

Upper Triassic (Carnian) mollusks from the Suoi Bang Formation in Me area, Ninh Binh Province, northern Vietnam

Toshifumi Komatsu¹, Yasunari Shigeta², Hung D. Doan³, Ha T. Trinh³, Hung B. Nguyen³, Minh T. Nguyen³, Nao Kusuhashi⁴, Takanobu Tsuihiji⁵, Takumi Maekawa¹, Julien Legrand⁶ and Makoto Manabe²

¹ Faculty of Advanced Science and Technology, Kumamoto University, 2–39–1 Kurokami, Chuo-ku, Kumamoto 860–8555, Japan

² Department of Geology and Paleontology, National Museum of Nature and Science, 4–1–1 Amakubo, Tsukuba, Ibaraki 305–0005, Japan

³ Vietnam National Museum of Nature (VNMN), Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Hanoi, Viet Nam

⁴ Department of Earth's Evolution and Environment, Graduate School of Science and Engineering, Ehime University, Ehime 790–8577, Japan

⁵ Department of Earth and Planetary Science, The University of Tokyo, 7–3–1 Hongo, Bunkyo-ku, Tokyo 113–0033, Japan

⁶ Department of Biological Sciences, Faculty of Science and Engineering, Chuo University, 1–13–27 Kasuga, Bunkyo-ku, Tokyo 112–8551, Japan

Abstract The Upper Triassic mollusks are found commonly in the lower part of the Suoi Bang Formation, northern Vietnam. In Me area, northern Ninh Binh Province, the formation is characterized by a typical shallowing upward succession from muddy shelf to storm- and wave-dominated coastal sandy deposits. The shelf mudstone commonly contains age-diagnostic mollusks such as an ammonoid *Discotropites* sp. and a bivalve *Halobia convexa* Chen, 1964, which indicate Carnian in age.

Key words: ammonoid, Carnian, halobiid bivalve, Song Da sedimentary basin, storm- and wave-dominated coastal environment

Introduction

The Upper Triassic Suoi Bang Formation is widely distributed in the Song Da sedimentary basin, northwestern Vietnam (Fig. 1). The formation, about 950 m thick, is divided into the lower part composed mainly of shallow marine siliciclastics and the upper part dominated by non-marine deposits intercalating with coal beds in the stratotype of Suoi Bang area, Son La Province and Dam Dun area, northwestern part of Ninh Binh Province, northern Vietnam (Vu Khuc and Nguyen, 1967; Dang, 2006). According to Dang (2006), the shallow marine deposits are predominated by fossiliferous sandstone and mudstone containing abundant mollusks. Norian

to Rhaetian molluscan assemblages characterized by several species of *Halobia* and *Zittelihalobia* (bivalves), as well as *Discotropites* (ammonoid), were described from the lower Suoi Bang Formation (Vu Khuc *et al.*, 1965; Vu Khuc, 1991), although Dang (2006) reported that the lower part of the formation is mainly Norian in stage.

In Me area, northern part of Ninh Binh Province, northeastern Vietnam, Upper Triassic deposits lithologically equivalent to the Suoi Bang Formation are exposed, and yield shallow marine bivalves such as *Costatoria* sp. and *Unionites* sp. and well preserved Upper Triassic plants (Nguyen *et al.*, 2016). However, age diagnostic species have never been described in this area, though an ammonoid *Discotropites* sp. was

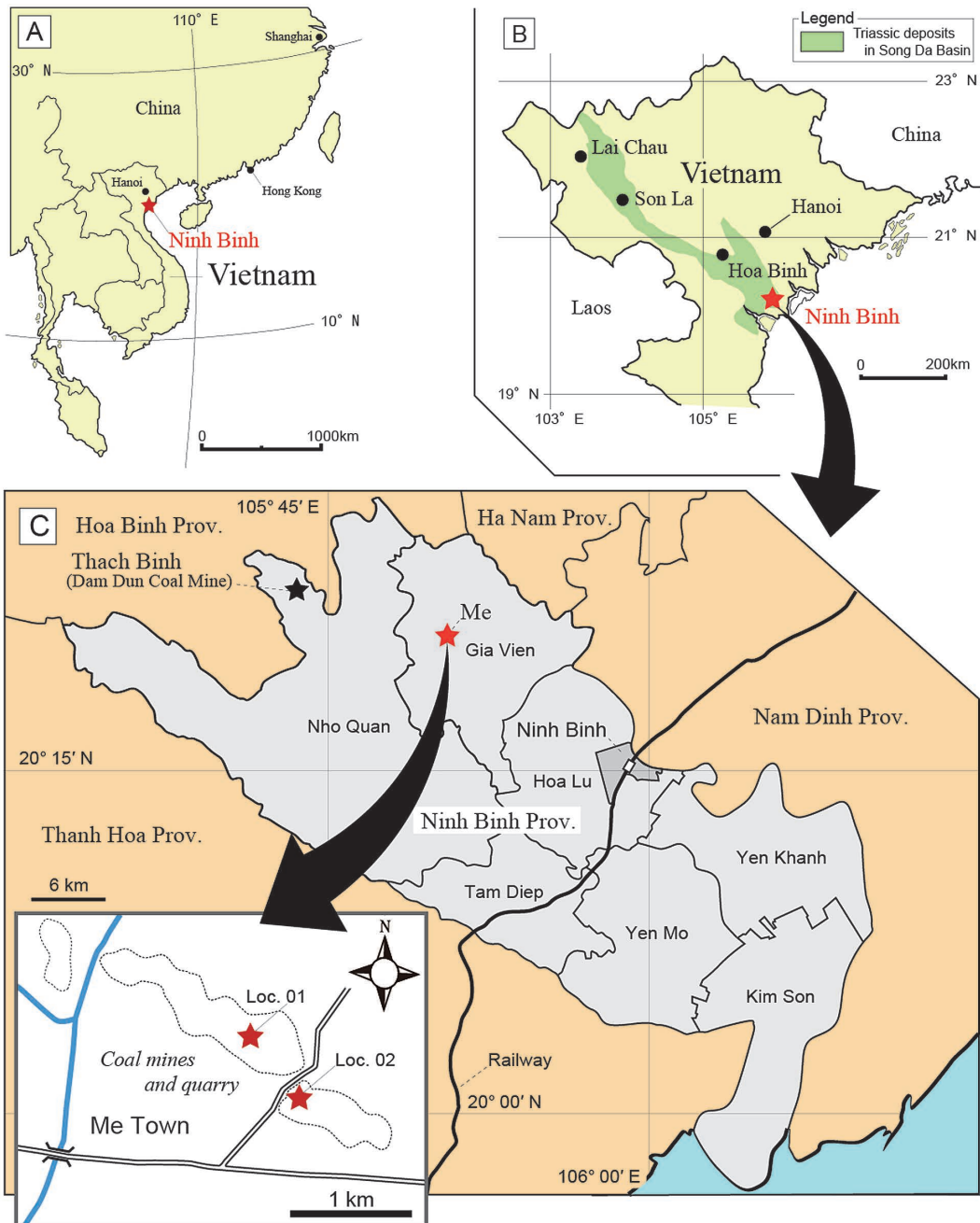


Fig. 1. Geographical location and geological context for fossil localities in Ninh Binh Province, northern Vietnam. A, locus of study area in northeast Vietnam; B, geographical position of Song Da basin; C, geographical markers at Dam Dun Coal Mine and study area in Me, Gia Vien District, Ninh Binh Province.

reported by Nguyen *et al.* (2016). In this paper, we describe key-species of bivalve and ammonoid from the lower part of the Suoi Bang Formation in Me area, and discuss the age and depo-

sitional environments of the formation.

Molluscan specimens described in the paper are stored in Kumamoto University (KMSP), Japan and Vietnam National Museum of Nature

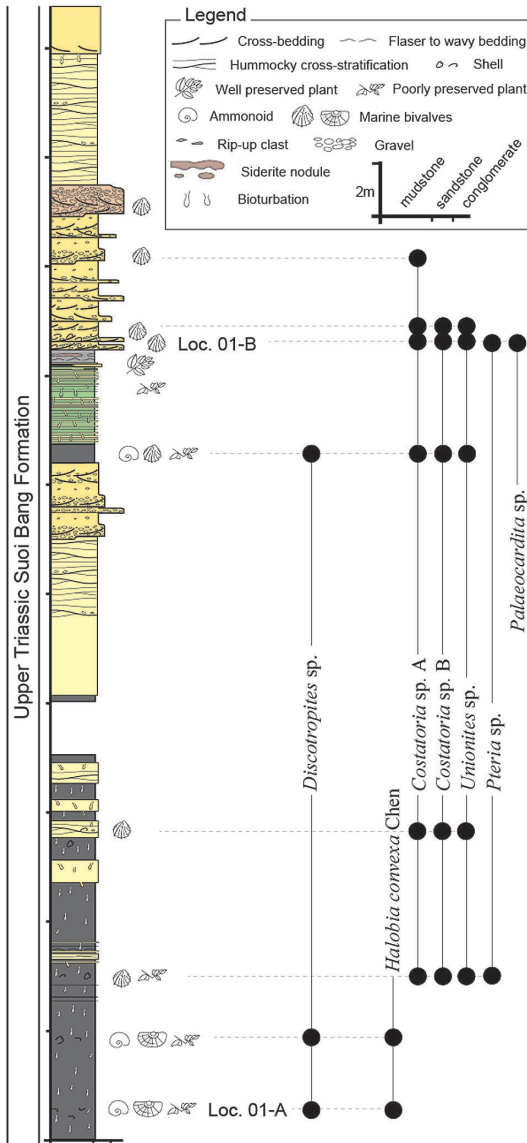


Fig. 2. Columnar section of the Suoi Bang Formation and stratigraphic occurrences of mollusks at the small quarry (Loc. 01) in Me, Gia Vien District, Ninh Binh Province.

(VNMN). All specimens are pair of external or internal molds and rubber casts.

Geologic Setting

In Dam Dun area, Fromaget (1935) reported Norian ammonoids *Tibetites* sp. and *Anatibetites*

sp. from the Suoi Bang Formation. “*Unio*” sp., “*Estheria*” sp. and plants are abundantly found in coaly mudstone and sandstone of the upper part of the formation in the Dam Dun Coal Mine (Fig. 1). In Me area, the lower part of the Suoi Bang Formation consists mainly of conglomerate, sandstone and mudstone containing coal seams. These siliciclastics commonly yield shallow marine bivalves, gastropods and ammonoids. In a small quarry (Loc. 01), a section, about 40 m thick, is composed of thick dark gray, organic rich mudstones overlain by sandstones intercalating with conglomerate and mudstone beds (Figs. 2, 3). The thick mudstones contain very fine sandstone layers characterized by weak lamination and bioturbations. Ammonoids and halobiid bivalves are commonly found in these thick mudstones, where their shell fragments occasionally form very thin lenticular shell concentrations. In the upper part of the section (Loc. 01-B), several lenticular shell concentrations, 1–3 cm thick, dominated by *Costatoria* spp. are found in the basal parts of trough cross-stratified pebbly sandstone and hummocky cross-stratified sandstone (Figs. 3, 4).

Systematic Paleontology

(bivalve by T. Komatsu and ammonoid by Y. Shigeta)

Order Pterioida Newell, 1965
 Superfamily Halobioidea Campbell, 1994
 Family Halobiidae Kittl, 1912
 Genus *Halobia* Bronn, 1830

Type species: Halobia salinarum Bronn, 1830.

Halobia convexa Chen, 1964

(Figs. 5A–G; Figs. 6A, B)

Holotype: No. 14445, figured by Chen (1964, p. 76–77, pl. 1, fig. 4) from Loc. F13, Ganzi area, Sichuan, China.

Material examined: CS. 460. 1, 5–8, 10, 12, 14

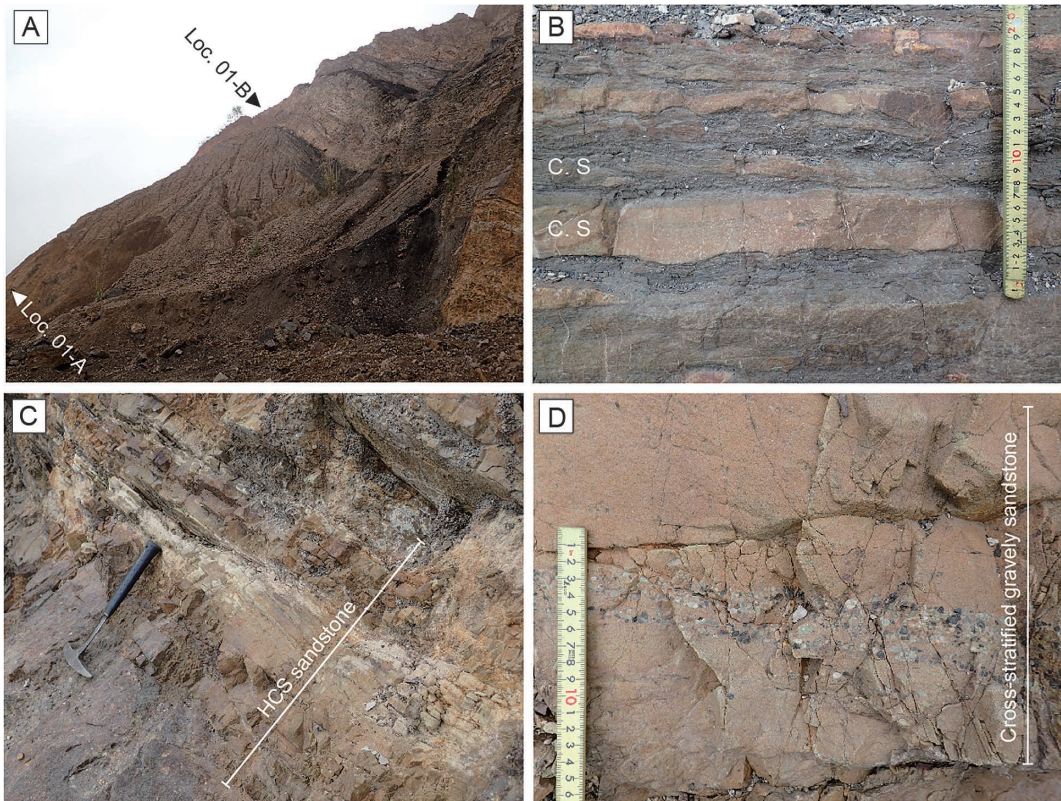


Fig. 3. A, Bivalve and ammonoid bearing horizons in the quarry (Loc. 01), Me, Gia Vien District, Ninh Binh Province. B, Thin alternations of mudstone and sandstone containing small scale cross-stratification (C. S.) and bioturbation (5m above Loc. 01-A). C, Hummocky cross stratified (HCS) sandstone (Loc. 01-B). D, Cross-stratified gravelly sandstone (Loc. 01-B).

in collections of VNMN. KMSp-5198, 5199 are stored in Earth and Environmental Science, Division of Natural Science, Kumamoto University.

Description: Moderate sized ovate shells, equivalve, more or less equilateral; anterior to posterior ventral margin evenly rounded, dorsal margin straight; umbo located at about 2/3 to 3/5 from the anterior end, slightly prominent above hinge line; hinge line shorter than the shell length; outer surfaces ornamented by broad, round-topped radial ribs bifurcated and rarely trifurcated by shallow furrows on the middle to late growth stages, irregularly broad concentric ribs on the early stage of the surface. Anterior and posterior auricles moderate size for the genus, byssal tube well defined. Hinge and ligament unknown.

Discussion: *Halobia convexa* was described

from the Xindugiao Formation, “Sikang series”, Yajiang area, Ganzi (Kantze), Sichuan Province, China (Chen, 1964). The type specimens of *H. convexa* are more or less deformed, and are obliquely ovate to ovate in shape. According to Chen (1964), growth stages of the species are divided into adolescent, early adult and adult stages. The juvenile to adolescent stage (= early stage) is characterized by ovate and typical convex shell ornamented by concentric and simple radial ribs. The several radials begin to bifurcate on early adult stage (= middle stage). In the adult stage (= late stage), bifurcated radial ribs (= secondary radial ribs) are common on obliquely ovate shell, and trifurcated radials are rarely found. Well-preserved *H. convexa* were reported from the lower unit of the Bayanhar Group, in northeast Malanshan, western Qinghai,

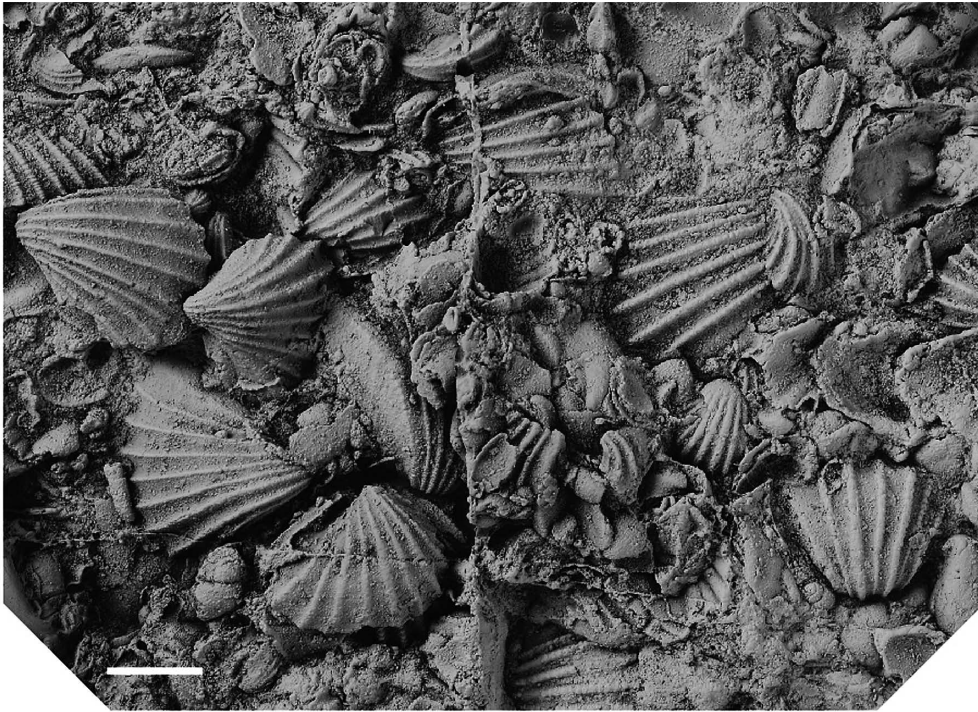


Fig. 4. Shell concentration composed mainly of *Costatoria* spp. (Loc. 01-B). Scale bar is 1 cm.

China by Sha (1995) and Sha and Grant-Mackie (1996), and are characterized by roundly ovate and obliquely ovate shells ornamented by bifurcated and rarely trifurcated broad radial ribs on the adult stage. Probably shell outline is variable from roundly to obliquely ovate, and especially shells of early to middle stages are ovate in shape.

Halobia convexa is similar to *Halobia styriaca* (Mojsisovics, 1874) and *Halobia austriaca* Mojsisovics, 1874 in patterns of concentric and radial ribs but differs in having more numerous and narrower radials. In addition, *H. styriaca* and *H. austriaca* are characterized by broad furrows. *Halobia plicosa* Mojsisovics, 1874 is close to *H. convexa*, but is clearly distinguished by its interference radial pattern and its much smaller size (Table 1). *Halobia convexa* differs from *Halobia partschi* Kittl, 1912 by its convex shell and distinct radial ribs on the anterior surfaces.

Occurrence: Described specimens were collected from the dark gray mudstone at Loc. 01-A. *Halobia convexa* was described from the Carnian

Xindugjiao Formation, "Sikang series", Ganzi area, Sichuan Province (Chen, 1964), and was commonly found in Carnian deep sea deposits in west and south China (Gu *et al.*, 1976; Sha, 1995; Sha *et al.*, 1990; Sha and Grant-Mackie, 1996).

Order Ceratitida Hyatt, 1884

Superfamily Tropitoidea Mojsisovics in Neumayr, 1875

Family Tropitidae Mojsisovics in Neumayr, 1875

Genus *Discotropites* Hyatt and Smith, 1905

Type species: *Ammonites sandlingensis* Hauer, 1850.

Occurrence: Upper Carnian in the Alps (Mojsisovics, 1893), Himalaya (Krystyn, 1982), Okinawa (Ishibashi, 1970), Alaska and California (Smith, 1927) and British Columbia (Tozer, 1994), and Carnian and upper Norian? in Vietnam (Vu Khuc, 1984).

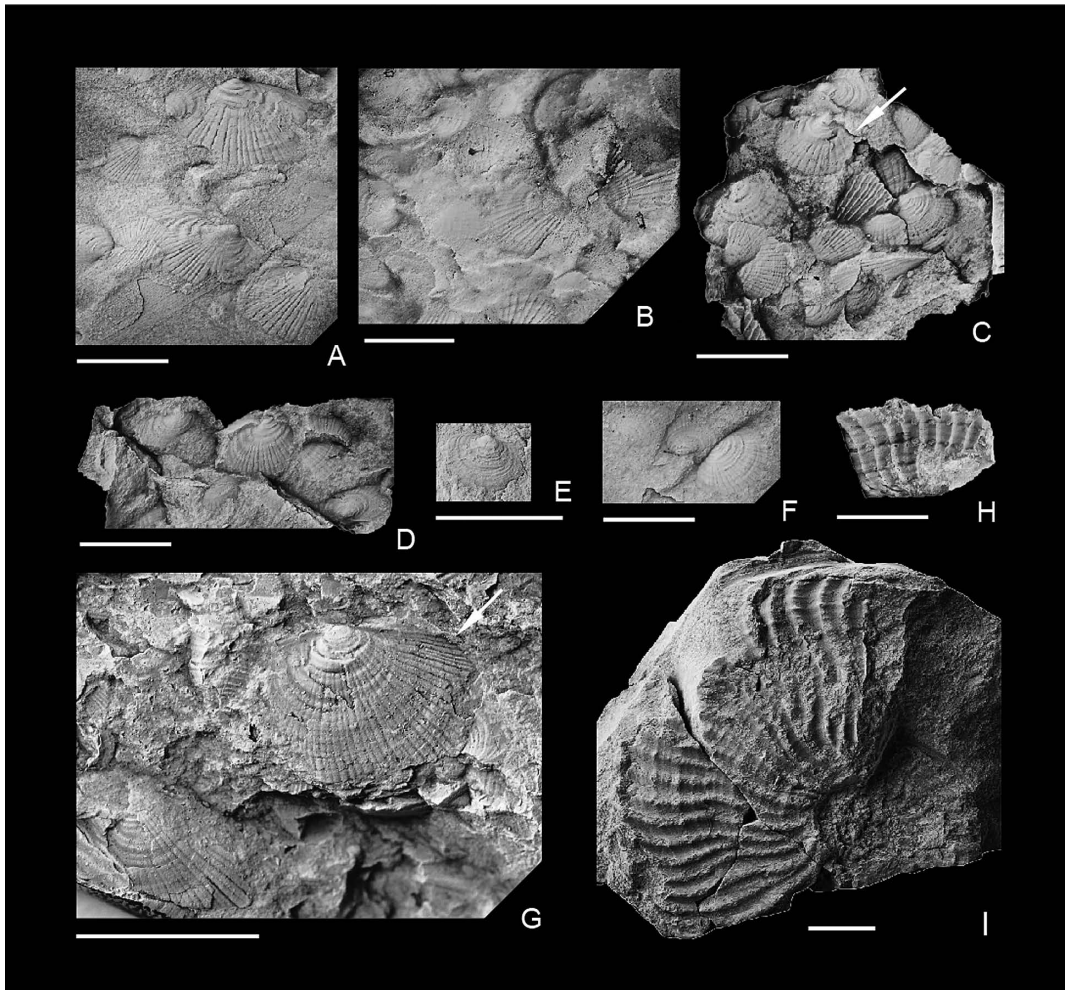


Fig. 5. Molluscan fossils from the lower part of the Suoi Bang Formation, in Me area, Gia Vien District, Ninh Binh Province. Scale bar is 1 cm. A–D, F, monospecific shell concentration consisting of convex-up disarticulated valves of *Halobia convexa* Chen, derived specimens from Loc. 01-A. A, CS. 460.7 B, CS. 460. 6; C, CS. 460. 12, right valve (arrow); D, CS. 460. 10; F, CS. 460.8 E, G, *Halobia convexa* Chen, 1964. E, CS. 460. 14, right valve, collected from Loc. 01-A; G, KMSp-5199, right valve (arrow), collected from Loc. 01-A. H, I, *Discotropites* sp. H, CS. 461. 7, a fragment, collected from 4m below Loc. 01-B; I, CS. 450, derived specimen from Loc. 01A.

***Discotropites* sp.**

(Figs. 5H, I)

Material examined: CS. 450 and CS. 461.7 in the collections of VNMN.

Description: Very involute, very compressed shell characterized by narrow venter with a high keel, indistinct ventral shoulders, and flat or gently convex flank. Umbilicus very narrow with low, nearly vertical wall and rounded shoulder.

Complex ornamentation includes numerous fine spiral lines and spiral rows of fine to coarse knots where the lines cross the ribs. Numerous, prorsiradial, sigmoidal ribs arise at umbilical seam and intercalation of ribs occurs on lower flank. Suture not visible.

Discussion: Smith (1927) classified *Discotropites* into three groups on the basis of the ornamentation. The *Discotropites sandlingensis* group is characterized by having fine spirals,

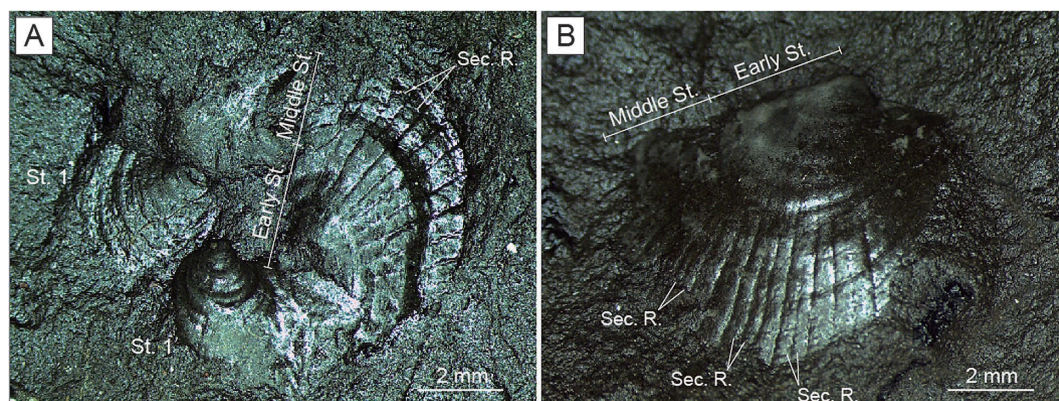


Fig. 6. *Halobia convexa* Chen, 1964, derived specimens from Loc. 01-A. A, fragments in a small shell concentration, CS. 460. 1. B, Right valve, CS. 460. 5. Growth stages of *H. convexa* are divided into early, middle and late stages. The early stage (Early St., St. 1) is characterized by concentric and simple radial ribs. Secondary rib (Sec. R.) appears in the middle stage (Middle St.). In the late stage, trifurcated radial ribs are occasionally found.

Table 1. Measurements of *Halobia convexa* Chen.

Specimen	Length	Height	Thick-ness	Valve
CS 460. 12 (arrow)	8.6 mm	7.1 mm	0.6 mm	Right
CS 460. 14	6.7 mm	4.5 mm	0.4 mm	Right
KMSP5198	7.4 mm	4.7 mm	—	Right
KMSP5199 (arrow)	13.2 mm	10.1 mm	—	Right

sharp ribs and no knots on the ribs. The *Discotropites theron* group has fine spirals, sharp ribs and rudimentary fine knots on the ribs. The ribs of the *Discotropites mojsvarensis* group are stronger and have distinct knots where the fine spiral lines cross the ribs. Because the specimen described here has stronger ribs and distinct knots, it belongs to the *D. mojsvarensis* group and is very similar to the specimens described as *Discotropites laurae* (Mojsisovics, 1893) and *Discotropites sengeli* (Mojsisovics, 1893) from the upper Carnian in Californian by Smith (1927, p. 42) and type specimens of *Discotropites gemmellaroi* from the Nammu Formaton in Vanyen area, Vietnam (Mansuy, 1913, p. 43). It is also somewhat similar to the type specimens of *D. noricus* Vu Khuc, 1984 from the upper Norian? in the Suoi Bang area, Vietnam. However, the fragmental nature and poor preservation precludes a definitive species assignment.

Occurrence: CS. 450 was collected from a float dark gray mudstone block found near Loc. 01-A. Although the exact horizon from which the mudstone block originated is uncertain, judging from the locality where it was found and its lithology, it almost certainly came from the dark gray mudstone in the lower part of the Suoi Bang Formation. Some fragments of *Discotropites* sp. are found in the mudstones about 2 m above Loc. 01-A and 4 m below Loc. 01-B (e.g. CS. 461.7).

Carnian Characteristic Bivalves and Shallow Marine Facies in the Song Da Sedimentary Basin

The Upper Triassic Carnian to Rhaetian? fossiliferous non-marine and marine deposits are widely distributed in the Song Da sedimentary basin. The Carnian marine deposits narrowly crop out in Lai Chau, Son La and Hoa Binh provinces, northwestern Vietnam (Dang, 2006). According to Dang (2006), the Pac Ma Formation containing typical shallow marine deposits characterized by coral reef crops out in Quynh Nhai area, northern part of Son La Province, and abundantly yields corals *Thecosmilia* sp. and *Isastrea* sp., brachiopods *Phaetina* spp., an ammonoid *Paratropites* sp., and Carnian bivalves *Halobia pacmaensis* Vu Khuc, 1991 and

Zittelihalobia cf. rugosa. In Quynh Nhai area, Son La Province, the Nam Mu Formation dominated by deep sea black argillaceous shale is exposed. Vu Khuc (1991) reported Carnian halobiids *Halobia talauana* Wanner, 1907 and *Halobia substyriaca* Chen, 1964 and Carnian to early Norian *Zittelihalobia superba* (Mojsisovics, 1874) from the Nam Mu Formation. In addition, the formation commonly yields Carnian molluscan assemblages consisting of ammonoids, *Margaritropites fongthoensis* Vu Khuc, 1984, *Juvavites* sp. and *Discotropites* sp., and bivalves, *H. austriaca*, *H. talauana* and *Z. superba*. The Song Boi Formation consisting of sandstone and mudstone is distributed in Kim Boi area, Hoa Binh Province, and yields Ladinian bivalve *Daonella udvariensis* Kittl, 1912 and Carnian to early Norian bivalves *Z. superba* and *H. austriaca* (Dang, 2006). Coastal deposits containing coral reefs and deep sea deposits have previously been reported from the northwestern area of the Song Da sedimentary basin. However, sedimentological study, especially reconstructions of Carnian depositional environments, in the Song Da basin remain largely unexplored.

In this study area, the lower part of the section (Loc. 01-A) predominated by thick dark gray mudstone yields typical Carnian mollusks, *H. convexa* and *Discotropites* sp. Overlying thick sandstone is characterized by hummocky cross-stratification (HCS). HCS is considered as having been formed by strong oscillatory or combined flows during a storm (e.g. Walker and Plint, 1992; Johnson and Baldwin, 1996). Thick HCS sandstone is generally accumulated in storm- and wave-dominated shoreface environments (e.g. Walker and Plint, 1992; Cheel and Leckie, 1993). At Loc. 01-A, thick mudstone intercalating with thin HCS sandstone beds and laminated sand layers seems to have been deposited in inner shelf and offshore transition between shelf and lower shoreface. The section likely represents typical shallowing upward sequence from shelf below the storm wave base to storm- and wave-dominated shoreface environments. The Carnian section of the Suoi Bang

Formation is located in the far-east of the Song Da Basin, which suggests that storm- and wave-dominated shallow marine coastal environments were distributed in the eastern part of the basin at least during the Carnian.

Costatoria spp. are abundantly found in shoreface sandstone characterized by HCS and trough cross-stratification, and are common in inner shelf sandstone and bioturbated mudstone. Bioturbated inner shelf mudstone contains in-situ preserved *Costatoria* spp. and *Unionites* sp. Outer shelf mudstone characteristically yields *Halobia convexa* and well-preserved *Discotropites* sp. Generally, paper-shell assemblages consisting of *Halobia*, *Daonella* and *Posidonia* are typical for Triassic basin-floor and offshore facies (e.g., Kobayashi and Tokuyama, 1959; Fürsich and Wendt, 1977; Aberhan, 1994; Komatsu *et al.*, 2004b). Furthermore, Aberhan (1994) reported that these bivalves are characteristic Late Triassic oxygen-controlled environments. On the one hand, abundant *Posidonia* were occasionally found in the storm dominated inner shelf mudstone containing bioturbation (Komatsu *et al.*, 2004b). The transitional zones from outer to inner shelf facies commonly yields *Daonella moussoni* and *Daonella* sp. (Komatsu *et al.*, 2004a). It appears that some species of these paper shells widely inhabited in shelf, continental slope and basin-floor environments.

Concluding Remarks

In Me area, northern part of Ninh Binh Province, northern Vietnam, the lower part of the Suoi Bang Formation is exposed in the eastern Song Da Basin, and is composed of storm- and wave-dominated shallow marine and muddy shelf deposits. The formation is characterized by a coarsening upward sequence from shelf mudstone to shoreface sandstone containing trough- and hummocky-cross stratifications in the study area. The organic rich shelf mudstone yields Carnian mollusks such as an ammonoid *Discotropites* sp. and a bivalve *Halobia convexa*. Overlying shoreface sandstone intercalates with several

shell concentrations dominated by *Costatoria*.

In the stratotype of Suoi Bang area, Norian to Rhaetian? molluscan assemblages consisting of *Halobia*, *Zittelihalobia* and *Discotropites* (Vu Khuc *et al.*, 1965; Vu Khuc, 1991; Dang, 2006) have been reported from the lower part of the Suoi Bang Formation. In our preliminary research in the stratotype area, undescribed mollusks containing halobiid bivalves, *Discotropites* and *Tropites* were found in the lowermost to lower parts of the formation. These molluscan assemblages seem to contain diagnostic species of the Carnian age. It is desirable to carry out more research to evaluate regional correlation of the Suoi Bang Formation between Me and stratotype of Suoi Bang areas.

Acknowledgements

We thank Yasuyuki Tsujino (Tokushima Prefectural Museum) for his review of the manuscript, and Nguyen H. Hung (Vietnam National Museum of Nature) for his cooperation in the field work. This research received initial internal support from the discretionary fund of the Director General, NMNS, and was financially supported by Grant-in-Aids for Scientific Research (KAKENHI) from the Japan Society for the Promotion of Science (16K05593 to Komatsu) and Project for Collecting Paleontological Specimens in Vietnam (BSTMV.28/15–18 to Doan).

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