Review

Vol. 22, No. 5, p. 857–869, October 2018
https://doi.org/10.1007/s12303-018-0036-x
pISSN 1226-4806 eISSN 1598-7477

Geosciences Journal GJ

Recognition of stratigraphic sequence in the northeast Asian continent: a critical essay

Sung Kwun Chough*

School of Earth and Environmental Sciences, Seoul National University, Seoul 08826, Republic of Korea

ABSTRACT: This paper discusses the equivocal nature of the refined definition of stratigraphic sequence for universal recognition. The current definition requires a couple of inferences to be drawn: diagnosis of "a full cycle of base-level change" and, in turn, evaluation of stratal lapout "systems tract". In the initial depositional models, the inferences were made in vertically exaggerated seismic profiles of passive continental margins with condensed clinoform geometry and bounding surfaces. In ancient outcrop sections, which are devoid of the clinoforms, the inferences are practically implausible. On the other hand, the cycle change is not always in phase with the unconformity, especially with the upper unconformity affected by tectonic movements. For these reasons, a sequence is limited for universal recognition. Intercontinental correlation of stratigraphic sequence is implausible. An alternative sequence can be defined by "a basin-wide correlation of recurrent facies succession bounded at the base by distinctive lithologic discontinuity or erosion surface". A sequence in alluvial deposits can be identified on the basis of its bounding discontinuities. The evolving definition of stratigraphic sequence signals the demise of the initial concept of sequence stratigraphy and leads to a new avenue for the recognition of stratigraphic sequence. A distinctive sequence can be recognized based on the descriptive characteristics and scale of the succession.

Key words: sequence stratigraphy, sequence, definition, Asian continent

Manuscript received June 1, 2018; Manuscript accepted August 6, 2018

1. INTRODUCTION

In spite of forty years of study on sequence stratigraphy since Vail et al. (1977) first proposed the paradigm, there is no general agreement on a standard definition of stratigraphic sequence. Initial definition of sequence is "a relatively conformable succession of genetically related strata bounded by unconformities or correlative conformities" (Mitchum, 1977). There are a number of formal definitions based on the diagnosis of stratigraphic surfaces and systems tracts relative to the base-level change (Catuneanu, 2006). Catuneanu et al. (2009) redefined the stratigraphic sequence as "a succession of strata deposited during a full cycle of change in accommodation or sediment supply". "Such cycles can be bounded by unconformities or correlative conformities and range in duration from hundreds of thousands to a few million years". Catuneanu (2017) has again proposed a revised definition of stratigraphic sequence, "a unit bounded by any recurring surface of sequence stratigraphy". This new definition is abstract, because recognition of "recurring surface" is impractical.

In retrospect, the refined definition (Catuneanu et al., 2009) was proposed to encompass the six formal models by reconciling the variable sequence boundaries (Catuneanu et al., 2011) (Fig. 1b). It is thus mandatory to discuss validity of the refined definitions of stratigraphic sequence in order to clearly understand its genesis. In a modern synthesis, Miall (2016) has reviewed the development history of formal definitions for sequence stratigraphy. Attention is currently given to the specifics of depositional processes in high-resolution geologic time scales. In this paper, I discuss the equivocal nature of the refined definitions of stratigraphic sequence for practical recognition in the Paleozoic and Mesozoic successions of the northeast Asian continent.

2. EQUIVOCAL NATURE OF SEQUENCE BOUNDARY

The initial definition of sequence (Mitchum, 1977) was developed primarily from the condensed seismic profiles of passive continental margins; the use of massive data of seismic reflection records provided powerful tool for correlation and sequence

***Corresponding author:**
Sung Kwun Chough (Professor Emeritus)
School of Earth and Environmental Sciences, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 08826, Republic of Korea
Tel: +82-10-8999-6748, Fax: +82-2-871-3269, E-mail: sedlab@snu.ac.kr

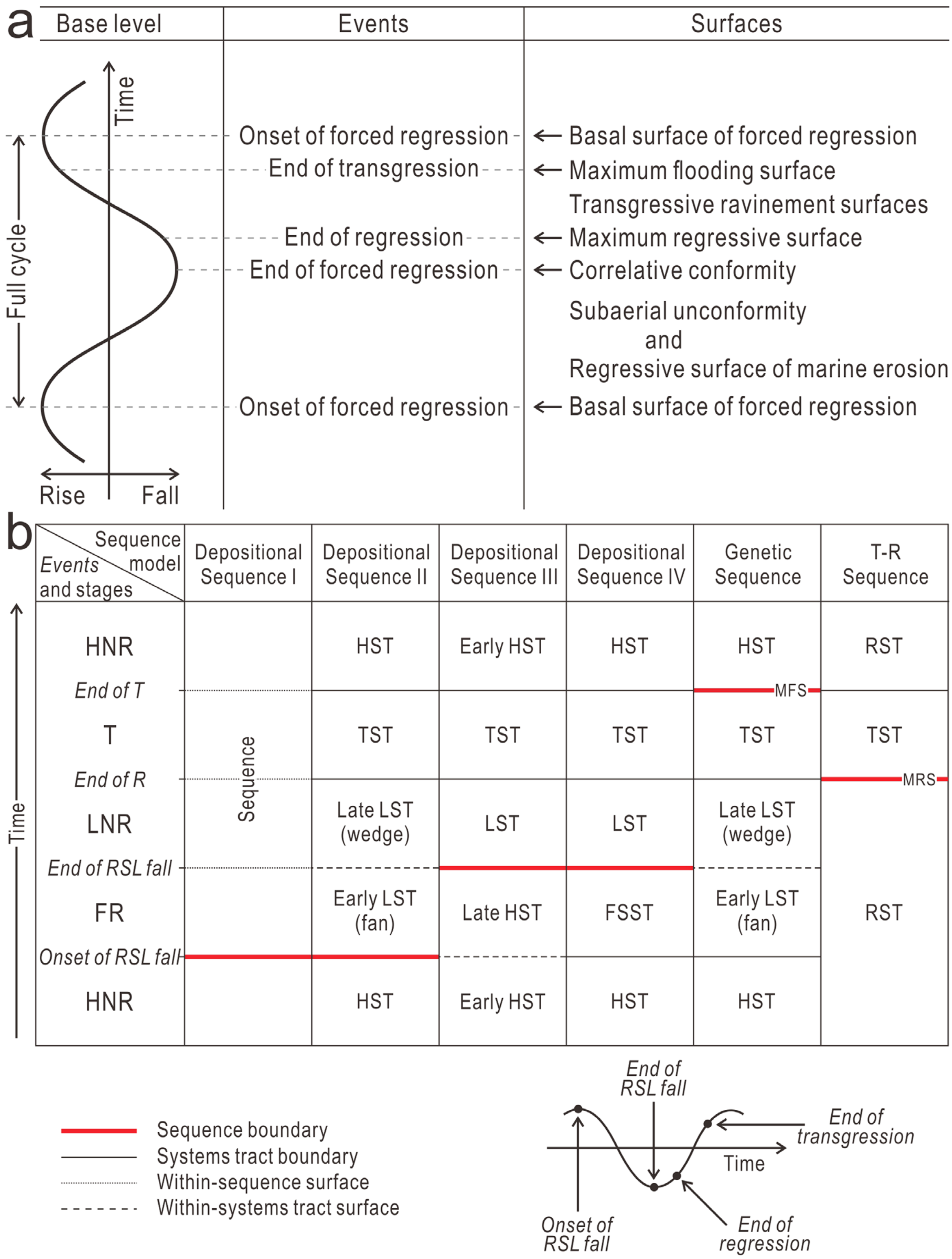

Fig. 1. (a) Stratigraphic surfaces used in the definition of sequences and systems tracts and their timing, relative to the cycle of base-level change (after Catuneanu, 2006). (b) Nomenclature of systems tracts and timing of sequence boundaries for the various sequence stratigraphic approaches. RSL = relative sea level, T = transgression, R = regression, FR = forced regression, LNR = lowstand normal regression, HNR = highstand normal regression, LST = lowstand systems tract, TST = transgressive systems tract, HST = highstand systems tract, FSST = falling-stage systems tract, RST = regressive systems tract, T-R = transgressive-regressive, MFS = maximum flooding surface, MRS = maximum regressive surface (after Catuneanu et al., 2011). (c) Sequence architecture, showing common characteristics of seismic reflection terminations (after Vail, 1987). (Note that there are no scales.) (d) Schematic cross-section through an ideal continental-margin succession, showing the relationships between the major surfaces (after Embry, 1995). DS = depositional sequence, TR = T-R sequence, GS = genetic stratigraphic sequence, CC = correlative conformity. (Note that there are no scales.)

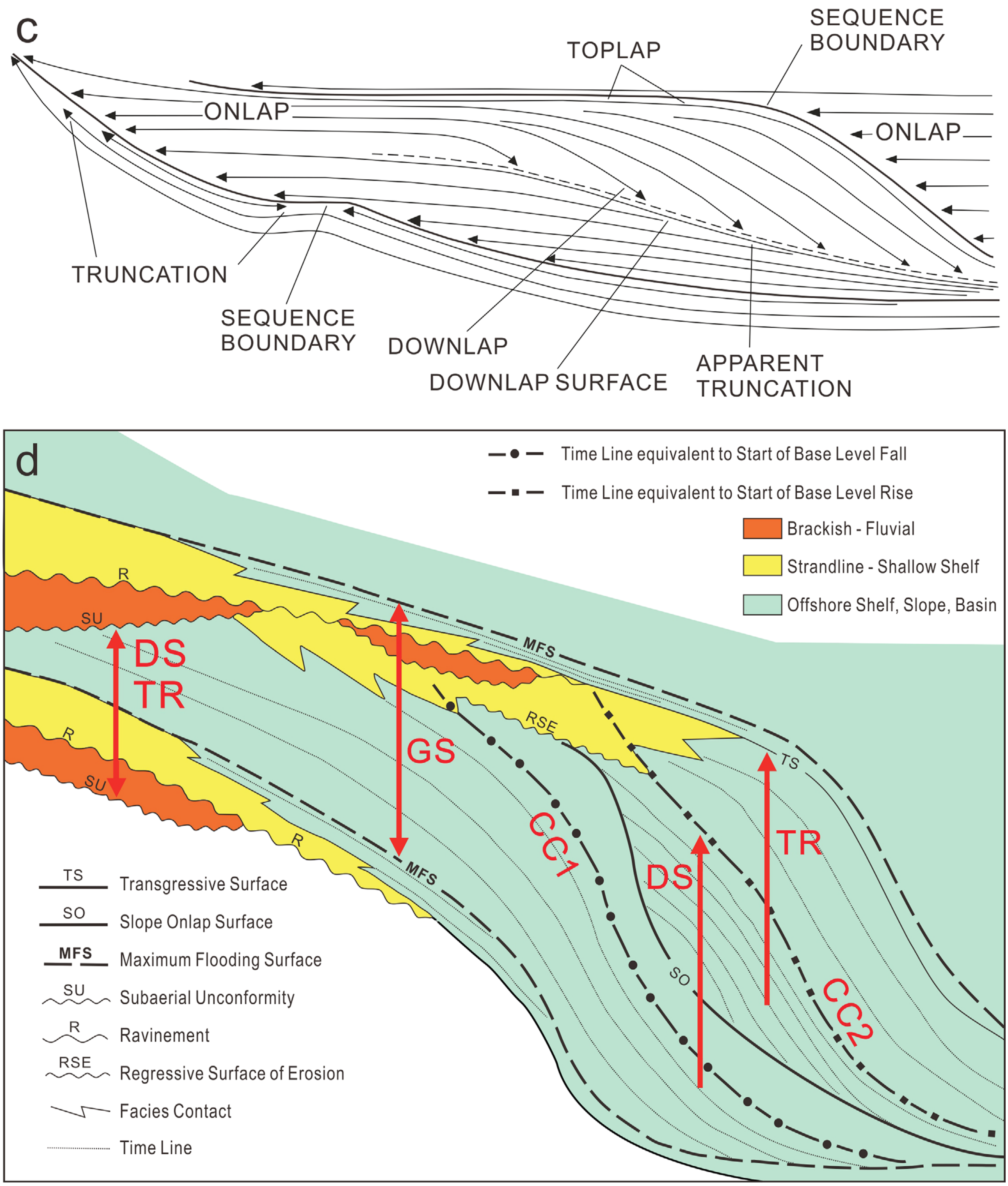

Fig. 1. (continued).

stratigraphic analysis. However, it was rooted in the simple notion that a sequence represents a "genetically related" unit that formed during a global (eustatic) cycle of sea-level fall and rise. Miall (2010) has summarized arguments on the implausible hypothesis of global eustasy. Catuneanu et al. (2009) proposed a refined definition. According to this definition, recognition of a sequence depends on the diagnosis of a full cycle of base-level change in accommodation or sediment supply (Fig. 1a).

Recognition of a full cycle of change is, however, practically limited; the "cycle of change" is a variable factor (non-descriptive

 https://doi.org/10.1007/s12303-018-0036-x

inference) which is diagnosed from another variable, the stratal lapout "systems tract". A systems tract is, in turn, evaluated from the clinoform geometry in relation to the bounding surface. For these reasons, a sequence can only be recognized in a succession with clinoform bed geometry. There are six formal sequence models, including depositional sequences I–IV, genetic sequence, and T-R sequence (Fig. 1b) (Catuneanu, 2006). In depositional sequences I and II, the sequence boundary is drawn at the "onset of forced regression" between the highstand systems tract and the lowstand systems tract; in depositional sequences III and IV, the sequence boundary is at the "end of forced regression"; in genetic sequence model, the boundary is between the transgressive systems tract and the highstand systems tract; in T-R sequence, it is between the regressive systems tract and transgressive systems tract. However, these models, except the genetic sequence model, can be only applicable to the succession where recognition of stratal stacking patterns (clinoform bed geometry in lieu of systems tract) is plausible or available. Otherwise, it is implausible to diagnose the "cycle of change".

The initial models of sequence stratigraphy have been primarily developed in vertically exaggerated seismic profiles of passive continental margins in which the horizontal scales are artificially contracted, commonly shown in line drawings (Fig. 1c). The clinoform bed geometry is particularly condensed and the slope angle is very enhanced, which are used for the relationships between the major surfaces. The sequence stratigraphic models were typically extracted from this kind of schematic cross-sections (Fig. 1d). This highly deceptive view is used as a template and compared with those in other basins. In most outcrop sections, the natural-scale clinoform bed geometries are seldom recognized, except for small-scale fault-bounded basin margins (alluvial fans and fan-deltas) and rare large-scale exposures such as the Book Cliffs, Utah.

For a succession, accumulated in marginal seas (epicontinental seas and carbonate platforms, etc.) without noticeable break in slope gradient, evaluation or diagnosis of the cycle of change in accommodation or sediment supply can be practically implausible. The seafloor topography (or bedform surface) would vary from place to place within a basin, depending on the source of sediment supply around the margin and production rate of carbonate sediment as well as hydrodynamic dispersal system. Especially, the changes in relative intensity of the depositional processes on a local scale can cause stratigraphic variations, which were commonly assumed as a constant regime throughout the sea-level cycle (Yoshida et al., 2007). As a result, the strata would not evolve into a uniform stratal pattern with clinoform geometry during transgression and regression. Although subaerial erosion may occur during lowered sea level, no clear evidence would exist for the demarcation of a sequence boundary between the highstand and lowstand systems tracts.

The lower-bounding unconformity is commonly recognized as a sequence boundary. However, the upper-bounding unconformity is seldom revealed in stratigraphic records, unless affected by tectonic movements (or significant sea-level fall). Especially, it is absent where prolonged depositional conditions are maintained without a change in accommodation. On the other hand, correlative conformity is a hypothetical surface and bears no indication of the key stratigraphic processes and events (Miall, 2016). A misdiagnosis of the upper sequence boundary casts doubt on the validity of "end of the cycle" for a stratigraphic sequence.

In the following, I discuss these practical issues in some ancient (Paleozoic and Cretaceous) outcrop sections of the northeast Asian continent.

3. UNCONFORMITY-BOUNDED LOWER PALEOZOIC SUCCESSION IN NORTHEAST ASIAN CONTINENT

3.1. General Geological Background

The lower Paleozoic (Cambrian–Ordovician) succession in the Korean peninsula comprises mixed siliciclastics and carbonates, unconformably overlying Precambrian granite gneiss and metasedimentary rocks and unconformably overlain by the upper Paleozoic (Carboniferous and Permian) succession (Chough, 2013). Identical succession occurs in the North China Platform and the Pyeongnam Basin, North Korea (Fig. 2), bounded by the unconformities below and above (Meng et al., 1997; Chough, 2013; Lee et al., 2017). The lower unconformity represents initial transgression, whereas the upper one formed during tectonic uplift in the late Ordovician. Deposition of marine siliciclastic sediments resumed in the Carboniferous, representing a significant time gap of about 100 million years in the Silurian and Devonian (Chough, 2013). The major tectonic boundaries of the Sino-Korean Block and the distribution of outcrops suggest that the Taebaek area was most likely located in the eastern margin of the North China Platform (more than 1000 km apart) (Fig. 2).

3.2. Taebaek Area

The Taebaek Group (1200 m thick) (Fig. 3) is exposed in numerous small-scale road- and stream-cut sections, where clinoform stratal stacking patterns are unrecognizable. Correlation of individual sections can be made by detailed description of lithofacies and geological mapping as well as biostratigraphy (Chough, 2013). Sedimentation was initiated in the Cambrian Series 2 with a global rise in sea level during the long-standing transgression for tens of millions of years. The platform was under mild climatic conditions with an explosive production of

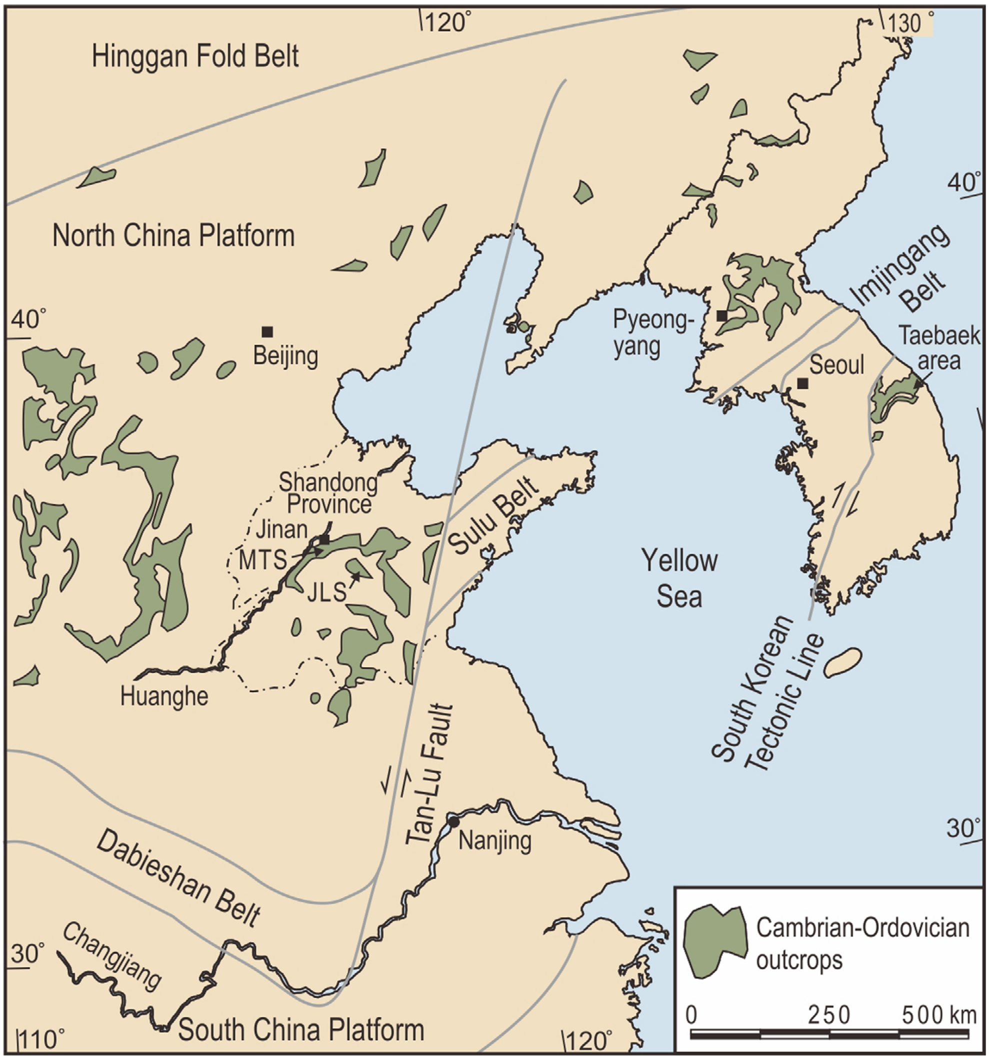

Fig. 2. Major tectonic boundaries of the Sino-Korean Block and the distribution of the Cambrian-Ordovician outcrops in the North China Platform (Shandon region, China and Taebaek area, South Korea). Note that the outcrops occur in the north of the Dabieshan Belt and Sulu-Imjingang Belt, offset by the left-lateral Tan-Lu Fault and the right-lateral South Korean Tectonic Line. According to the tectonic reconstruction (Chough et al., 2000, 2013), the Taebaek area was most likely located in the eastern margin of the platform in the Paleozoic. MTS = Mantoushan, JLS = Jiulongshan. After Chough (2013).

calcium carbonates by organisms such as algae, crinoids, trilobites, and brachiopods as well as microbes.

Entire succession was recognized to comprise four (super) sequences based on the lithofacies distribution such as the shallowing-upwards or deepening-upwards cycles (Kwon et al., 2006). Sequence I represents an initial inundation and subsequent drowning during the Cambrian Series 2 to 3. Sequence II formed by prolonged marine flooding with abundant carbonate production in peritidal environments during the Cambrian Series 3 to the Furongian and was terminated by the supply of large amounts of siliciclastic sediments at the Cambrian–Ordovician boundary. Input of siliciclastic sediments was interpreted as representing regional epeirogenic crustal movements, although there is no evidence of subaerial unconformity or erosion. Sequence III comprises the siliciclastics, followed by shale of marine flooding and platform carbonates in the Early Ordovician. Following the global sea-level fall in early Middle Ordovician, sequence IV formed on the subaerial surface by resumed marine flooding in the Middle Ordovician. This recognition of the four sequence units was simply deductive based on the comparison with the global sea-level cycles.

3.3. Shandong Region

The North China Platform was an extensive epeiric sea (more than 1500 km east-west and 1000 km north-south) (Meng et al., 1997) (Fig. 2). The sedimentary succession comprises thick (ca. 1800 m thick) mixed carbonate and siliciclastic sediments (Fig.

 https://doi.org/10.1007/s12303-018-0036-x

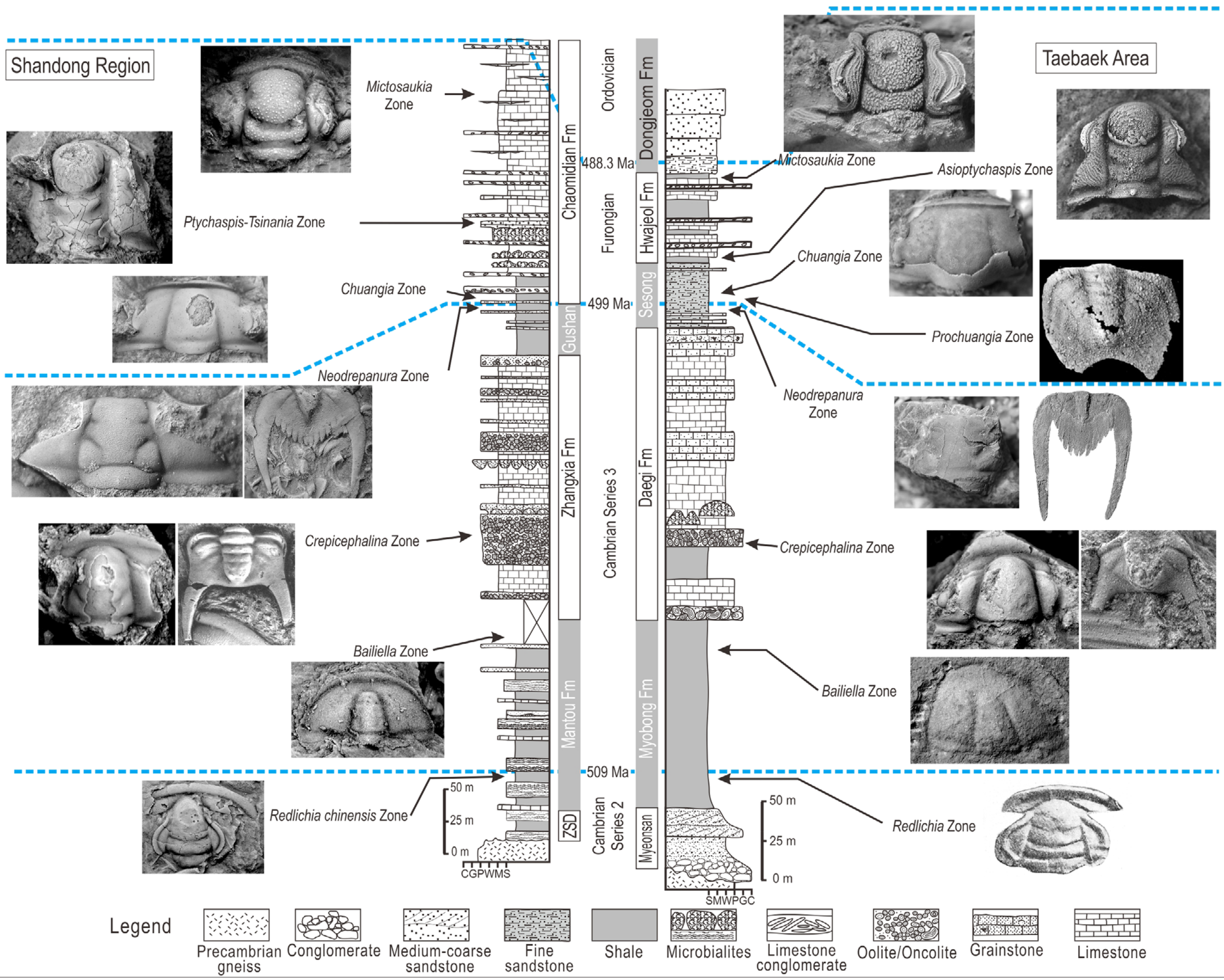

Fig. 3. Comparison of the Cambrian stratigraphy between the Shandong region and the Taebaek area, based on trilobite biostratigraphy. ZSD = Zhushadong Formation. Modified after Chough (2013).

3). It is superbly exposed in the western part of Shandong Province (Chough et al., 2010). Meng et al. (1997) identified two megasequence units in the entire succession of the North China Platform: Lower Cambrian through Lower Ordovician strata and Middle through Upper Ordovician strata, separated by a major paleokarst. However, they recognized a number of discontinuities within the entire succession.

Detailed facies analysis of the Cambrian succession in Shandong Province has revealed that there are numerous depositional cycles and discontinuities. The lower part of the Cambrian succession (Liguan, Zhushadong, and Mantou formations) (mixed siliciclastic and carbonate deposits) represents initial marine flooding and stabilization of shallow marine environments (Lee and Chough, 2011). Siliciclastic sediments were derived from unsubmerged archipelago and deposited in coastal floodplains under strong tidal regime, whereas carbonates were produced in flooded peritidal environments. With ensued rise in sea level, carbonate production kept pace and formed numerous depositional cycles comprised of lime mudstone, dolomite, stromatolite, and purple mudstone, showing a general shallowing-upward trend. Here, the shallowing cycles are culminated by a prominent bed (unit 6) (about 25 m thick) (Fig. 4) formed in supratidal environments with occasional subaerial exposure. It occurs in the entire area (120 km east-west, 110 km north-south) in Shandong Province.

Production of carbonates kept up with the rise in sea level in the overlying Zhangxia Formation (Cambrian Series 3), dominated by oolite and various microbialite facies, representing optimum conditions for carbonate production and microbial activities (Woo and Chough, 2010). The microbialite-dominated carbonate platform in the upper part of the Zhangxia Formation was subsequently drowned; the overlying succession consists mainly

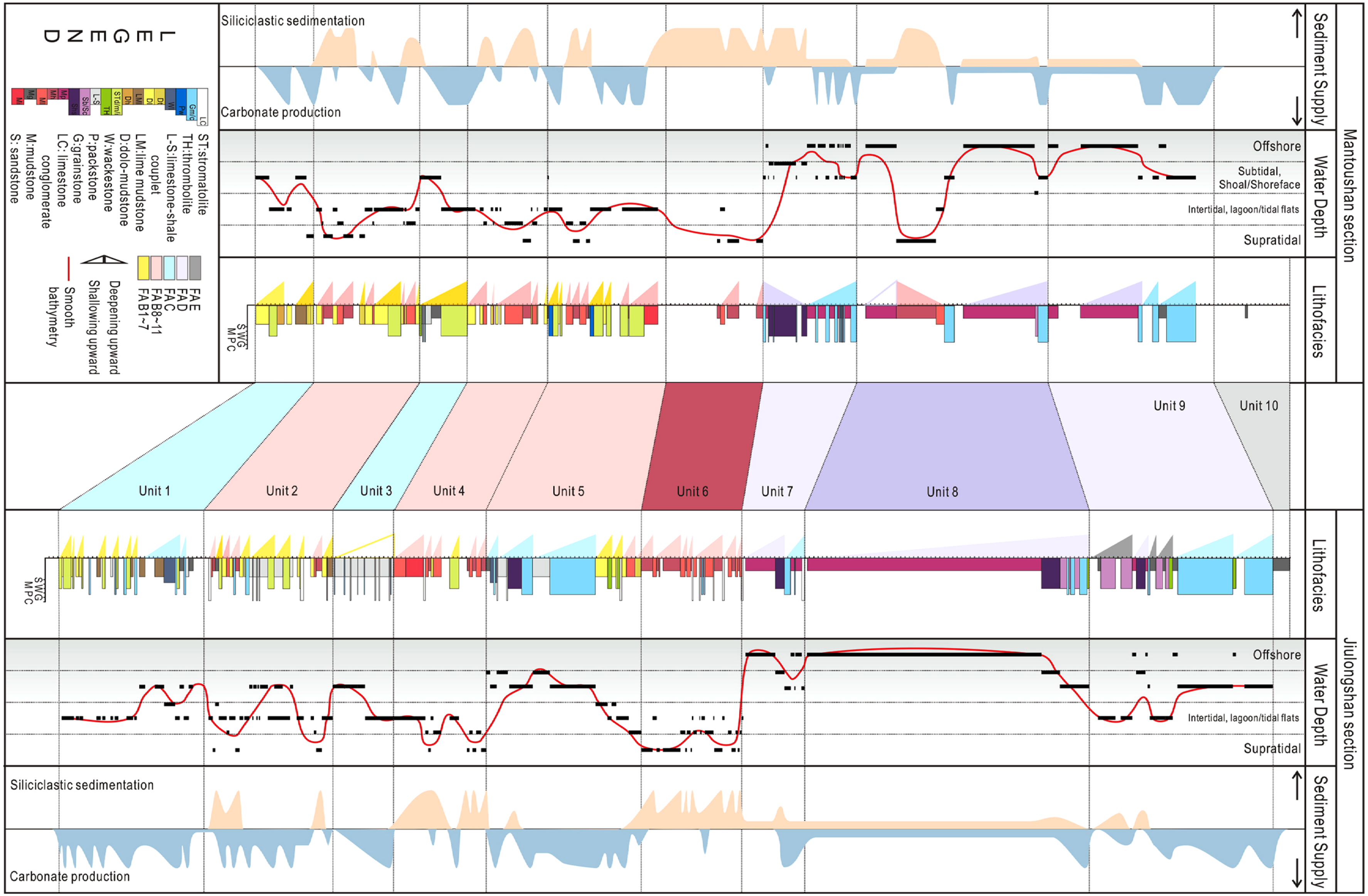

Fig. 4. Columnar summary of depositional characteristics for the Zhushadong and Mantou formations compared in two sections (Mantoushan and Jiulongshan). A potential sequence boundary (unit 6) is characterized by thick homogeneous purple mudstone and fine sandstone with abundant halite pseudomorphs and desiccation cracks. It is underlain by numerous shallowing-upward cycles of mixed siliciclastic and carbonate lithofacies formed in subtidal to uppermost intertidal environments, and, in turn, overlain by shoreface deposits formed in progressively deepening-water environments. Inferred water depths are based on detailed facies distributions. For location, see Figure 2. Modified after Lee and Chough (2011).

https://doi.org/10.1007/s12303-018-0036-x

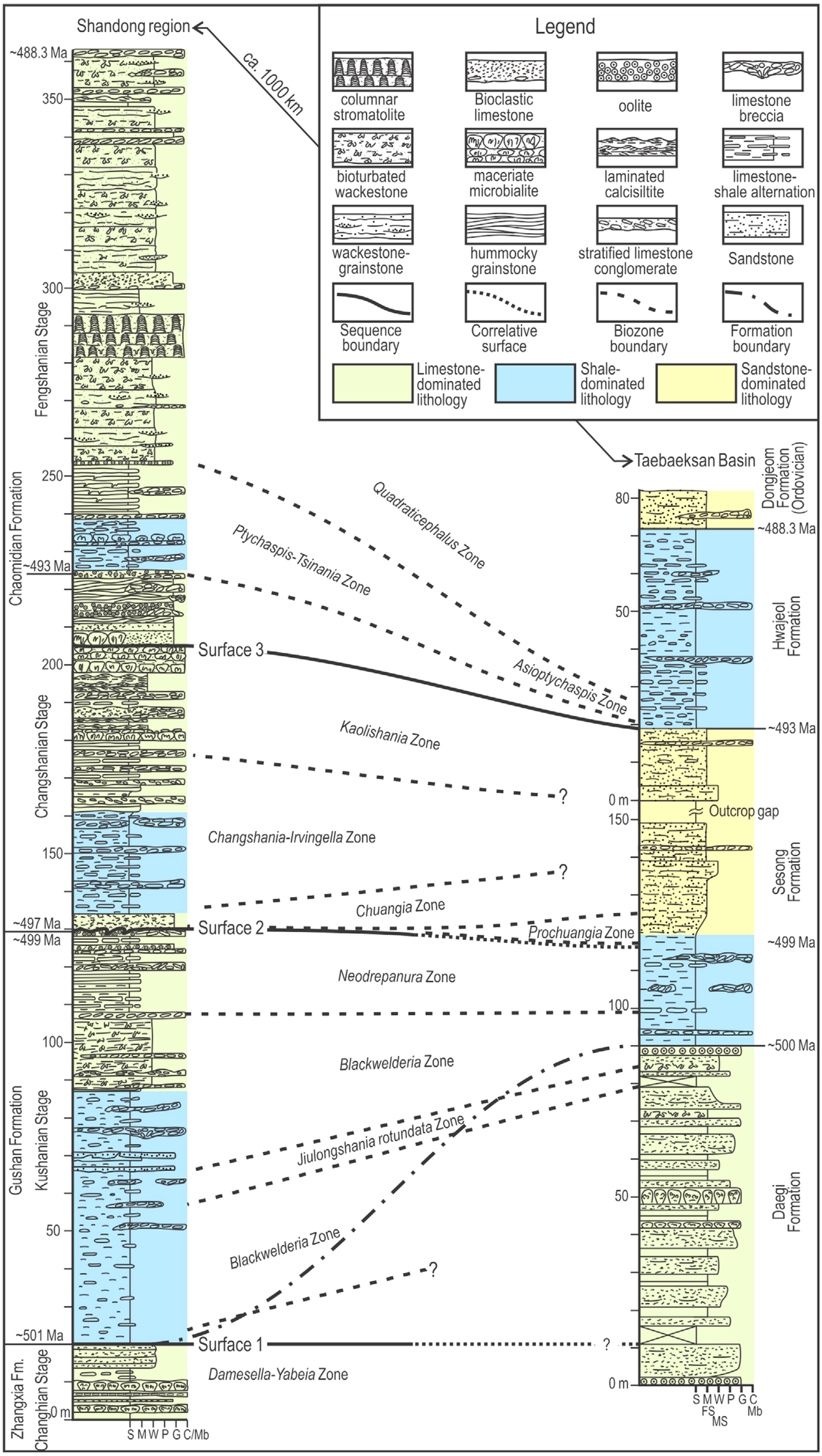

Fig. 5. Correlation of the Cambrian Series 3 to Furongian succession between the Shandong region and the Taebaek area (Chen et al., 2012). The bounding surface shows a significant diachroneity over 1000 km distance. The distinct lithologic characteristics of deformed conglomerate and its erosional surface (bounding surface 2) at about 499 Ma are completely absent in the Sesong Formation in the Taebaek area. The lithologic boundary between a microbialite bed and the overlying oolite (bounding surface 3) at about 493 Ma in the Shandong region is equivalent to the sandstone-shale boundary in the Taebaek area. S = shale, M = lime mudstone, W = wackestone, P = packstone, G = grainstone, C = limestone conglomerate, Mb = microbialite, FS = fine sandstone, MS = medium sandstone.

of shale (Gushan Formation) and various carbonate facies (Chaomidian Formation) (Chen et al., 2011). Toward the upper part of the Gushan Formation, carbonate production caught up with sea-level rise, accumulating more carbonates. The shallow subtidal carbonate deposits were deformed and subsequently exposed forming a cryptic subaerial unconformity (Chen et al., 2011). Microbialites resurged and flourished and the platform was submerged again during the Furongian. An extensive microbialite bed occurs in the middle part of the Chaomidian Formation, indicating a broad microbial flat (Lee et al., 2010). The epeiric platform was maintained through the late Furongian to the Early Ordovician.

3.4. Comparison of Sequence Units in the Cambrian Succession

The lithostratigraphic units of the Cambrian succession are well correlated between the Shandong region and the Taebaek area (Fig. 3). The occurrence of quartzite at the base of the succession is identical in both areas. In the Shandong region, the sandstone beds at the base of the succession extend for about 150 km (Lee et al., 2018); those in the Taebaek area underlie the entire succession for about 30 km (Woo et al., 2006). The overlying lithologic unit of siliciclastics and carbonates (Zhushadong and Mantou formations) is equivalent to that of shale-dominant Myobong Formation. The co-occurrence of *Redlichia chinensis* in the Mantou and Myobong formations is indicative of the Cambrian Series 2 and 3 in age. The *Bailiella* Zone is also well correlated. The overlying carbonate-dominant succession (Zhangxia Formation) is very similar to the Daegi Formation. The mixed shale and limestone (Gushan and Chaomidian formations versus Sesong and Hwajeol formations) are generally well correlated in both lithology and biozone of trilobites.

However, there is high variability of discontinuities within the comparable units. In the Zhushadong and Mantou formations, fine-grained siliciclastic and carbonate sediments formed numerous shallowing-upward units (Fig. 4). A prominent bed (unit 6 in Fig. 4) can be a potential sequence boundary. In the Taebaek area, however, it is absent in the equivalent Myobong Formation. In the overlying succession (Zhangxia and Daegi formations), production of carbonates kept up with the rise in sea level and oolite and microbialite facies formed under the optimum conditions (highstand sea level) (Hong et al., 2016). In the Shandong region, however, local slopes formed in the eastern part of the platform in which sedimentation was dominated by hemipelagic settling and episodic gravity flows (Woo, 2009). In the Taebaek area, local slope was absent during this period.

In the Cambrian Series 3 and Furongian, a prominent bounding surface shows a significant diachroneity over a 1000 km distance (Chen et al., 2012; Lee et al., 2012) (Fig. 5). The distinctive lithologic characteristics of the deformed conglomerate and its erosional surface of the bounding surface 2 in the Chaomidian Formation at about 499 Ma is absent in the Sesong Formation of the Taebaek area. The lithologic boundary between the microbialite bed and the overlying grainstone bed (surface 3) at about 493 Ma in the Chaomidian Formation is approximately equivalent to the sandstone-shale boundary in the Taebaek area. These bounding surfaces in the Shandong region are recognized within the entire outcrop sections (120 km east-west, 110 km north-south) (Chen et al., 2011, 2012). The high variability of bounding surfaces is understood as resulting from regional difference in topographic relief, carbonate production rate, siliciclastic input, and hydrodynamic conditions.

To sum up, correlation of sequence bounding surfaces is implausible for the Cambrian successions more than 1000 km apart. The succession in the Taebaek area comprises two sequence units, recognized by the facies successions (shallowing-upwards). In the Shandong region, however, there are a number of potential sequence boundaries, recognized by basin-wide correlation of facies associatons (bounded by lithologic discontinuity or erosion surface). High-resolution dating will show precisely the relative position and age of geologic events or depositional processes.

4. MISINTERPRETED UNCONFORMITY OF THE GYEONGSANG SUPERGROUP

International Subcommission on Stratigraphic Classification (ISSC) (1987) adopted “synthem” (Chang, 1975a) as an unconformity-bounded unit, “a body of rock bounded above and below by specifically designated discontinuities in the stratigraphic succession (angular unconformities, disconformities, and so on), preferably of regional or interregional extent”. However, the authority disregarded field criteria for the alleged unconformities, which are not regional (or interregional) in magnitude and are incomparable in thickness to the stratigraphic system. Because of the variable age, they were not categorized as chronostratigraphic in character (Miall, 2010). The term was not adopted by the sedimentological community worldwide (Miall, 2016), although it was considered as an alternative candidate for an unconformity-bounded unit by Mitchum et al. (1977). On the other hand, Bhattacharya (2011) argued the arbitrary nature (cutoffs) of the upper sequence boundary in fluvial-deltaic wedges. In the following, I explain how the upper-bounding unconformity was misinterpreted for the nonmarine succession of the Gyeongsang Supergroup.

The Cretaceous alluvial succession in the Korean peninsula (Fig. 6a) was classified into three major lithostratigraphic units (Chang, 1975b). The strata of the lower Sindong Group (Hauterivian

 https://doi.org/10.1007/s12303-018-0036-x

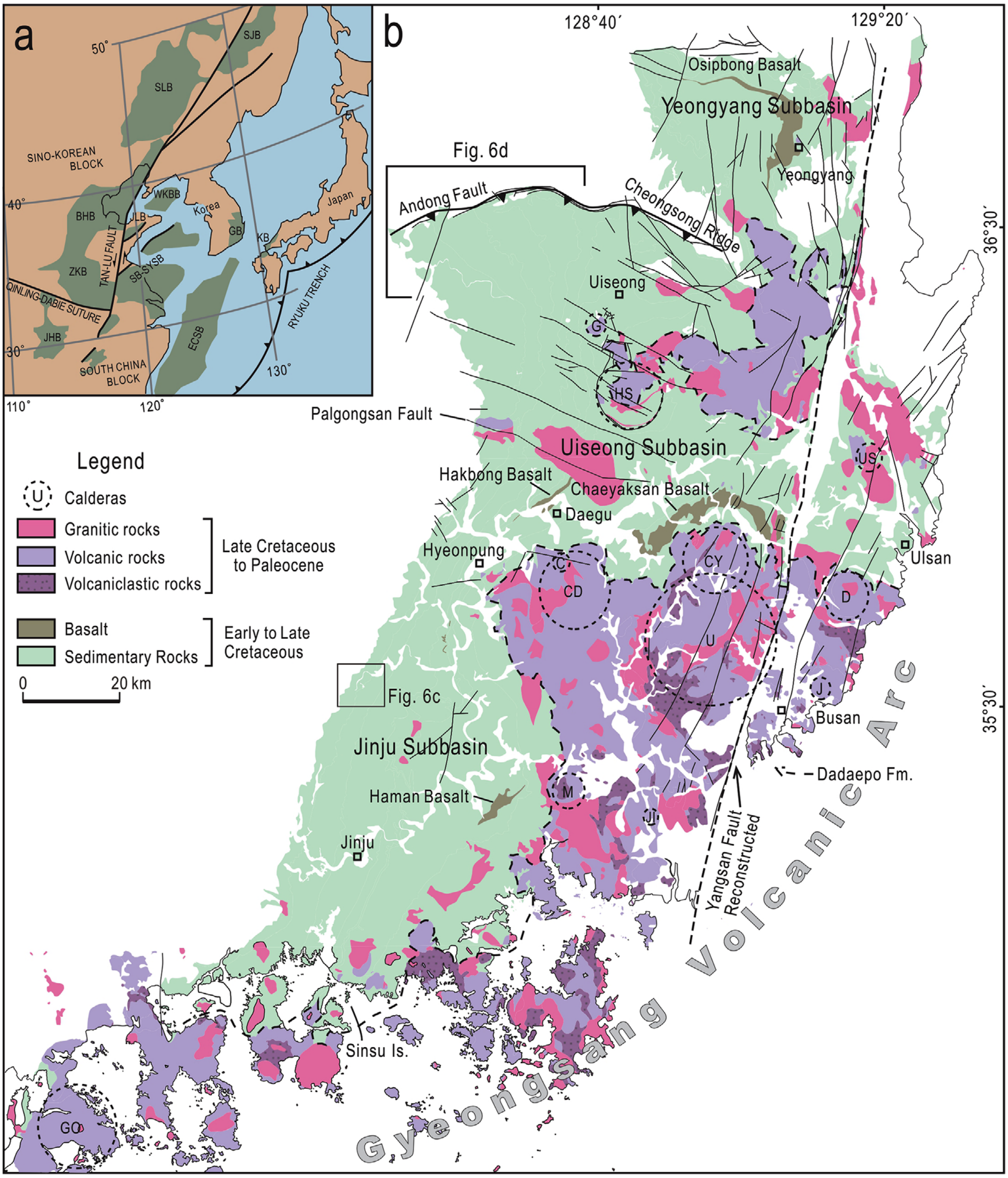

Fig. 6. (a) Simplified tectonic map of northeast Asia, showing the distribution of Cretaceous–Tertiary sedimentary basins (after Chough, 2013). BHB = Bohai Basin, ECSB = East China Sea Basin, GB = Gyeongsang Basin, JLB = Jiaolai Basin, KB = Kanmon Basin, SB = Subei Basin, SJB = Sanjiang Basin, SLB = Songliao Basin, SYSB = South Yellow Sea Basin, WKBB = West Korean Bay Basin, ZKB = Zhoukou Basin. (b) Simplified geological map of the Gyeongsang Arc System (Gyeongsang Volcanic Arc and Gyeongsang Backarc Basin). The sedimentary rocks and intercalating basalts are regarded as filling a backarc basin, whereas the volcanic/volcaniclastic rocks and the granitic rocks are regarded as constituting a volcanic arc platform. Note the subdivision of the backarc basin into three subbasins. Dotted circles with characters at center represent approximate boundaries of volcanotectonic depressions or calderas (Cha and Yun, 1988): Goseong (Go), Geumseongsan (G), Hwasan (HS), Unmunsa (U), Choijeongsan (C), Cheongdo (CD), Chaeyaksan (CY), Ulsan (US), Daeunsan (D), Jangsan (J), Jinrye (JI), and Mageumsan (M). After Chough and Sohn (2010). (c) Distribution of facies assemblages in the Hapcheon area. Note that the supposed formational boundaries (dashed lines) between the Nakdong and Hasandong formations (line N–H) as well as the Hasandong and Jinju formations (line H–J) are not in accordance with the lithologic distribution. After J.-H. Lee et al. (unpublished manuscript). (d) Geologic map of the northwestern part of the Gyeongsang Basin with paleocurrent data. Five allomembers (A1, A2, A3, ASA, and AJ) are recognized. G = conglomerate, G/S = conglomerate/sandstone, GS = gravelly sandstone, G/GS/PM = conglomerate/gravelly sandstone/purple mudstone, S = sandstone, S/PM = sandstone/purple mudstone, M = dark gray mudstone. For locations, see Figure 6b. After Jo and Chough (2001).

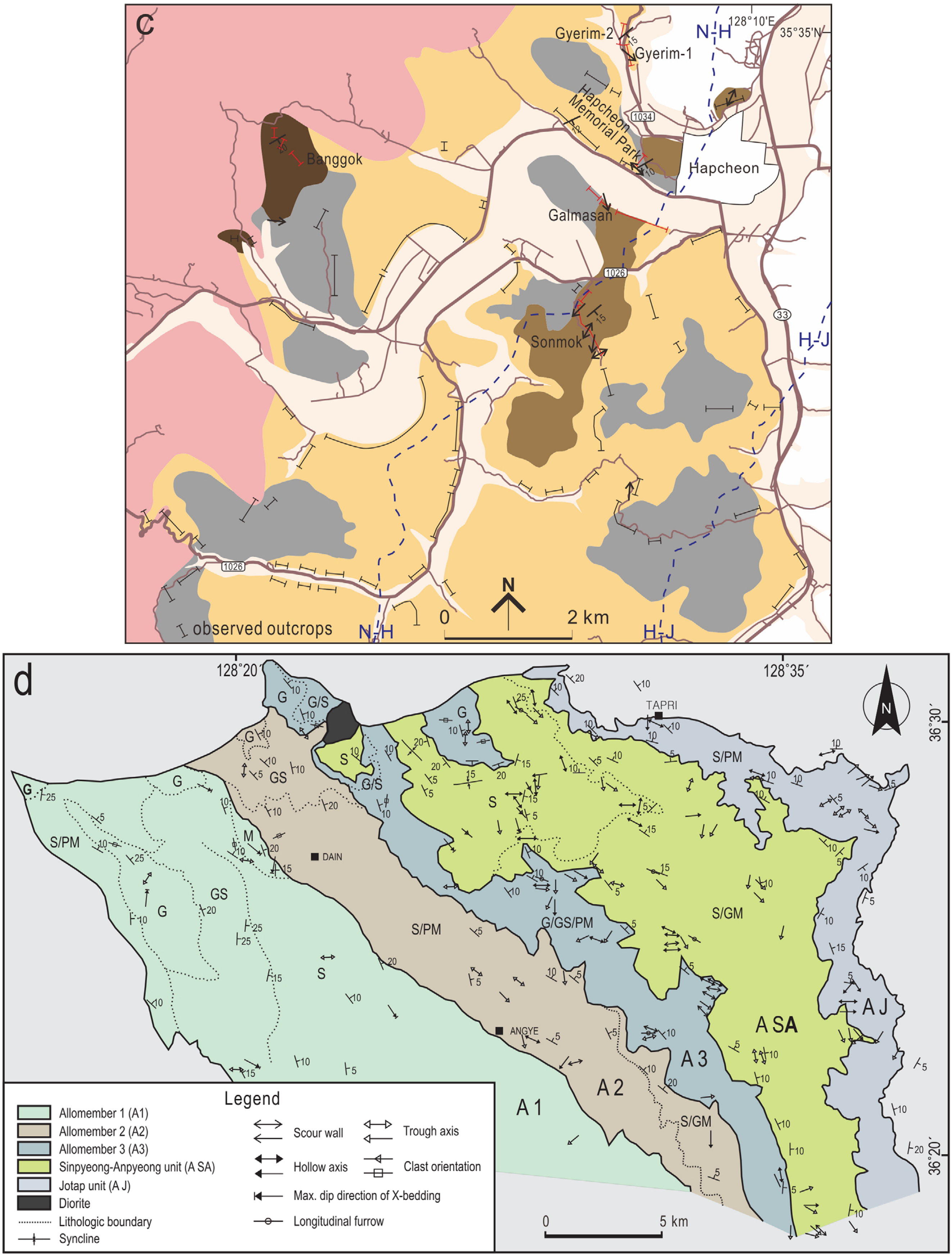

Fig. 6. (continued).

https://doi.org/10.1007/s12303-018-0036-x

to Barremian in age) and the middle Hayang Group (Aptian to Albian in age) are exposed mostly in the northern and southwestern parts of the basin and comprise conglomerate, gravelly sandstone, sandstone, mudstone/shale, and carbonate rocks (Fig. 6b). The strata overlie the basement, bounded by an unconformity (nonconformity) at the base. The division of the succession into the groups was based on incremental intercalation of volcanic sediments, i.e., the lower-middle group boundary for the first appearance of volcanics, whereas the middle-upper boundary for the climactic intercalation of volcanics/volcaniclastics (Chang, 1975a, b). Chang (1975a) placed an unconformable boundary at the first major intercalation of volcanic/volcaniclastic deposits based on the occurrence of fluvial conglomerates. However, the overlying volcanic rocks represent sudden emplacement of volcaniclastic sediments without a significant geologic time gap or tectonic disturbance (Chough and Sohn, 2010). Deposition of these deposits was thus spatially controlled and coeval, although the volcanics tend to occur largely in the late stage of the arc evolution (Fig. 6b). Nevertheless, the sedimentary succession is not bounded by an upper unconformable boundary. There is no significant time gap in the deposition of sedimentary versus volcanic successions. The upper lithologic boundary is not regionally recognized, as volcanic deposits formed under subaerial conditions during the Paleogene. The arc volcanism ceased in the Late Paleocene to Eocene as the loci of volcanic activity shifted progressively eastward with rollback of the subduction of the paleo-Pacific plate.

A basin-wide correlation of the succession in terms of unconformities is implausible, because the basin was compartmental (Fig. 6b). Furthermore, the lithostratigraphic sequence division in the southwestern subbasin is practically implausible, because the facies distribution is laterally variable, depending on the location of dominant depositional systems such as alluvial fans and the associated fluvial environments (J.-H. Lee et al., unpublished manuscript) (Fig. 6c). Besides, there is no discernable objective criteria for the base-level change. Detailed sedimentary facies analysis in the northern margin of the basin has demonstrated that the succession can be divided into a number of allomembers bounded by stratigraphic discontinuities marked by distinct facies transitions, abrupt emplacement of conglomerates, and thin, laterally persistent mudstone interbeds (Rhee et al., 1998; Jo and Chough, 2001) (Fig. 6d). The discontinuities were most likely related to the shift in depositional site, reflecting block faulting in the northern basin margin. The discontinuities provide an independent domain for an allostratigraphic analysis.

5. CONCLUSIONS

The initial and refined definitions of sequence are not universally applicable to the global stratigraphic correlation of sedimentary successions. The evolving definition of stratigraphic sequence signals the demise of the original deductive "sequence stratigraphy". A single standard, template definition is insufficient to encompass variable geologic events or whole complexity of depositional processes in (geologic) time and (accommodation) space. Instead, the generic definition of a sequence, "a succession of geologic events, processes, or rocks, arranged in chronological order to show their relative position and age with respect to geologic history as a whole", (Neuendorf et al., 2005) will suffice it. In practice, an objective description by way of an inductive sedimentary facies analysis is required to recognize a (stratigraphic) sequence in order to encompass the details of geologic events or depositional processes. A distinct sequence can be recognized based on the descriptive characteristics and scale of the succession.

ACKNOWLEDGMENTS

I gratefully acknowledge discussions with a number of colleagues, notably D.-J. Lee, I.G. Hwang, H.R. Jo, and J.-H. Lee. I thank two anonymous reviewers for helpful reviews.

REFERENCES

Bhattacharya, J.P., 2011, Practical problems in the application of the sequence stratigraphic method and key surfaces: integrating observations from ancient fluvial-deltaic wedges with Quaternary and modeling studies. Sedimentology, 58, 120–169.

Catuneanu, O., 2006, Principles of Sequence Stratigraphy. Elsevier, Amsterdam, 375 p.

Catuneanu, O., Abreu, V., Bhattacharya, J.P., Blum, M.D., Dalrymple, R.W., Eriksson, P.G., Fielding, C.R., Fisher, W.L., Galloway, W.E., Gibling, M.R., Giles, K.A., Holbrook, J.M., Jordan, R., Kendall, C.G.St.C., Macurda, B., Martinsen, O.J., Miall, A.D., Neal, J.E., Nummedal, D., Pomar, L., Posamentier, H.W., Pratt, B.R, Sarg, J.F., Shanley, K.W., Steel, R.J., Strasser, A., Tucker, M.E., and Winker, C., 2009, Towards the standardization of sequence stratigraphy. Earth-Science Reviews, 92, 1–33.

Catuneanu, O., Galloway, W.E., Kendall, C.G.St.C., Miall, A.D., Posamentier, H.W., Strasse, A., and Tucker, M.E., 2011, Sequence stratigraphy: methodology and nomenclature. Newsletters on Stratigraphy, 44, 173–245.

Catuneanu, O., 2017, Sequence Stratigraphy: guidelines for a methodology. In: Montenari, M. (ed.), Stratigraphy and Time Scales. Academic Press, 2, p. 1–57.

Chang, K.H., 1975a, Unconformity-bounded stratigraphic units. Geological Society of America Bulletin, 86, 1544–1522.

Chang, K.H., 1975b, Cretaceous stratigraphy of southeast Korea. Journal of the Geological Society of Korea, 11, 1–23.

Chen, J., Chough, S.K., Han, Z., and Lee, J.-H., 2011, An extensive erosion surface of a strongly deformed limestone bed in the Gushan and Chaomidian formations (late Middle Cambrian to Furongian), Shandong Province, China: sequence-stratigraphic implications.

Sedimentary Geology, 233, 129–149.

Chen, J., Chough, S.K., Lee, J.-H., and Han, Z., 2012, Sequence-stratigraphic comparison of the upper Cambrian Series 3 to Furongian succession between the Shandong region, China and the Taebaek area, Korea: high variability of bounding surfaces in an epeiric platform. Geosciences Journal, 16, 357–379.

Chough, S.K., 2013, Geology and Sedimentology of the Korean Peninsula. Elsevier, London, 363 p.

Chough, S.K., Lee, D.-J., and Ree, J.-H., 2013, Whereabouts of the collision belt between the Sino-Korean and South China blocks in the northeast Asian margin. Geosciences Journal, 17, 397–401.

Chough, S.K. and Sohn, Y.K., 2010, Tectonic and sedimentary evolution of a Cretaceous continental arc-backarc system in the Korean peninsula: new view. Earth-Science Reviews, 101, 225–249.

Chough, S.K., Kwon, S.T., Ree, J.H., and Choi, D.K., 2000, Tectonic and sedimentary evolution of the Korean peninsula: a review and new view. Earth-Science Reviews, 52, 175–235.

Chough, S.K., Lee, H.S., Woo, J., Chen, J., Choi, D.K., Lee, S.-B., Kang, I., Park, T.Y., and Han, Z., 2010, Cambrian stratigraphy of the North China Platform: revisiting principal sections in Shandong Province, China. Geosciences Journal, 14, 235–268.

Embry, A.F., 1995, Sequence boundaries and sequence hierarchies: problems and proposals. In: Steel, R.J., Felt, V.L., Johannessen, E.P., and Mathieu, C. (eds.), Sequence Stratigraphy on the Northwest European Margin. Norsk Petroleumsforening Special Publication, Elsevier, Amsterdam, 5, p. 1–11.

Hong, J., Lee, J.-H., Choh, S.J., and Lee, D.-J., 2016, Cambrian Series 3 carbonate platform of Korea dominated by microbial-sponge reefs. Sedimentary Geology, 341, 58–69.

International Subcommission on Stratigraphic Classification, 1987, Unconformity-bounded stratigraphic units. Geological Society of America Bulletin, 98, 232–237.

Jo, H.R. and Chough, S.K., 2001, Arcitectural analysis of fluvial sequences in the northwestern part of Kyongsang Basin (Early Cretaceous), SE Korea. Sedimentary Geology, 144, 307–344.

Kwon, Y.K., Chough, S.K., Choi, D.K., and Lee, D.J., 2006, Sequence stratigraphy of the Taebaek Group (Cambrian–Ordovician), mideast Korea. Sedimentary Geology, 192, 19–55.

Lee, D.-C., Choh, S.-J., Lee, D.-J., Ree, J.-H., Lee, J.-H., and Lee, S.-B., 2017, Where art thou "the great hiatus?" – review of Late Ordovician to Devonian fossil-bearing strata in the Korean Peninsula and its tectonostratigraphic implications. Geosciences Journal, 21, 913–931.

Lee, H.S. and Chough, S.K., 2011, Depositional processes of the Zhushadong and Mantou formations (Early to Middle Cambrian), Shandong Province, China: roles of archipelago and mixed carbonate-siliciclastic sedimentation on cycle genesis during initial flooding of the North China Platform. Sedimentology, 58, 1530–1572.

Lee, H.S., Chen, J., Han, Z., and Chough, S.K., 2018, Depositional processes and environmental changes during initial flooding of epeiric platform: Liguan Formation (Cambrian Series 2), Shandong Province, China. Geosciences Journal. https://doi.org/10.1007/s12303-018-0027-y

Lee, J.-H., Chen, J., and Chough, S.K., 2010, Paleoenvironmental implications of an extensive maceriate microbialite bed in the Furongian Chaomidian Formation, Shandong Province, China. Palaeogeography, Palaeoclimatology, Palaeoecology, 297, 621–632.

Lee, J.-H., Chen, J., and Chough, S.K., 2012, Demise of an extensive biostromal microbialite in the Furongian (late Cambrian) Chaomidian Formation, Shandong Province, China. Geosciences Journal, 15, 275–287.

Miall, A.D., 2010, The Geology of Stratigraphic Sequences (2nd edition). Springer, Heidelberg, 522 p.

Miall, A.D., 2016, Stratigraphy: A Modern Synthesis. Springer International Publishing AG, Cham, 454 p.

Meng, X., Ge, M., and Tucker, M.E., 1997, Sequence stratigraphy, sea-level changes and depositional systems in the Cambro-Ordovician of the North China carbonate platform. Sedimentary Geology, 114, 189–222.

Mitchum Jr., R.M., 1977, Seismic stratigraphy and global changes of sea level, part 11: glossary of terms used in seismic stratigraphy. In: Payton, C.E. (ed.), Seismic Stratigraphy – Applications to Hydrocarbon Exploration. American Association of Petroleum Geologists Memoir, 26, p. 205–212.

Mitchum, Jr., R.M., Vail, P.R., and Thompson, III, S., 1977, Seismic stratigraphy and global change of sea level, part 2: The depositional sequence as a basic unit for stratigraphic analysis. In: Payton, C.E. (ed.), Seismic Stratigraphy – Applications to Hydrocarbon Exploration. American Association of Petroleum Geologists Memoir, 26, p. 53–62.

Neuendorf, K.K.E., Mehl, J.P.Jr., and Jackson, J.A., 2005, Glossary of Geology (5th edition). Springer-Verlag, Berlin, 779 p.

Rhee, C.W., Jo, H.R., and Chough, S.K., 1998, An allostratigraphic approach to a nonmarine basin: the northwestern part of Cretaceous Kyongsang Basin, SE Korea. Sedimentology, 45, 449–472.

Vail, P.R., 1987, Seismic stratigraphy interpretation using sequence stratigraphy, Part 1: seismic stratigraphy interpretation procedure. In: Bally, A.W. (ed.), Atlas of Seismic Stratigraphy. American Association of Petroleum Geologists Studies in Geology, 27, p. 1–10.

Woo, J., 2009, The Middle Cambrian Zhangxia Formation, Shandong Province, China: depositional environments and microbial sedimentation. Ph.D. Thesis, Seoul National University, Seoul, 243 p.

Woo, J. and Chough, S.K., 2010, Growth patterns of the Cambrian microbialite: phototropism and speciation of *Epiphyton*. Sedimentary Geology, 229, 1–8.

Woo, J., Shinn, Y.J., Kwon, Y.K., and Chough, S.K., 2006, The Jangsan and Myeonsan Formations (Early Cambrian) of the Taebaek Group, mideast Korea: depositional processes and environments. Geosciences Journal, 10, 35–57.

Yoshida, S., Steel, R.J., and Dalrymple, R.W., 2007, Changes in depositional processes – an ingredient in a new generation of sequence-stratigraphic models. Journal of Sedimentary Research, 77, 447–460.

 https://doi.org/10.1007/s12303-018-0036-x