New Data of Silurian-Devonian Stratigraphy and Paleontology in the Da Bac-Hoa Binh Section, Hoa Binh Province, Northwest Vietnam

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Abstract: On the basic of sedimentary, paleontologic materials collected from the new outcrops exposed along the Provincial HighwaysĐT433 from Da Bac Town to Hoa Binh City, the following formations of the Silurian-Devonian succession are divided: The Bo Hieng Formation ($S_{3-4}bh$) is composed of dolomite limestone, sandstone, siltstone over 900m thick yielding the brachiopod *Retziella weberi-Iridistrophia praeumbracula* Assemblage and the mollusc *Schizodus-Paleozygopleura* Assemblage of the Late Silurian age. The Song Mua Formation (D_1^1sm) is composed chiefly of black shale, very poor paleontological remains, 650m thick, overlying conformably the Bo Hieng Formation. The Ban Nguon Formation (D_1^2bn) is composed of sandstone, siltstone, 450m thick bearing the brachiopod *Orientospirifer wangi-Tulynetes hoabinhensis* Assemblage of the Pragian-Emsian age and *Euryspirier tonkinensis– Zosterophyllum* Assemblage of the Early Emsian age, overlying conformably the Song Mua Formation. The Ban Pap Formation (D_1^3-D_3bp) of 750m thick is characterized by medium to thick-bedded limestone, recrystallized limestone containing three fossil assemblage:*Favosites goldfussi- Amphipora raritalis* Assemblage of the Late Emsian age, *Amphipora-Dendrostella* of the Eifelian age? *Caliapora battersbyi - Amphipora ramose* Assemblage of the Givetian age and *Stachyodes costulata-Amphipora laxeperforata* of the Early Frasnian age.

Keywords: Silurian, Devonian, paleontology, stratigraphy, Hoa Binh, Northwest Vietnam.

1. Introduction

The Da Bac Town-Hoa Binh City Section (in the previous study named the Tu Ly-Hoa Binh Section)situated in the lower course of Song Da River, western side of Hoa Binh City, northwest side of the Hoa Binh Hydroelectric Dams, Hoa Binh Province, Northwest Vietnam(Fig. 1), where well exposed sedimentary succession of the Upper Silurian to Upper Devonian. Although this sedimentary succession also fossils in it were reported in many geologic, stratigraphic, paleontologic works by Vienamese also foreign authors but recently, some problems concerning the stratigraphic division, nomenclature and the age of paleontologic assemblages are rather confused. In 2020-2021, the Provincial Highways ĐT433 from Da Bac Town (or Tu Ly Village) to Hoa Binh City have been enlarged, many new outcrops containing rocks and fossils of the Silurian-Devonian sediments exposed continuously in the left slope of mountains. At this very time, the authors together with the staff of the Hanoi Fossil Museum (HFM) conducted a survey; many new fossil assemblages of of the Late Siluarian age in the Bo Hieng Formation and the Pragian-Emsian age in the Ban Nguon Formation have found. The new finding reporte below to propose a new arrange of stratigraphic order for the Devonian succession, simultaneously to supplement paleontological asemblages to the Bo Hieng and Ban Nguon formations, editing some fossils of brachiopod identification of the early Devonian in previous study.

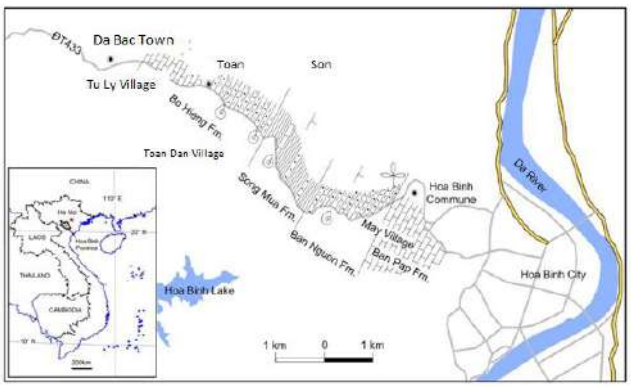

Fig 1. Map showing the location and exposure of the Upper Silurian-Devonian sediments in the Da Bac Town –Hoa Binh City Section, Hoa Binh Province, Northwest Vietnam.

2. History of stratigraphy, paleontology and stratigraphic nomenclature in the Da Bac Town-Hoa Binh City Section

Mansuy H. [13] first described brachiopod *Chonetes hoabinensis* sp.n. collected from the interval between Hoa Binh City and Tu Ly Village (presently is Da Bac Town). Dovjikov A. E. *et al* [2] stated that the Silurian-Devonian sediments exposed in this section belonging to the Fanxipan Zone with sedimentary successions as following: The bottom of the section include dolomitic

limestone, sandstone and siltstone belonging to the Sinh Vinh Formation of the Late Ordovic-Early Silurian age. The Song Mua Formation overlying unconformably is characterized by chiefly black shale of 800m thick, no fossils have been found. It was assigned to the Early Devonian age?-Efelian Stage. The quartz sandstone and shale containing the brachiopod *Euryspirifer tonkinensis*(Mansuy) lying conformably upon the Song Mua Formation was assigned to the Eifelian Stage. The limestone containing abundant corals, stromatoporoids of 700m thick at the top of section is described under the name "Eifelian, Givetian Stages"overlying conformably upon the Eifelian Stage.Dương Xuan Hao [4] fisrt gave the name Suoi Tra Formation for the Early Devonian sediments with stratotype located in a small stream named Suoi Tra, flowing in the NW-SE direction, in parallel with the Provincial Highways ĐT 433, in the interval between two Toan Son and Hoa Binh communes. The lower part of formation is composed of siltstone and shale containing brachiopod *Schellwienella* aff. *praeumbraculum*, *Stropheodonta* aff. *subinterstrialis*; while the upper part is composed of shale and siltstone containing brachiopod *Hysterolites wangi*, *Chonetes* cf. *striatella*, *Strophochonetes* sp. The name Suoi Tra Formation was revised by him [5] named the Suoi Tra Suite (hic!); simultaneously stated that the Suoi Tra Suite lies unconformably upon the Bo Hieng Formation. Nguyen Vinh [17] established the Bo Hieng Formation of the Late Silurian age on the basic of the stratotype near the Bo Hieng Village, Van Ho District, Son La Province, Northwest Vietnam. He also considered the dolomitic limestone and sandstone, siltstone exposed at the bottom of the Da Bac-Hoa Binh Section containing the brachiopod*Retziella weberi* Assemblage of the Late Silurian belonging to the Bo Hieng Formation. Nguyen Vinh [17] also stated that the sediments containing brachiopods of the Early Devonian which was described by Duong Xuan Hao [4, 5] under the name Suoi Tra Formation or Suoi Tra Suite belonging to the Song Mua Formation sensu Dovjikov A. E. [2]. The limestone sequence containing corals, stromatoporoids of the Eifelian-Givetian age exposed at the top of the section at the May Village, Hoa Binh City was assigned to the Ban Pap Formation sensu Nguyen Xuan Bao [18, 19]. Tong-Dzuy Thanh, Vu Khuc et *al*. [25, 26] ; Tran Van Tri, Vu Khuc *et al*.[27, 28]agree with Nguyen Vinh's view point [17] in the stratigraphic division in the Da Bac Town-Hoa Binh City Section. On paleontology, the brachiopod species *Chonetes hoabinhensis* first described by Mansuy H. [13], or *Strophochonetes hoabinhensis* described by Duong Xuan Hao 1980 was revised by Racheboeuf P. 2000 precisely the type species of genus *Tulynetes* gen. nov. Boucot J. & Fang Z. H. [24], Nguyen Huu Hung [16] recorgnized the precence of the Late Silurian brachiopods *Retziella weberi*, *Tadschikia xuanbaoi*, *Lissatrypa* sp., *Fardenia*? sp., and bivalve *Modiomorpha brevis* in this section.

3. Materials and Methods

The paleontologic samples identified in this paper are fossils collected from the different rocks and stratigraphic levels. In the Bo Hieng Formation, the fossils collected from soft siltstone, so before wrapping up neatly by soft materials as cotton woolor toilet paper, need coving on the surface of samples by the super glue 502. This method also applied for paleontologic samples collected from the soft rocks as siltstone, sandstone weathring of the Ban Nguon Formation. For brachiopod *Retziella weberi* and gastropods collected from the marly shale in the uppermost part of the Bo Hieng Formation coving by notification. All lithologic and paleontologic samples in the Da Bac Town-Hoa Binh City collected in ascending order in beds from the Da Bac Town to Hoa Binh City.

In the laboratory, paleontological samples processed by geology tools and Air Scriber. All paleontological samples photographed by Leica Microscope Camera IC90E, and CanonEOS60D with macro lenses 100mm by authors. About 300 fossil and lithologic examples have been collected from the Bo Hieng, Ban Nguon, Ban Pap formations and housing at the Hanoi Fossil Museum, VMT Building, No 1, Lane 82, Duy Tan Street, Hanoi City, Vietnam.

4. The Da Bac Town-Hoa Binh City Section

The geological section from Da Bac Town to Hoa Binh City with the fossil assemblages has been surveyed and collected by the Hanoi Fossils Museum in May 2021.

4.1. Bo Hieng Formation ($S_{3\text{-}4}$*bh*)

The Upper Silurian sediments and fossils of the Bo Hieng Formation exposed continuously 3,5km long, along the road ĐT433, SE direction, from Da Bac Town to Toan Dan Village, Toan Son Commune, Da Bac District Fig. 1):

Member 1: is composed mainly of grey medium-bedded limestone intercalated with dolomitic limestone and sandy limestone, 450m thick. No fossils have been found in this member.

Member 2: is composed mainly of yellowish-brown, thin to medium-bedded siltstone and fine-grained sandstone, 400m thick; exposed continuously on left slope of the road ĐT433, at Toan Dan Village; containing abundant brachiopods of the *Iridistrophia praeumbracula- Retziella weberi* Assemblage of the late Silurian age.

Fig 2. Fossils have been found from the Member 2 of the Bo Hieng Formation: A, B, C –brachiopod *Retzie eberi* Nik.; A– ventral and dorsal valves, x2, HFM 0101; B-dorsal valve, x3, C –ventral valve, HFM 0102; E –brachiopod *Iridistrophia praeumbracula* (Koz.), ventral valve, x3, HFM 0103; E, F -*Nikiforovaena* cf. *vietnamensis* Boucot, ventral valves, x3, HFM 0104; H -bivalve*Cypricardella* ? sp., x2, right valve, HFM 0104 (Collection of the HFM 2021).

Member 3: is composed mainly of chocolate marly shale intercalated with green siltstone, 50m thick, containing abundant brachiopods *Retziella weberi* Nik., *Nikiforovaena vietnamensis* Boucot; bivalves *Schizodus* cf. *myducensis* Fang, *Eoschizodus* sp., *Cypricadella*? sp; gastropods *Paleozygopleura* aff. *Reifenstuhli* Frýda & Blondgett, *Havlicella* sp. and*Subulites*(*Fuspira*) *dabacensis* Hung sp.nov. This member underlies conformably the beds of black shale of the Song Mua Formation. Total thickness of the formation is over 900m.

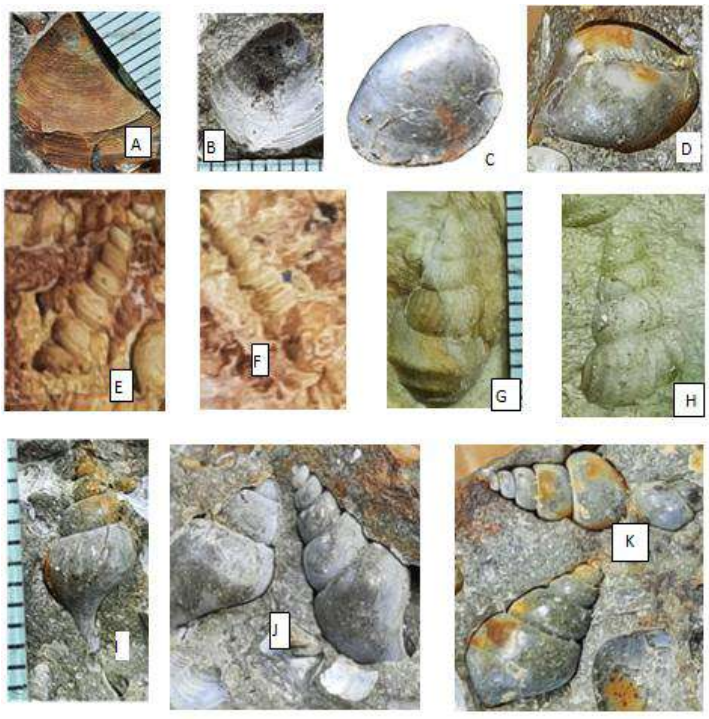

Fig3. Mollusc fossils have been found from the Member 3 of the Bo Hieng Formation: A –bivalve *Eoschizodus* sp., left valve, x3, HFM 02996Bi1; B, C, D - *Schizodus* cf. *myducensis* Fang; B, C – right valves, all x3, HFM 02996Bi2; D -dorsal viewof internal mold, x3,HFM02996Bi3; E, F –gastropod *Murchisonia* sp.,lateral view, x3, E -sampleHFM02997G1; F -sample HFM02997G2; G, H –gastropod *Palaeozygopleura* (*Rhenozyga*)_ aff. *reifenstuhli* Frýda & Blondgett, lateral view, x3, G -sample HFM029996G1, H–sample HFM02996G2; I–*Havlicella* sp., lateral view, x3,HFM02996G3; J, K – *Subulites* (*Fusispira*) *dabacensis* Hungsp. nov., lateral view, x3: J-sampleHFM02996G4-5, K -sample HFM0996G6-9 (Collection of HFM 2021).

4.2. Song Mua Formation (D_1^1*sm*)

Rocks of the Song Mua Formation exposed continuously 1,7km long, from Toan Dan Village way down to Hoa Binh City, on the left taluy siding of the road ĐT433.

Member 1: is composed mainly of black shale with a limestone interbed of 5m thick containing some tabulate remians, may be Favositidae. Total thickness of this member reaches 400m. This member overlies conformably upon the Bo Hieng Formation.

Member 2: is composed mainly of black shale intercalated with some beds of grey quartz sandstone, 250m thick. No fossils have been found. This member underlies conformably the Ban Nguon Formation. Total thickness of the Song Mua Formation reaches 650m.

4.3. Ban Nguon Formation (D_1^2*bn*)

Sediments of the Ban Nguon Formation exposed continuously on the left taluy siding 2,3km western from the Hoa Binh People's Committee (Fig. 1).

Memmber 1: is composed mainy of brown thin-bedded siltstone intercalated with grey shale, 300m thick, bearing abundant brachiopods *Tulynetes hoabinhensis* (Mans.), *Orientospirifer wangi*(Hou), *Eoschuchertella guangxiensis*Wang et Rong, *Mesodouvillina* cf. *subinterstrialis* (Koz.), *Howellella* sp., *Ferganella* sp., *Cyatina* sp., *Parathyrisina* sp., *Corvinopugnax, Latonotoechia* sp., bivalves *Ptychopteria* (*Actinopteria*) *producta* Pojecta, Zhang et Yang, *Sphenotus* sp., *Mytilarca* sp.. This member overlies conformably the Song Mua Formation.

Member 2: is composed chiefly of brown quartz sandstone intrecalated with siltstone, 150m thick. Silty beds of the lower member bearing brachiopods *Euryspirifer tonkinensis* (Mans.), *Acrospirifer laosensis*(Mans.), *Nervostrophia* sp., *Athyris* sp. Many plants *Zosterophyllum* have been found in the quartz sandstone in the uppermost part of the Member 2. Total thickness of the formation is about 450m.

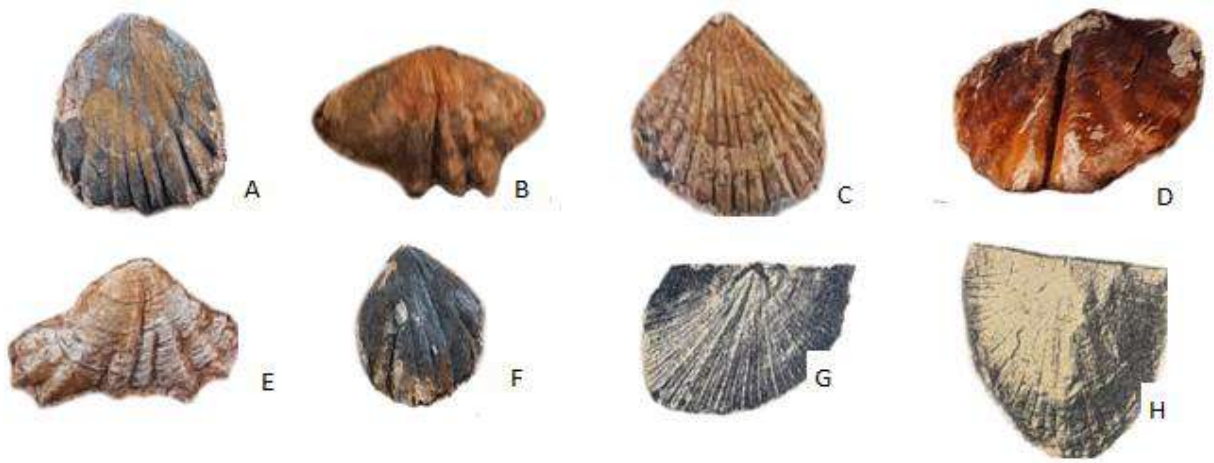

Fig4. Brachiopod fossils in the Member 1 of the Ban Nguon Formation: A -*Ferganella* sp., ventral valve, x2, HFM 0101/1; B -*Corvinopugnax* sp., dorsal valve, x 2, HFM0101/2; C -*Latonotoechia* sp., ventral valve x1,5; HFM0101/3; D -*Howellella* sp., ventral valve, x2, HFM0101/4; E –*Parathyrisina* sp., ventral valve, x2; HFM 0101/5; F -*Barbarothyris* sp., ventral valve,x2; HFM 0101/6 (Collection of HFM 2021); G -*Eoschuchertella guangxiensis* Wang et Rong, ventral valve,x2; H –*Mesodouvillina* cf. *subinterstrialis* (Koz.), dorsal valve, x2 (Collection of Duong Xuan Hao 1980).

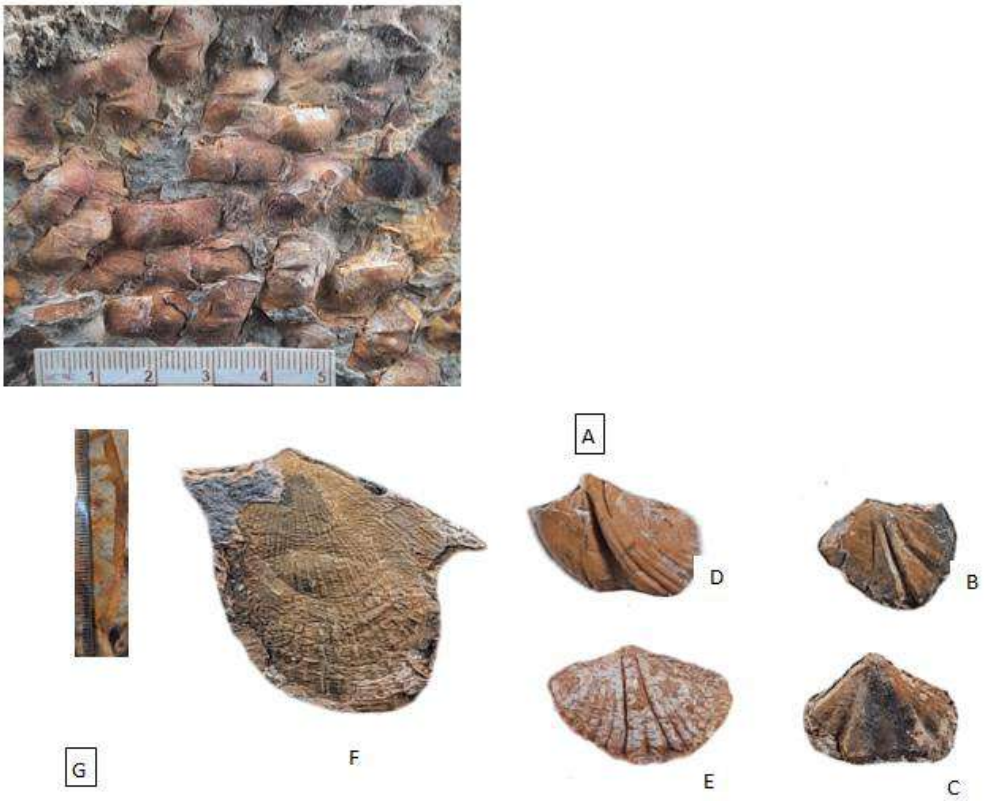

Fig 5. Fossils of the Ban Nguon Formation: A -*Tulynetes hoabinhensis*(Mans.),ventral and dorsal valves, HFM0102/1; B, C -*Cyatina* sp., dorsal valve (B), ventral valve (C), all x2, HFM0102/2; D,E -*Orientospirifer wangi* (Hou), D -ventral valve, E-dorsal valve, all x2, HFM0102/3; F -*Ptychopteria* (*Actinopteria*)*producta* Pojeta *et al*., left valve, x 2, HFM0102/4;; G –plant *Zosterophyllum* sp., HFM 0102/5 (Collection ofHFM 2021).

4.4. Ban Pap Formation (D_1^3-D_2gv*bp*)

The Ban Pap Formation well exposed in the May Village Quarry, western side of Hoa Binh City belongs to the top of the Da Bac-Hoa Binhsection, including three members:

Member 1: is composed of grey medium-bedded limestone intercalated with some black shale layers containing abundant fossils showing the Late Emsianage: tabulates *Favosites kolimaensis* Rukh.,, *Squameofavosites alveosquamatus* Tong-Duy, *Thamnopora* sp., *Caliapora* sp. and stromatoporoids *Amphipora raritalis* Yav.,350m thick.

Member 2: is composed of light-grey, thick-bedded recrystallized limestone,150m thick containing abundant stromatoporoids *Amphipora* sp., *Stachyodes* sp.; tabulates Favositidae; rugose *Dendrostella* ? indet.of the Eifelian age ?

Member 3: is composed of dark-grey, medium to thick-bedded limestone, 250m thick; containing abundant fossils of the Givetian age: stromatoporoids *Actinostroma clathratum*, *Amphipora ramosa*, *Stachyodes laichauensis*, *Dendrostroma oculatum*; tabulate *Caliapora battersbyi*; rugose *Dendrostella rhenana*, *Grypophyllum* sp.; *brachiopod Stringocephalus grandis*. In the uppermost part of this member,the appearance of the Frasnian stromatoporoids: *Stachyodes costulata*, *Amphipora laxeperforata*. Total thichness of the formation is over 750m. Although the limestone sequence of the Ban Pap Formation has stratigraphic position overlying the Ban Nguon Formation in many sections of the Devonian successions in Northwest Vietnam but in this section, it is interrupted by the Suoi Tra Stream flowing in the NW-SE direction, seeming to be a tectonic contact. The Ban Pap Formation is overlaid by terrigenous and carbonate sediments of the Yen Duyet Formation of the Late Permian age.

5. Discussions

5.1. Stratigraphy

The Bo Hieng Formation ($S_{3\text{-}4}$*bh*): the presence of the Bo Hieng of the Late Silurian age in the Da Bac Town-Hoa Binh City is recognized widely in many research works except the Geological map 1: 500.000 North Vietnam of Dovjikov A. E. *et al*. [2].

The Song Mua Formation: is established by Dovjikov A. E. [2] on the basic of the stratotype exposed along the upper course of the Song Mua River, Phu Yen District, Son La Province. According to Dovjikov A. E.[2]

the formation is composed mainly of black shale intercalated with some sandstone and quartzitic layes, no fossils have been found, 800m thick, having a tectonic contact with the Lower Paleozoic sediments and underlying conformably the Eifelian sediments containing brachiopod *Euryspirifer tonkinensis* (Mans.).

Nguyen Vinh [17] revised the stratotype at the course of the Song Mua River. He referented the stratotype of the Song Mua Formation with five member: Member 1 - black shale with some thin interbeds of sandstone, 900m thick, no fossils; Member 2 -black calcareous clay shale, 700m thick, no fossils; Member 3 -black calcareous clay shalewith interbeds of sandstone, lenses of limestone, 400m thick; brachiopods *Howittia wangi* (Hou), *Chonetes* sp, ? *Pugnacina* sp., *Athyris* sp., *Lingula* sp., bivalves *Pterina* (*Actinopteria*) sp.; Member 4 –black shale, quartzitic sandstone, 400m thick; brachiopods *Howittia*cf. *wangi* (Hou), ? *Pugnacina* sp., *Lingula* sp., bivalves *Pterina* (*Actinopteria*) sp., *Sphenotus* ? cf. *spatulata*, *Mytilarca* ? Member 5 –grey marly shale, massive quartzitic sandstone, 170m thick; poorly preserved rugoses. Total thickness of the formation is 2570m.In the Da Bac–Hoa Binh Section, the Song Mua Formation is divided by him [17] into 5 Member: Member 1 -black calcareous clay shale, 580m thick, poorly preserved fossils; Member 2 –black marly shale, 500m thick; brachiopods *Mesodouvillina* aff. *subinterstrialis* (Koz.), *Iridistrophia* aff. *praeumbracula* (Koz.), *Howellella* sp., *Schiellwieniella* sp., *Camarotoechia* sp., *Platyorthis* sp.; bivalves *Sphenotus*? sp.,*Pteria* sp., *Posidonia* sp.; Member 3 –black clay shale interbedded with siltstone and sandstone, 180m thich; brachiopods*Howittia wangi* (Hou), *Strophochonetes* sp., *Howellella* sp., *Pugnacina* sp.; bivalves *Sphenotus* ? cf. *spatulata*(Mans.), *Pteria* (*Actinopteria*) sp., *Mytilarca* sp., *Paracyclas* ?sp.; trylobite *Gravicalymene*; Member 4 –black banded clay shale interbedded with quartzitic sandstone, 130m thick; brachiopods *Camarotoechia* sp., spiriferids; Member 5 –dark grey cherty-clay shale interbedded with sandstone, 50m; brachiopods *Howittia wangi* (Hou), *Strophochonetes* sp., *Tulynetes hoabinhensis*(Mans.), *Pugnacina* aff. *baoi*Zuong et Rzons.; bivalve *Pterina* (*Actinopteria*) *subdecussata* Hall. Total thickness of the Song Mua Formationin the Da Bac-Hoa Binh Section is 1230m.

Tong-Dzuy Thanh, Vu Khuc *et al*. [25, 26]; Tran Van Tri, Vu Khuc *et al*. [27, 28] agree with the Nguyen Vinh's viewpoint [17] in the stratigraphic division for the Song Mua Formation of Northwest Vietnam.

We suggest that descriptions of the Song Mua Formation by Nguyen Vinh [17] in both the Song Mua River and the Da Bac-Hoa Binh sections belonging to two different facies: The black shale (Member 1 and Member 2 with total thickness 1600m, no fossils) in the Song Mua River Section and 580m thick of the black shale (Member 1) in the Da Bac-Hoa Binh Section belonging to deep marine facies which was described before by Dovjikov A. E. [2]; Nguyen Xuan Bao [18. 19] to the Song Mua Formation. The grey shale intercalated with quartzitic sandstone, 970m thick (Member 3,4,5)in the Song Mua River Section and 860m thick in the Da Bac-Hoa Binh Section containing abundant brachiopods of *Mesodouvillina* aff. *subinterstrialis* (Koz.), *Iridistrophia* aff. *praeumbracula* (Koz.), *Howellella* sp., *Schiellwieniella* sp., bivalves *Pterina* (*Actinopteria*) *subdecussata* Hallect. belonging to the shalow marine nearshore facies was described before by Dovjikov A. E. [2] to the " Eifelian Stage" and by Nguyen Xuan Bao [18, 19] to the Ban Nguon Formation, and to the Suoi Tra Formation by Duong Xuan Hao [4].The descriptions of the Song Mua Formation by Nguyen Vinh [17] is not sutable with standard of a formation, primary unit of lithostratigraphy in the International Stratigraphic Guide[15]. On other hand, the Song Mua Formation composing mainly of black shale, no fossils given earlier by Dovjikov A. E. [2].

The Suoi Tra Formation(D_1^2st):is established by Duong Xuan Hao [4] or **the Suoi Tra Suite** [5]on the basic of two fossil horizonts: the lower part contains brachiopods *Stropheodonta* aff. *Subinterstrialis* Koz. [8], *Schellwienella* aff. *praeumbraculum* Koz. [8]; the upper part containing brachiopod *Strophochones* aff. *striatisimus* Will. et Breger, *S. hoabinensis* (Mans.),*Hysterolites* (*Aldamispirifer*) *wangiformis* Zuong, *Pugnacina baoi* Zuong et Rzons. Duong Xuan Hao [4] stated that two brachiopod horizons cited above are older than the *Euryspirifer tonkinensis* Assemblage of the Ban Nguon Formation sensu Nguyen Xuan Bao [18, 19]. The stratigraphic division of the Suoi Tra Formation sensu Duong Xuan Hao [4, 5]on the basic of paleontologic data is not sutable with the critaria of a formation. The Suoi Tra Formation is considered as a synonym of the Ban Nguon Formation.

The Ban Nguon Formation(D_1^2st):is established by Nguyen Xuan Bao [18, 19]for the Geological map 1:200.000 Van Yen Sheet in order to replace the term the "Eifelian stage" used before by Dovjikov A. E. [2] on the basic of the stratotype situated in the Ban Nguon Village, upstream course of the Song Mua River, Phu Yen District, Son La Province. The formation is composed of four members: Member 1 –sandstone intercalted with shale,120m thick; no fossils have been

found. Member 2 –shale intercalated with sandstone, siltstone, 160m thick; containing abundant brachiopods of the *Euryspirifer tonkinensis* Assemblage. Member 3 –quartzitic sandstone intercalated with black shale, 50m thick; brachiopod *Euryspirifer tonkinensis* (Mans.), bivalve *Posidonia* sp. Member 4 – shale intercalated with siltstone, 50m thick; brachiopod *Euryspirifer tonkinensis* (Mans.), *Stropheodonta* aff. *pattei* Yin, *Undispirifer* sp., coral *Calceola* sp. Total thickness of the formation is 380m thick. The Ban Nguon Formation is conformable the underlying Song Mua Formation and the overlying Ban Pap Formation.

We suppose that the terrigenous successions containing abundant brachiopods, bivalves and plants in the Da Bac–Hoa Binh Section which were assigned to the Suoi Tra Formation by Duong Xuan Hao [4, 5] precisely the Ban Nguon Formation sensu Nguyen Xuan Bao [18, 19]. Two fossil assemblages of the Ban Nguon Formation in the Da Bac-Hoa Binh Section can be divided: -the *Tulynetes hoabinhensis-Orientospirifer wangi* Assemblage of the Pragian age and the *Euryspirifer tonkinensis-Zosterophyllum* Assemblage of the Early Emsian age.

The Ban Pap Formation (D_1^3-D_3fr *bp*): The limestone sequence of 1200m thick containing abundant tabulates *Squameofavos alveosquamatus* of the Late Emsian age; stromatoporoids *Amphipora ramosa*, *Stachyodes* sp., *Parallelopora* sp. of the Givetian age exposed near the Ban Pap Village in the upstream course of the Song Mua, Phu Yen District, Son La Province was described by Nguyen Xuan Bao [18, 19]under the name Ban Pap Suite*for the Geological map 1:200.000 Van Yen Sheet. Limestone sequence of the Ban Pap Formation exposed largely in the provinces of Northwest Vietnam. In Hoa Binh Province, the Ban Pap Formation exposed at western side of Hoa Binh City with the total about 750m thick, containing four fossil assemblages: *Squameofavosites alveosquamatus-Amphipora raritalis* of the Late Emsian age; the *Dendrostella-Amphipora* of the Eifelian age; the *Caliapora battersbyi-Amphipora ramosa* of the Givetian age and the *Stachyodes costulata- Amphipora laxeperforata* of the Early Frasnian.

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*Suite: recently, the term “Suite” used in the previous stratigraphic works in Vietnamwas replaced by term “Formation”.

5.2. Paleontology

The fossil assemblage of the Bo Hieng Formation in the Da Bac-Hoa Binh Section have been found by Nguyen Vinh [17] including brachiopod *Retziella weberi*, *Orbiculoidea*, *Strispirifer* sp., *Schellwienella* sp., *Lingula* sp., *Camarotoechia* sp.; bivalves *Modiomorpha* sp., *Modiopsis* sp. The new paleontologic discovery by the Hanoi Fossils Museum in 2021 in this section including *Iridistrophia praeumbracula* (Koz.)-the guide brachiopod species for the Upper Silurian-Lowermost Devonian in Europe [1, 21] first found in the Bo Hieng Formation; *Nikiforovaena vietnamensis* Boucot & Rong, a brachiopod endemic species has been established by Boucot et Rong [24] from the Upper Siluarian sediments of the Dai Giang Formation in North-central Vietnam and of the Kien An Formation in Kien An District, Hai Phong City, Northeast Vietnam. *Eoschizodus* sp. and *Schizodus* cf. *myducensis* Fang established by Fang Z. J. [24] are bivalves known from the Dai Giang and Kien An formations of the Late Silurian [16, 24]. The gastropod assemblage *Murchisonia* sp., *Palaeozygopleura* (*Rhenozyga*) aff. *reifenstuhli* Frýda & Blondgett *Havlicella* sp., *Subulites* (*Fusispira*) *dabacensis* Hung sp. nov. first found from the Upper Silurian sediments in the Bo Hieng Formation, Northwest Vietnam are affinity with the Late Silurian-Early Devonian gastropods in the World.

The fossil brachiopod assemblage from the Member 1 of the Ban Nguon Formation sensu Nguyen Xuan Bao [18, 19] or Suoi Tra Formation sensu Duong Xuan Hao [4, 5] is an important to point out. When establishing the Suoi Tra Formation, Duong Xuan Hao [4] based on the brachiopod assemblages *Stropheodonta* aff. *Subinterstrialis* Koz. [8], *Schellwienella* aff. *praeumbraculum* Koz. [8], *Strophochones* aff. *striatisimus* Will. et Breger, *Strophochonetes. hoabinensis* (Mans.) [5], *Hysterolites* (*Aldamispirifer*) *wangiformis* Zuong [5], *Pugnacina baoi* Zuong et Rzons.[4]. Revision of identification and description of the brachiopod assemblages cited above showing as follow: *Stropheodonta* aff. *Subinterstrialis* Koz. (Duong Xuan Hao, 1980, p. 108, pl. 35, figs. 3,5,7) belonging to genus *Mesodouvillina* Williams, conformis with *M. subinterestrialis* (Koz.) [21];*Schellwienella* aff. *praeumbraculum* Koz.(Duong Xuan Hao 1980, p.110, pl. 35, figs.1,2,4) belonging to *Eoschushertella guangxiensis* Wang et Rong (Wang and Rong 1978, p. 112, pl. VIII, figs. 1-4, 8-14).*Strophochones* aff. *striatisimus* Will. et Breger (Duong Xuan Hao 1980, p. 112, pl. 36, figs. 1,4; pl. 37, figs. 1); *Strophochonetes. hoabinensis* (Mans.) (Duong Xuan Hao 1980, p. 112, pl. 36, fig. 6; pl.37, fig. 2) belonging to *Tulynetes hoabinhensis* (Mans.), have been revised by Racheboeuf P. [20].

Brachiopod species *Hysterolites* (*Aldamispirifer*) *wangiformis* Zuong is one of the debate topic in the study of brachiopod classification in Vietnam. In previous works, this species was described under the different names: *Spirifer cabedanus*-Mansuy H. [11], *Spirifer bijugosus*- Mansuy H.[12, 13], *Spirifer* cf. *granulosus*-Mansuy H. [14],*Spirifer* cf. *cabedanus*-Mansuy H. [14], *Spirifer zicack*-Patte E. [22], *Eospiriferina* ? *wangi*-Duong Xuan Hao and Rzonsniskaya M. A. [2, 3], *Hysterolites wangi*-Duong Xuan Hao [4], *Hysterolites* (*Aldamispirifer*) *wangiformis* Zuong, sp. nov. -Duong Xuan Hao [5]. Nguyen Dinh Hong in Tong-Dzuy Thanh *et al.* [23] described under the name *Howittia wangi* (Hou) and recently, the later name is used widely in geological, stratigraphical publications of Vietnam.

Hou Hong Fei [6] established two new brachiopod species from the Nakaoling (Nagaoling) Formation in the sedimentary sequence of the Lower Devonian-Eifelian in Guangxi Province, South China under the names *Eospiriferina nakaolingensis* and *Eospiriferina wangi*. Revision on two brachiopods cited above, Hou H. F. & Xian [7] established a new genus, named *Orientospirifer*. Since that day in the names *Orientospirifer nakaolingensis* and *Orientospirifer wangi*are used widely in the Chinese paleontological publications [9, 10, 11, 30, 31].

Pugnacina baoi Zuong et Rzons. gen. et sp. nov. is first described [3] from the Mia Le Formation exposed in the Ban Tac Village, Thai Nguyen Province. Presently, this brachiopod species known from the Mia Le Formation of the Early Emsian in the Ban Nhuan Village, Cho Moi District; Yen Lac Town, Na Ri District, Bac Kan Province of Northeast Vietnam and in the Ban Nguon Formation in provinces of Northwest Vietnam.

6. Conclusions

The Silurian-Devonian succession in the Da Bac-Hoa Binh Section is monoclonal SE direction, composed of the following formations:

6.1. The Bo Hieng Formation: is represented by carbonate and terrigenous sediments, over 900m thick containing the brachiopod *Retziella weberi-Iridistrophia praeumbracula* Assemblage and the mollusk *Schizodus-Paleozygopleura* of the Late Silurian-Early Devonian belonging to shallow marine facies.

6.2. The Song Mua Formation: is represented by black shale, 650m thick, very poor paleontological remains of the Early Devonian in general, belonging to the deep marine facies.

6.3. The Ban Nguon Formation: is represented by mainly terrigenous sediments of the nearshore marine facies, 450m thick; containing the *Orientospirifer wangi-Tulynetes hoabinhensis* Assemblage of the Pragian-Emsian age and *Euryspirier tonkinensis*–*Zosterophyllum* Assemblage of the Early Emsian age.

6.4. **The Ban Pap Formation:** is represented by mainly limestone of the carbonate platform facies, 750m thick, bearing the *Squameofavosites alveosquamatus-Amphipora raritalis* Assemblage of the Late Emsian age, the *Amphipora-Dendrostella* of the Eifelian age ? the *Caliapora battersbyi - Amphipora ramosa* Assemblage of the Givetian age and the *Stachyodes costulata-Amphipora laxeperforata* of the Early Frasnian age.

6.5. The lower boundary of the Bo Hieng Formation with the older sediments is not clear. It underlies conformably the Song Mua Formation. The Song Mua Formation is continuous up the Ban Nguon Formation. The stratigraphic relation between the Ban Nguon and Ban Pap formation is not clear, seeming a tectonic contact in the Da Bac-Hoa Binh Section.

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