthogneiss and amphibolite, are found in its axial part and is surrounded by Lower and Middle Palaeozoic formations. Carbonate and terrigenous formations, dated as Carboniferous, Permian and Triassic, are interstratified with spilite and basalt porphyrite and occur in the southwestern and southeastern part of the Hoang Lien Son zone.

To the northwest from its central part, there appears a series of intrusive, subvolcanic massifs dated as Jurassic, Cretaceous and Paleogene. Ky (1977) described these magmatic formations as follows:

i) Gabbro-diabase formation related to mafic volcanite in the Tu Le area.

ii) Porphyrite syenite, granophyre granite formation related to mafic volcanites, trachyte and orthophyre dated 79-81 Ma. The concentration of K_2O is similar to Na_2O.

iii) Granitoid formation consisting of quartz diorite, quartz monzonite, plagiogranite, granodiorite and alkali-feldspar granite. Petrochemically, this formation is rich in alumina, calc-alkaline and is dated at 45-58 Ma. The biggest magmatic massif belonging to this formation outcrops over a surface area of 1000 km^2

iv) The normarkite formation is the youngest magmatic one found in Hoang Lien Son zone, dated at 29-53 Ma. It consists of alkaline quartz syenite, alkaline granosyenite in the form of small intrusive veins or lenses.

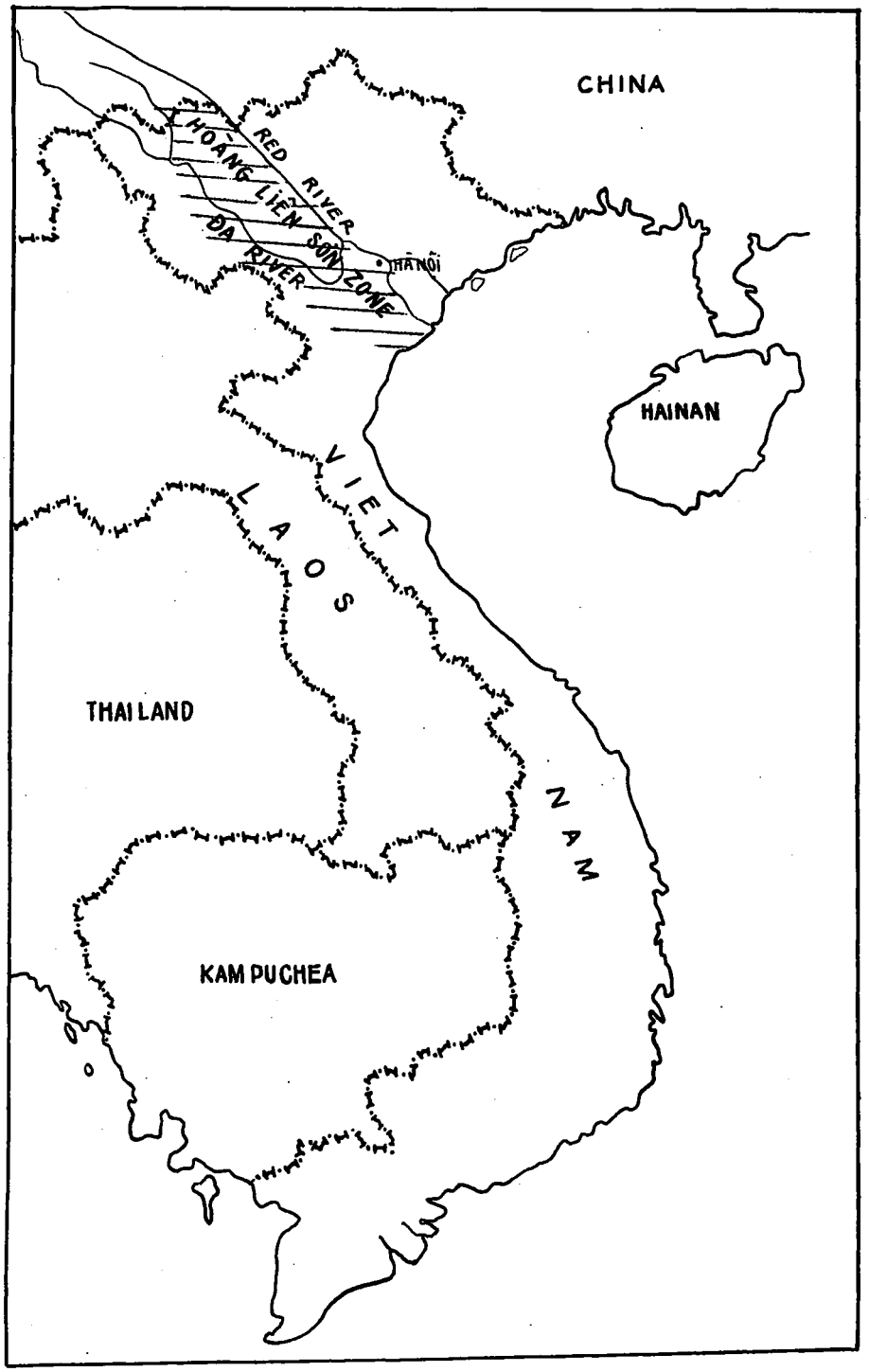

Fig. 1 Location map showing the Hoang Lien Son Zone.

In general, magmatic formations of the Hoang Lien Son zone are of enormous volume changing from mafic to calc-alkaline and alkaline. The petrochemical characteristics of these rocks prove to be of mantle origin and mixing with crustal materials subducted along a Benioff zone. Due to subduction and collision activities between the two above mentioned plates, these magmas erupted and were emplaced within the Hoang Lien Son overriding zone.

Alkalinization is widespread in the zone, affecting various magmatic and metamorphic rocks; even the Permo-Triassic mafic volcanite has been metasomatosed into apilite-like rocks (Leventov, 1978)

Metamorphism: Different kinds of metamorphism are found within the Hoang Lien Son zone and they include regional, contact and metasomatic. In many cases the rocks were overprinted by various metamorphic cycles, especially the Proterozoic and Lower Palaeozoic rocks. Metamorphism is seen even in the rocks of Jurassic, Cretaceous and Palaeogene. Vinh (1971) noted that some part of the Jurassic volcanites are affected by greenschist facies. Palaeogene granite in some places were once considered to be Huronian or Hexinian gneisses (Fromaget, 1941). The metasomatic alkalinization related to the Cretaceous to Palaeogene magmatic activities is noticed in various kinds of rocks. Leventov (1978) described the spilite-like rocks as products of metasomatic metamorphism of Triassic mafic volcanite in the Nam Bac area, where he showed the rare earth elements are related to Palaeogene syenite. It is known that dynamometamorphism violently affected all kinds of rocks in Hoang Lien Son zone causing numerous brecciated, crushed and mylonitised zones elongated parallel to the trend of the zone.

By interpretation of the data on the metamorphism in the Upper Triassic coal beds in the Da River basin and the Hoang Lien Son zone it is possible to identify some features of the regional metamorphism in the region since Late Triassic. Moreover based on these data, the low grade metamorphism of the coal beds in the Da River basin can be explained. In fact, coal in the Da River basin is hosted by strongly folded and faulted Upper Triassic formations with well-preserved fat and coking coal, in some places, even gas-fat coal. By contrast, coal of the same age in Vietnam in almost all coal basins is of anthracite and semi-anthracite.

Along the Da River valley from Dong Giao, Dam Dun, Van Yen to Quynh Nhai, coal is of high percentage of volatiles 20-33% (26,9% in Dong Giao, 22.8-27.3% in Dam Dun; 20-24% in Van Yan; 32-33.4% in Muong Lum, and 28.8% in Quynh Nhai, (Fig 4). However further to the northeast into the Hoang Lien Son zone, the type of coal changes from place to place by a decrease in volatiles, that is from fat coal into semianthracite to anthracite (13.16% in Doihoa, 13-18.4% in Suoi Hoa, 9.3% in Kim Boi, 4-9.6% in Nui To; 4.1-9.8% in Than Uyen, 4.9% in Nghia Lo and 4.13% in Tinh Nhue).

Metamorphism of the coal in the Da River basin can only be explained by a model of geothermal diapirs from the subduction zone (see fig. 6). The Da River was likely located near the trench above the subduction zone in which the geothermal heat went down resulting in a low degree of metamorphism of the coal. Further into the Hoang Lien Son zone, the overriding zone, the heat went up causing the high temperature metamorphism of the coal. It is known that the two factors, the heat and pressure cause metamorphism but heat plays a more important role.

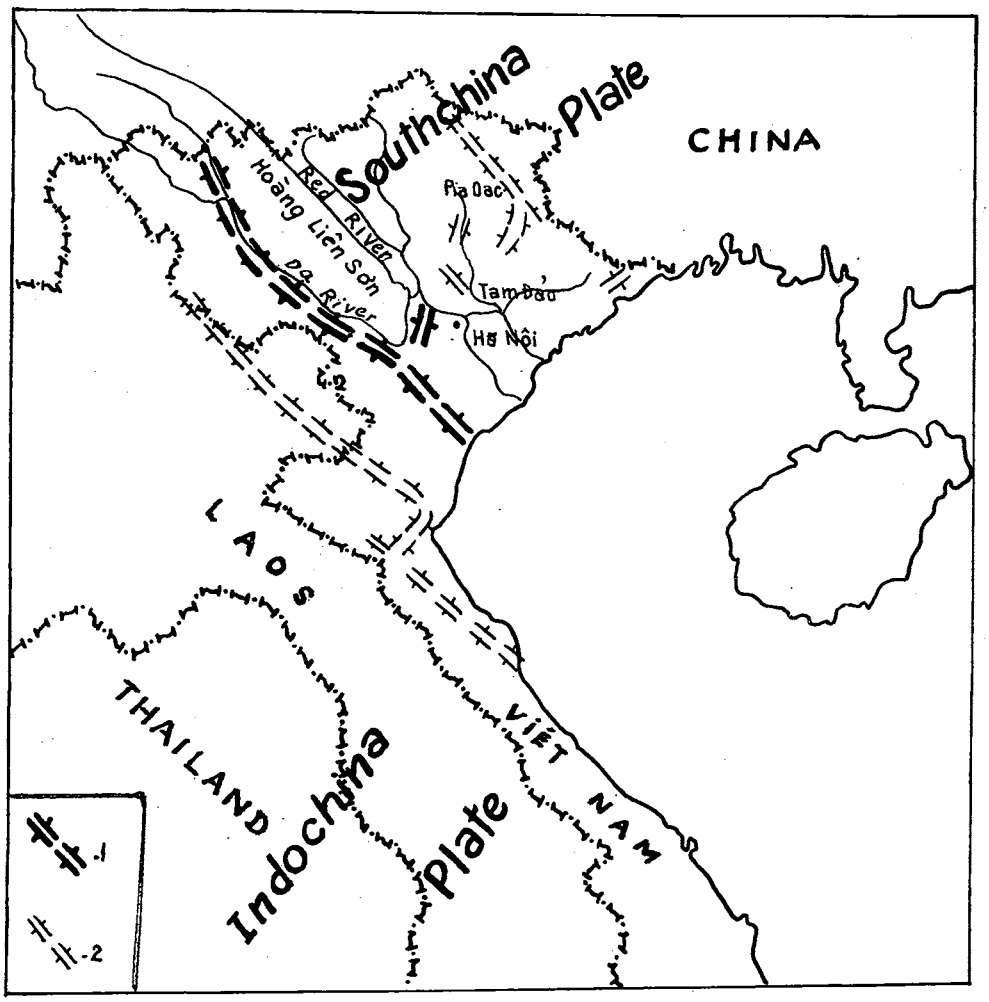

Fig. 2 Rifting activity in Late Paleozoic-Early Mezozoic. 1. Rift zone with mafic and ultramafic rocks (mafic volcanic, ultramafic intrusive). 2. Rift zone with predominantly acidic rocks (volcanic, intrusive).

CONTRACTION OF THE DA RIVER BASIN

The Palaeozoic and Mesozoic cover of the Da River basin is very complicated folded with many thrust faults and reclined folds. This proves that the primary width of the Da River basin was greatly decreased, but it is difficult to estimate by how much the basin has been contracted. Fromaget (1941) considered a boulder and breccia layer at the foot of limestone massifs in the basin as tectonic materials which played the role of thrust zone melange.

While prepearing the geological map of the Da River area, Bao (1969) found this layer to be widespread in the region covering all the formations including Cretaceous ones. Hence he interpreted it as a Tertiary formation. In fact there have been various interpretations by

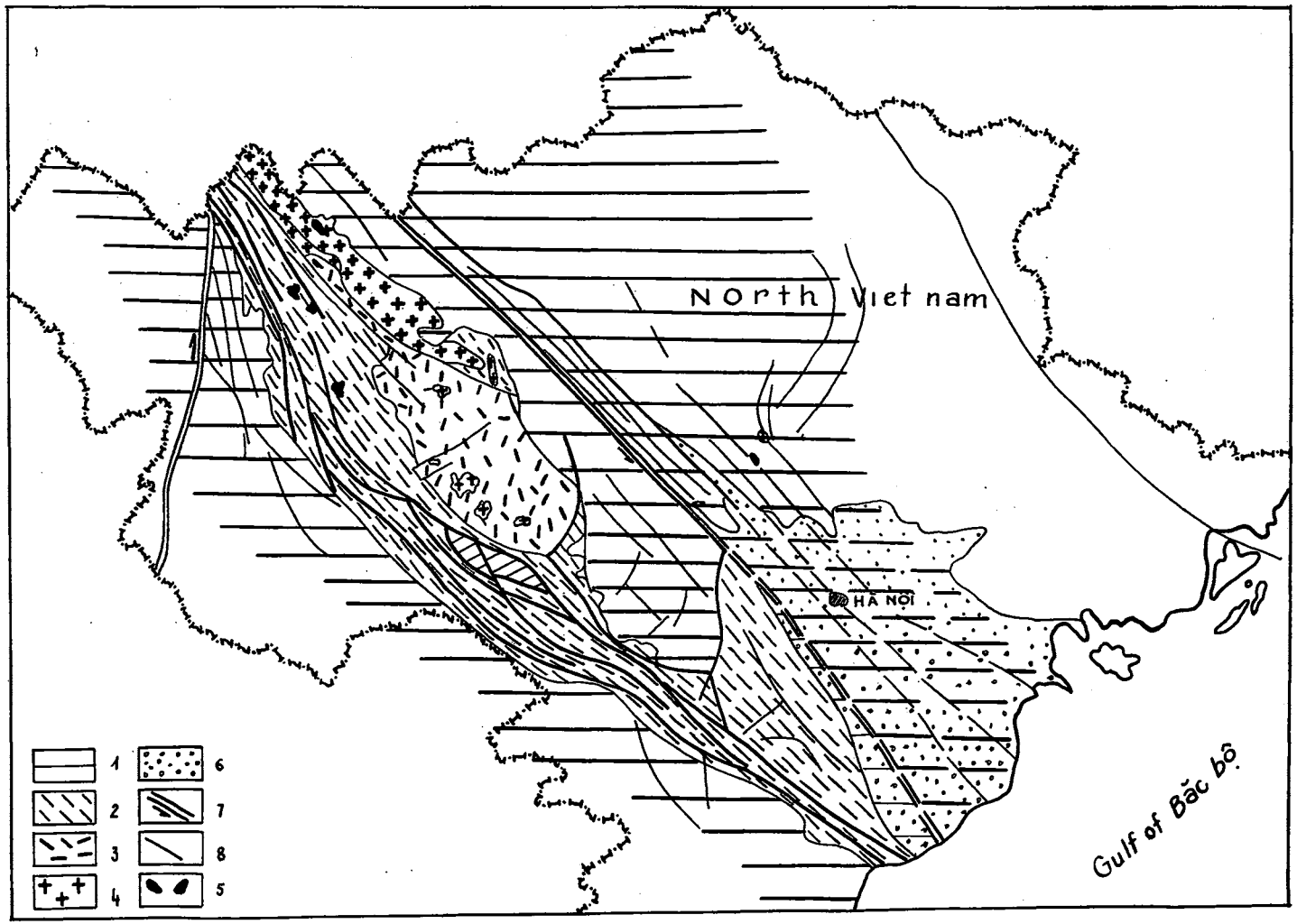

Fig. 3 Map showing geology and structure of the Hoang Lien Son zone (Captions not supplied by author).

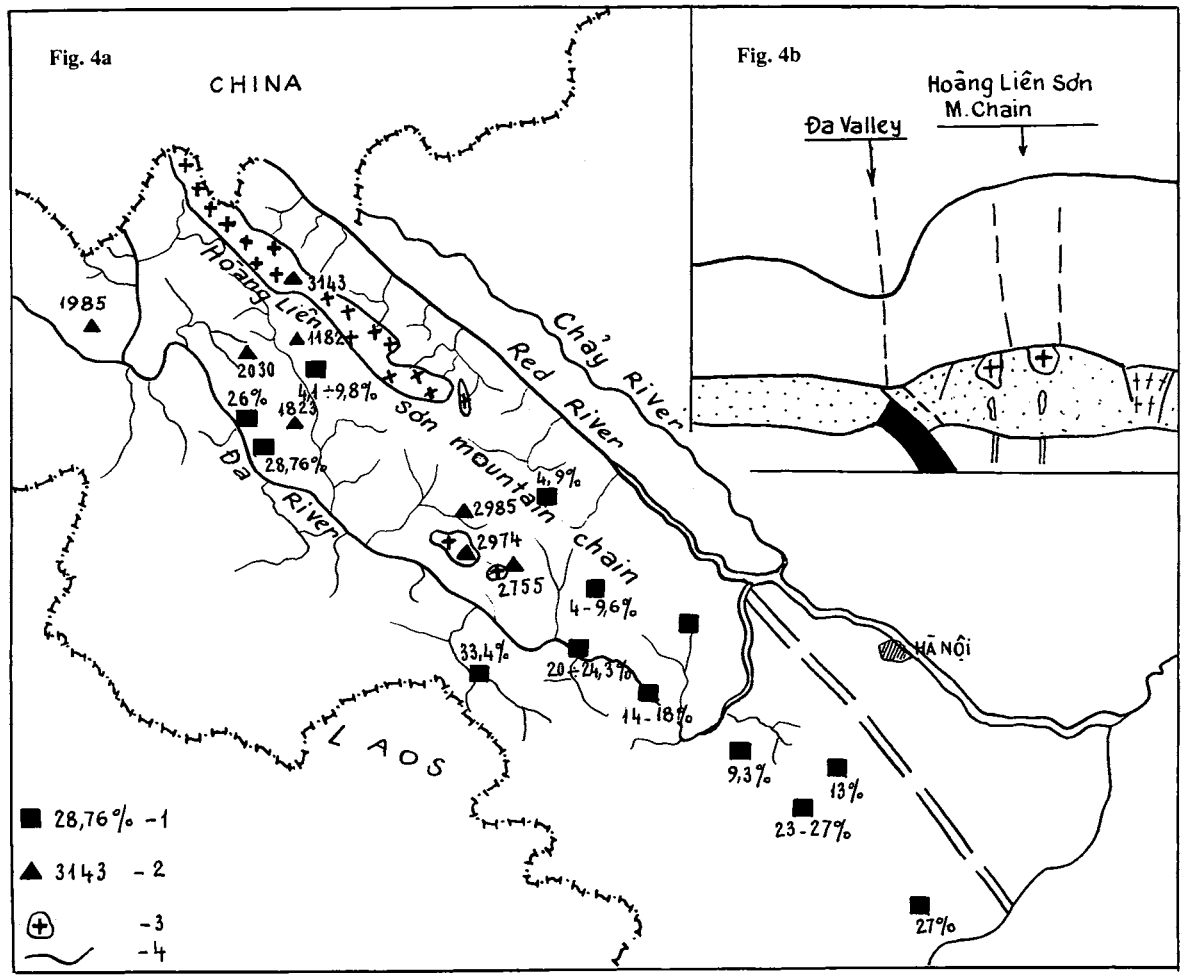

Fig. 4a. Map showing Hoang Lien Son zone with mountain peaks and coal occurences.
Fig. 4b. Schematic cross-section of the Da Valley and Hoang Lien Son Mountain chain (Captions not supplied by author).

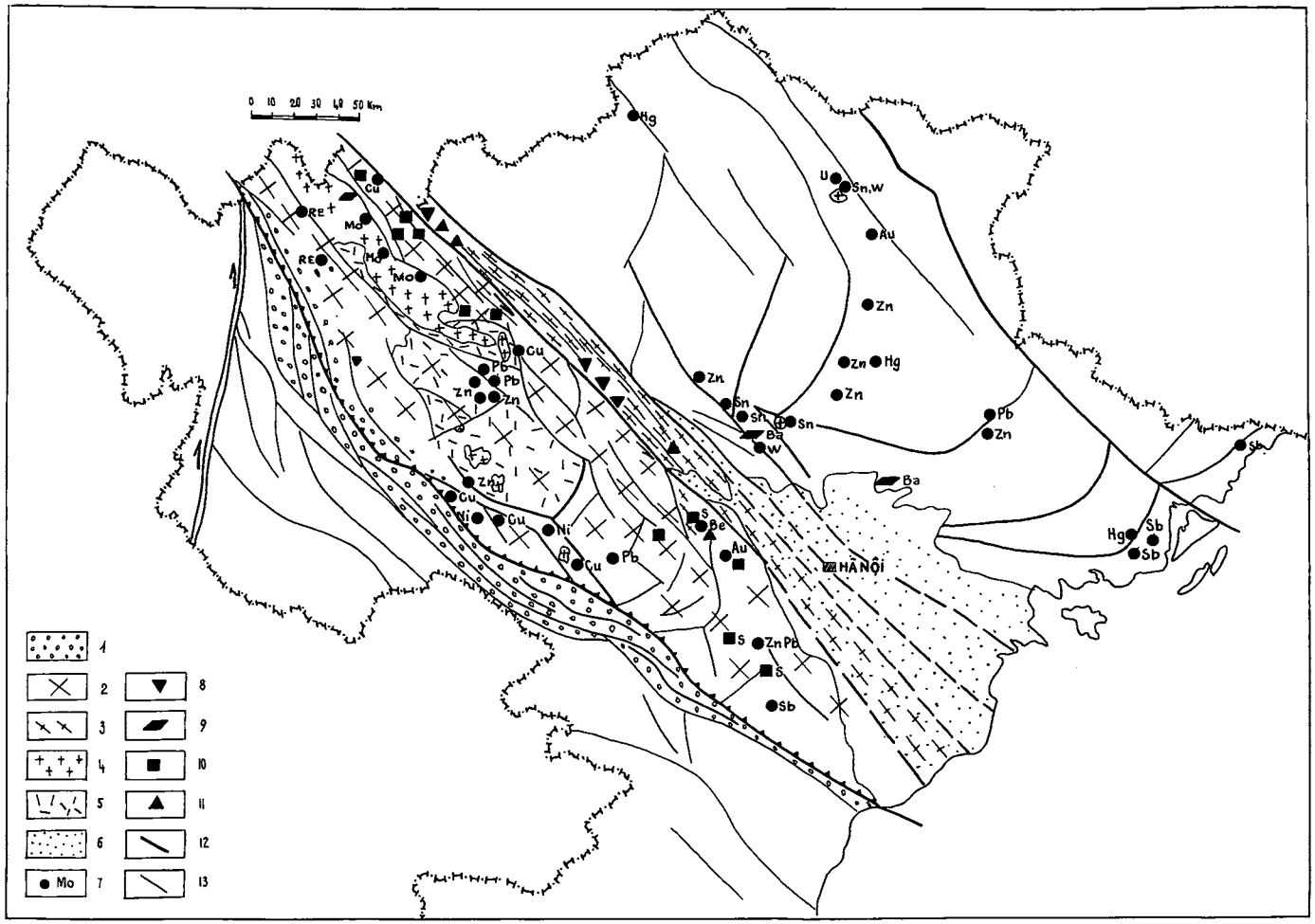

Fig. 5 Mineralization of the Hoang Lien Son zone (Captions not supplied by author).

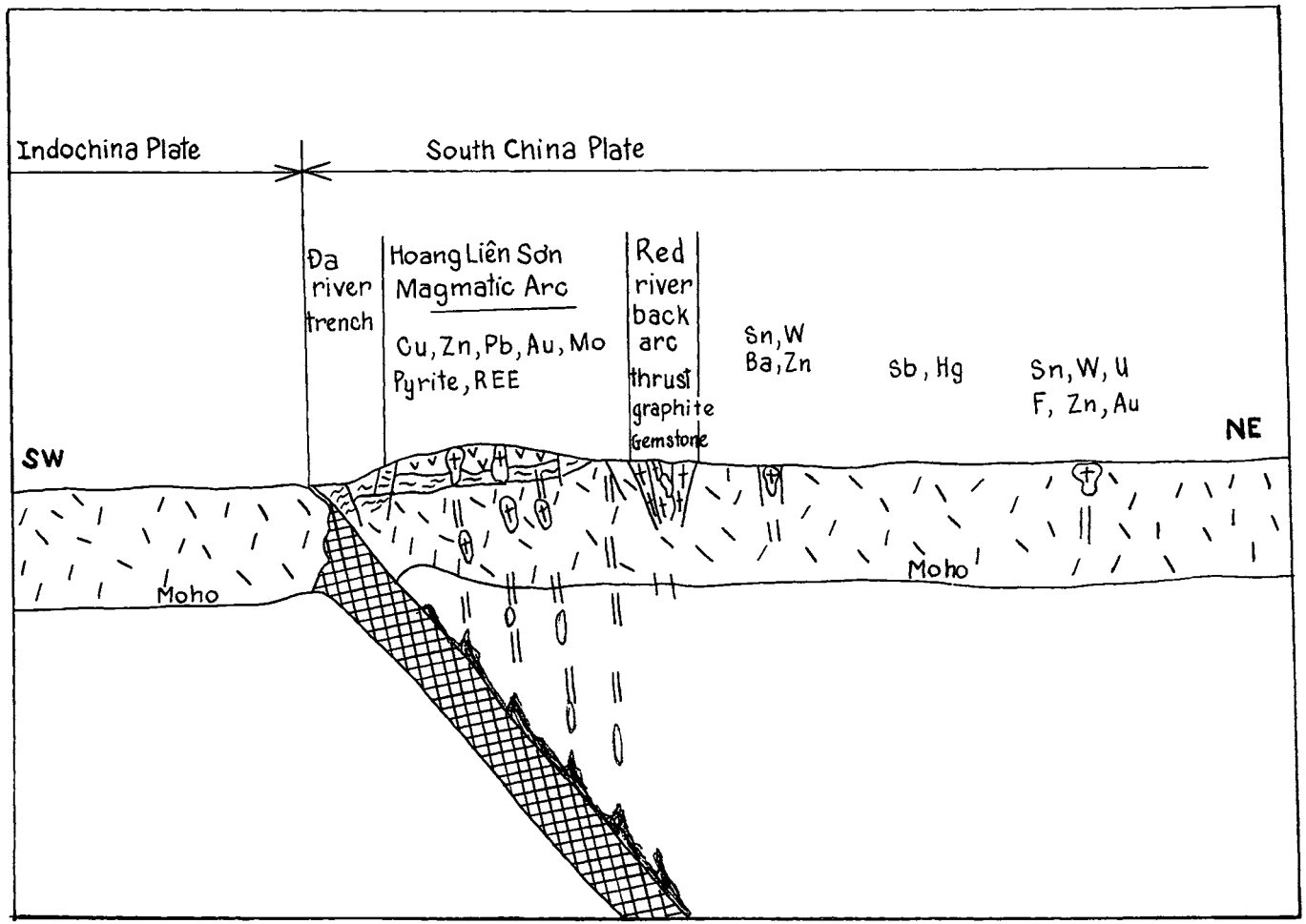

Fig. 6 Schematic cross-section showing the Hoang Lien Son overriding plate and the magmatic arcs related to subduction.

different authors concerning this formation. However it must be regarded as a tectonic formation made during the contraction process of the Da River basin by thrusting and sliding of the sedimentary cover.

MINERALIZATION

Mineralization of the Hoang Lien Son zone is abundant and diversed. It is displayed as iron ore in the Proterozoic metasediments of the Lang My, Hung Khanh and Lang Lech areas; as apatite ore in the Lower Cambrian Cam Duong suite. Nickel, copper, asbestos and pyrite deposits are considered to be the products of the Late Palaeozoic-Early Mesozoic rifting period uplifted by late subduction activities. Hydrothermal, pneumatolytic and pegmatitic deposits of Cu, Zn, Pb, Mo, Fe, Sb, Hg, Au, rare earths, fluorite, barite, talc, graphite and beryl are seen as direct products of subduction and collision activities.

Metallogenically, the Hoang Lien Son zone is tentatively divided into two subzones running parallel to the main direction of the zone:

Front subzone: This coincides with the peripheral belt of the Hoang Lien Son zone, next to the Da River trench. Mineralization found here is mainly related to mafic and ultramafic rocks of the rifting epoch. Known copper sulphide and asbestos deposits are related to the ultramafic massifs in the Ta Khoa, Suoi Can and Dong Nghe areas. Pyrite of stratiform type is found in the Permian volcano-sedimentary formations in the Ba Trai and Lang Vo areas. Chalcopyrite in vein quartz type is observed in mafic volcanite in Van Sai, copper sulfide occurs in shear zone in Carboniferous and Permian limestone in Quan Tan Trai and Hat Lot areas, native copper in the form of small irregular pockets and nodules is found disseminated in mafic volcanites in Hat Lot and Yen Chau areas.

Major subzone: This subzone occupies the axis of the Hoang Lien Son zone and extends to the Hong River faults of the northeastern boundary. Mineralization of this subzone is more clearly related to the above mentioned magmatic formations e.g. molybdenite, fluorite and pyrite in the pegmatite veins surrounding Paleogene granite massifs. Sphalerite and galena occur in the quartz veins found in the Jurassic volcanite of the Tu Le area. The association of rare earth, carbonate, barite and fluorite in the form of veins cutting Triassic mafic volcanite and Paleogene syenite is seen in the extreme northern part of the Hoang Lien Son mountains.

There are also many deposits and minerals of the vein type of copper, pyrite, iron ore, lead, zinc and mercury in the Proterozoic metasediments, terrigenous sediments and limestone along the faulted zone. In particular, the large ore bodies of copper sulphide associated with magnetite, orthite and gold are found in the Proterozoic metasediments in the Sinh Quyen deposits. These deposits have been considered to be of hydrothermal or of metasomatic origin (Dung, 1976).

A major part of mineralization in this subzone is considered to have been the result of subduction and collision activities. The economic elements could have been remobilized from the hanging part of the Benioff zone and deposited there. On the other side of Hong River, there is a zone of mica schist, gneiss with some lenses of marble and also pegmatite

bodies and small size intrusives of granite dated 80 Ma. Along shear zones, graphite in the form of matrix ores are being explored.

This zone could be considered the back arc thrust and is being prospected for gemstones like garnet, ruby and beryl. Further northeast, there is a zone rich in Sn, W, Pb, Zn Au and Hg mineralization, likely to be the last mineralization phase of the Cretaceous Paleogene period.

CONCLUSIONS

Interpreting structural, magmatic, metamorphic and metallogenic evidences, the author comes to the conclusion that the Hoang Lien Son zone was once an overriding margin of the South China continental plate over the Indochina plate. Remnants of the subduction zone still exist such as the Da River trench, Hoang Lien Son magmatic arc in the form of a mountain chain, and the Hong River thrust belt sitting next to it. But through analysis of the sedimentary formations and palaeomorphology of the Da River and Hoang Lien Son zones from Late Triassic to Paleogene, an idea about the collision of the two plates mentioned above could be formulated, The alkaline characteristics of the magmatic rocks of the Jurassic-Paaleogene period and the abundance of sulphide ores of Cu, Fe, Pb and Zn show that the mantle had an influence on the zone.

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