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Tectonic implications of quartzite-shale and phyllite beds in the Seochangri Formation (Okcheon Group), Bonghwajae section, mid-Korea

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ABSTRACT: This study focuses on the depositional and deformational features of quartzite-shale and phyllite beds in the lower part of the Seochangri Formation, Okcheon Group, mid-Korea. Each quartzite unit (25–320 cm thick) is massive, whereas the overlying laminated shale unit (0.5–10 cm thick) is either homogeneous or slightly laminated. Although these interbeds were strongly deformed under brittle-ductile conditions (ca. 300 °C), the quartzite units show a thickening-upward trend. The quartzite-shale interbeds represent deposition from turbidity currents, i.e., Bouma-A and -D/E divisions. The thickening-upward quartzite-shale units are suggestive of progradation of sand lobes in the middle-outer fan. The overlying phyllite beds with thin quartz interlayers most likely represent outer fan and basinplain environments. The Seochangri Formation in the Bonghwajae section forms a thrust front against the limestone and dolomite beds of the Joseon Supergroup in which the quartzite-shale units are overlain by the phyllite beds and, in turn, underlain by the folded limestone beds. The phyllite and limestone beds were strongly deformed, showing upright isoclinal to tight folds, sheath folds, and boudins. The fold axes generally trend north-northeast with a low plunge angle. The thrust front represents part of the restraining bend of a dextral fault, the South Korean Tectonic Line. It is the major structural discontinuity between the Okcheon Group (Proterozoic) and the Joseon Supergroup (Lower Paleozoic). The collisional offset between the Gyeonggi Massif (South China Block) and the Yeongnam Massif (Sino-Korean Block) most likely occurred in the Jurassic prior to the emplacement of the mafic dyke and amphibolite.

Key words: Seochangri Formation, Okcheon Group, South Korean Tectonic Line, Bonghwajae section, thrust

1. INTRODUCTION

A quartzite-shale alternation occurs at the base of the Seochangri Formation, Okcheon Group, mid-Korea along the boundary between deformed carbonate sequence of the Joseon Supergroup and the overlying age-unknown siliciclastic rocks of the Okcheon Group (Lee and Park, 1965) (Fig. 1). Although Kihm et al. (1996) and Kihm and Kim (2003) regard that the boundary is conformable, the abrupt changes in both sedimentary facies and deformational features are suggestive of major stratigraphic discontinuity formed by changes in either depositional environments or post-depositional tectonic deformations. In the Bonghwajae section, it occurs in a narrow zone of thrust, although the boundary is partly obliterated by intrusion of metavolcanics and amphibolites (Lee and Park, 1965; Kim and Kim, 1974). We have measured metasedimentary sequence across the boundary in detail, paying particular attention to primary sedimentary structures overprinted by deformational and metamorphic features. In this paper, we focus on the quartzite-shale interbeds and phyllite of the Seochangri Formation for depositional environments and deformational features in order to understand tectonic history of the South Korean Tectonic Line (Chough et al., 2000).

2. GEOLOGIC SETTING

The Bonghwajae section comprises metamorphosed siliciclastics of the Seochangri Formation (Okcheon Group) on the west and deformed carbonate sequence (Joseon Supergroup) on the east (Lee and Park, 1965; Kihm et al., 1996) (Figs. 1 and 2). The Okcheon Group comprises metasedimentary rocks (quartzite, slate, phyllite, schist, marble, and calc-silicate) in which primary sedimentary structures are largely obliterated by polyphase metamorphic and deformational events. The group has been divided into more than 10 formations (Lee and Park, 1965; Reedman et al., 1973; Lee, 1987) (Fig. 1). The lowermost Seochangri Formation consists mainly of phyllite (Fig. 3) intercalated with black slate. The phyllite shows a sharp lithologic boundary (Fig. 3B) and contains thin laminae of fine-grained quartzite (Fig. 3C). It is also characterized by penetrative foliation and crenulation. The Buknori Formation comprises clast-bearing phyllitic rocks with calcareous sandy matrix (Fig. 3D). The Myeongori Formation is composed of dark gray phyllite and chlorite schist (Lee and Park, 1965). The Hansu limestone (marble) bed (about 5 m thick) is interlayered between the Buknori and Myeongori formations and laterally continuous

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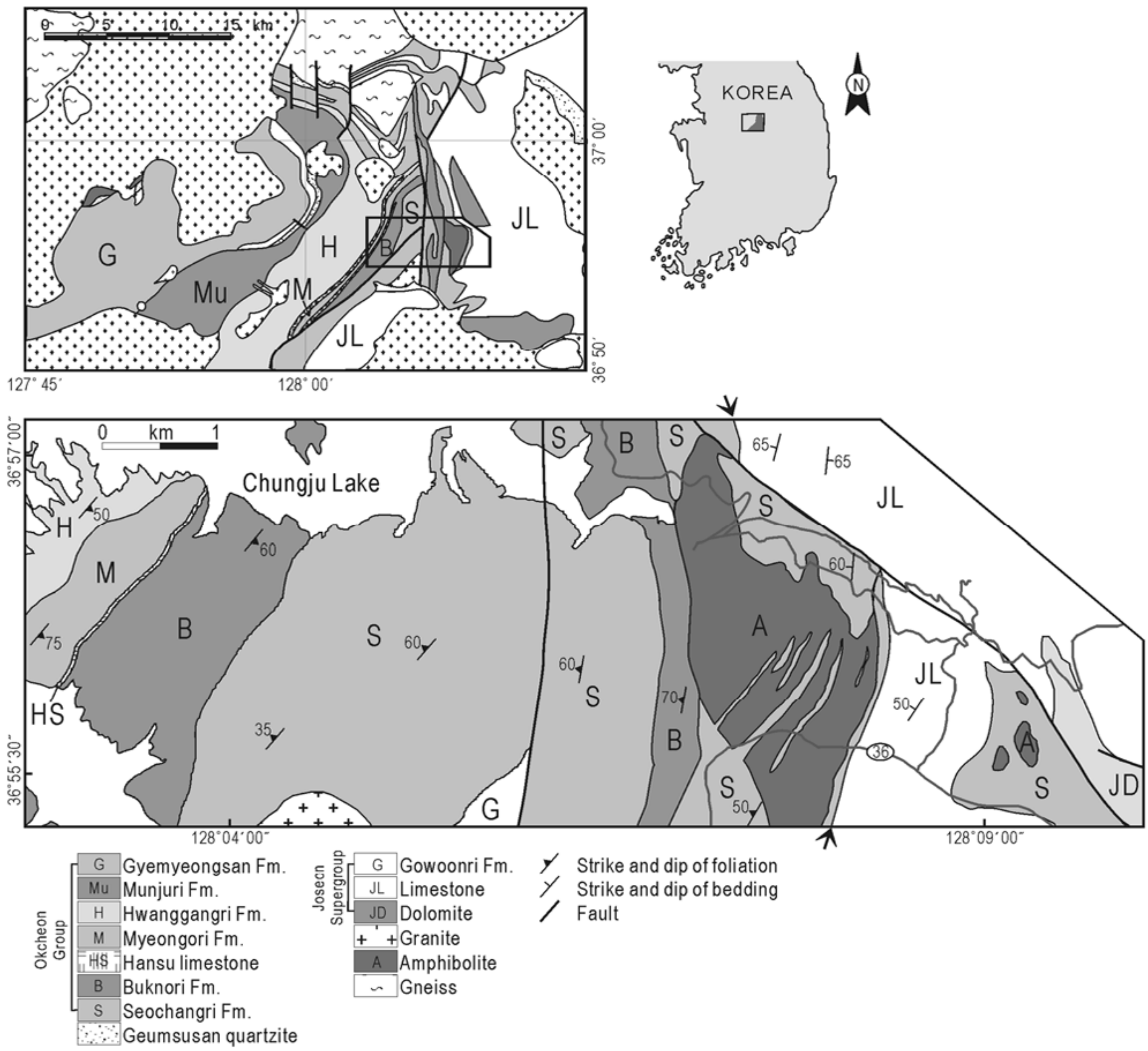

Fig. 1. Geologic map of the Bonghwajae area (modified after Lee and Park, 1965). Arrows indicate the boundary between the Okcheon Group and the Joseon Supergroup.

for long distances (Fig. 1). The Hwanggangri Formation consists of clast-bearing calcareous and argillaceous sandstone (quartzite) and mudrock (Bahk, 1990). The Munjuri Formation consists of light greenish gray chlorite schist (Lee and Park, 1965).

The lithofacies and stratigraphic relationships of the carbonate rocks of the Joseon Supergroup in the east of the Bonghwajae section are still uncertain, although Kihm and Kim (2003) have classified them into a number of lithologic units. The supergroup comprises light gray massive, bedded and laminated limestone, dolomite, and alternation of limestone and shale. Some beds are interlayered with shale and chert nodules, and contain brachiopod, crinoid stems, and sponges of the Ordovician (Fig. 4). Part of the carbonate sequence of the Joseon Supergroup (Fig. 2) shows an alternation of medium crystalline dolomitic lime mudstone and nodules and chert layers (Fig. 4).

Figure 5 shows a structural model of the Okcheon Group in the Chungju lake area (W–E section) based on regional measurements of foliations (Reedman et al., 1973). It suggests that the entire sequence was folded during compressional deformation. The Seochangri Formation in the Bonghwajae section probably represents an eastern limb of a tight fold (Fig. 5). Amphibolites occur along the boundary between the Okcheon Group and the Joseon Supergroup (Lee and Park, 1965).

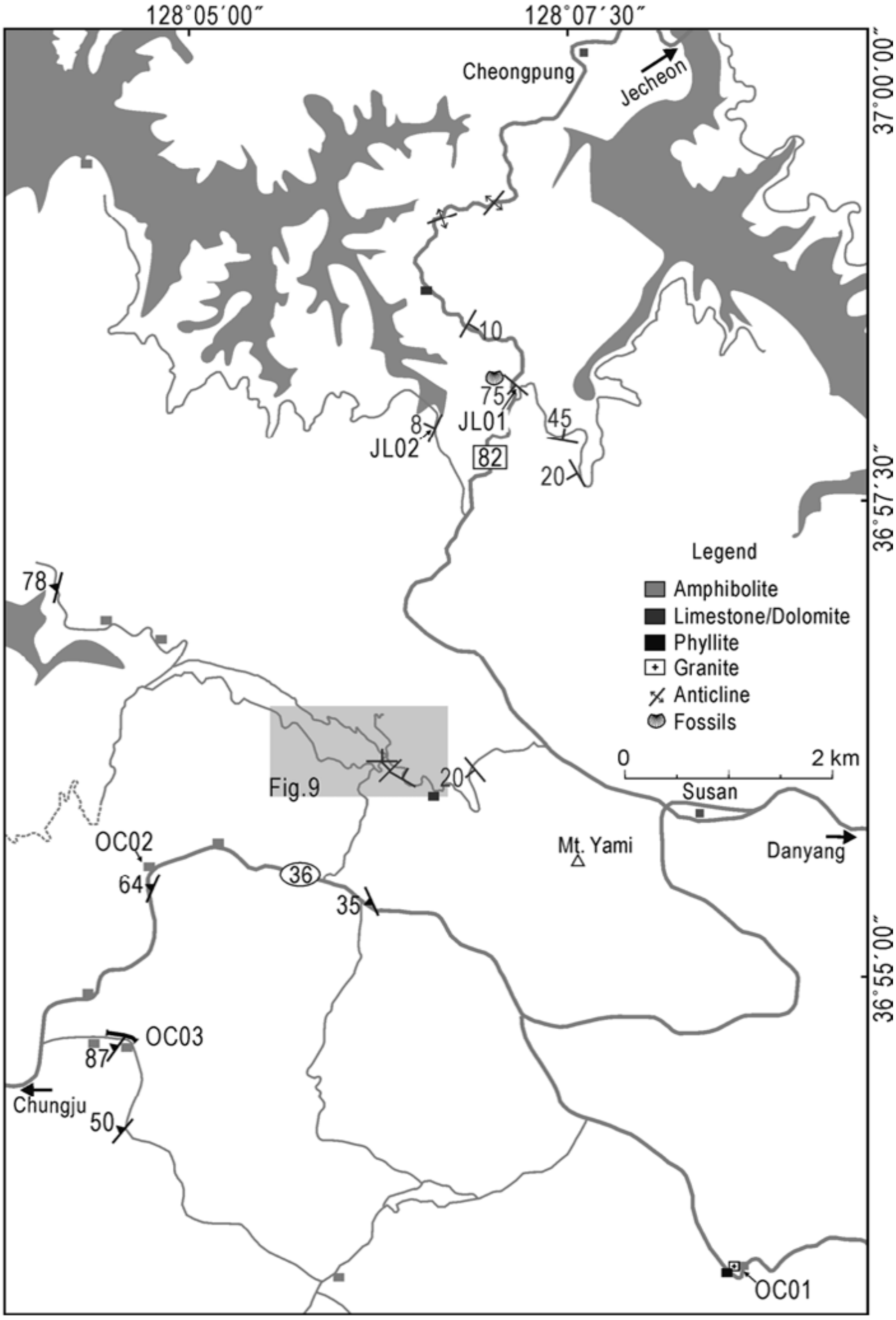

Fig. 2. Location map of outcrops in the vicinity of the Bonghwajae section.

3. QUARTZITE-SHALE BED

3.1. Description

Figure 6 shows 58 quartzite-shale beds at the base of the Seochangri Formation. Each bed consists of a thick quartzite (sandstone) and a thin shale (mudstone). The quartzite is generally massive in the lower and middle parts and thinly interlayered with shale in the upper part (Fig. 6B). The shale is sharply eroded by the overlying quartzite bed, whereas the quartzite is transitional to the overlying shale (Fig. 6C). The quartzite-shale and phyllite beds are commonly deformed, including pseudonodules, injection, and flame structures as well as strong foliation. Each quartzite bed thickens upward (Fig. 6B) in the lower part and is underlain by shale-dominant bed with intercalation of thin sandstone layers. In the upper part of the section, it thickens, up to about 320 cm (Fig. 6B) and is overlain by thick phyllite of the Seochangri Formation. In shale (phyllite)-dominant Seochangri Formation, very thin quartzite layers are interlayered with the phyllite characterized by foliation and crenulation (Fig. 3B).

The quartzite comprises quartz grains of about 0.2–0.5

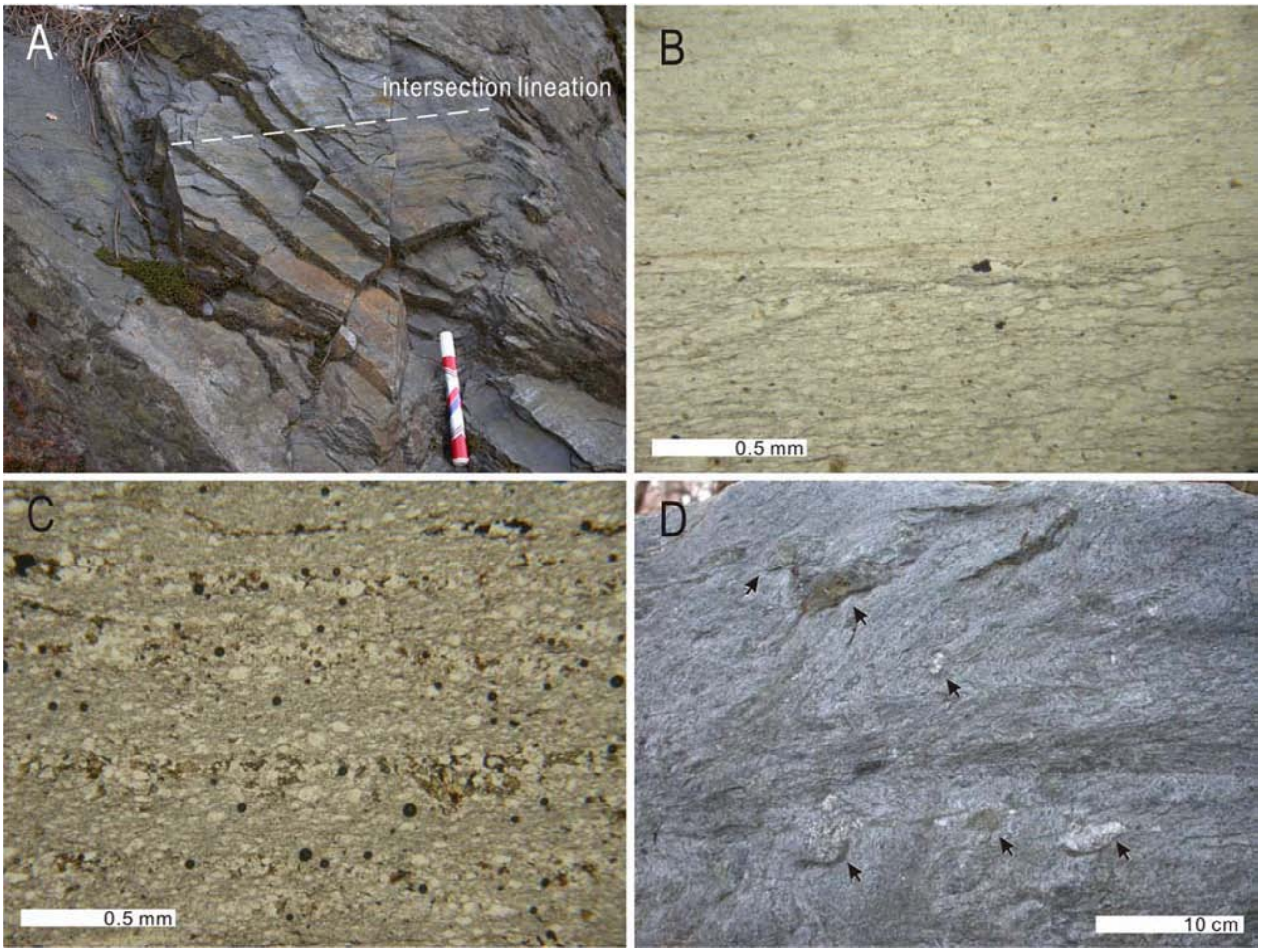

Fig. 3. (A) Photograph of the Seochangri Formation showing intersection lineation in phyllite (location 001 in Figure 9). (B) Sharp lithologic boundary in phyllite of the Seochangri Formation (sample from location 002 in Figure 9). See Figure 6B for stratigraphic horizon of the sample. The underlying unit contains slightly coarser quartz grains. (C) Laminae of fine sand-sized grains (location 002 in Figure 9). (D) Photograph of pebble-bearing phyllite of the Buknori Formation (arrows indicate clasts) (location 003 in Figure 9).

mm in average size (fine to medium sand). Quartz grains are in contact with each other with irregular pressure solution surface whose boundaries are sutured and interlocked (Fig. 7A). The grains are stretched along the bedding plane and composed of monocrystalline quartz with undulatory extinction and polycrystalline quartz. There are minor proportions of heavy minerals such as zircon (Fig. 7A). Although the quartzite is massive in texture, the grain size varies within a bed. The grain size variation is, however, not systematic except for the uppermost part of the bed where both grain size and quartz/muscovite ratio decrease upward (Fig. 7B).

3.2. Interpretation

The quartzite-shale beds most likely formed in marginal deep-water environments where shoreface sediments were transported into a prograding fan (Fig. 8A) (e.g., Stow et al., 1996). The association of single facies, i.e., Bouma-A, -D/E divisions in the Bonghwajae section, reflects certain morphological element in deep-water fan (Reading and Richards, 1994). The general thickening-upward trend is indicative of progradation of depositional lobes in the middle and outer fan beyond digitating channels (Fig. 8B, C) (e.g., Mutti and Ricci Luchi, 1972; Stow, 1985). This type of fan commonly forms in sand-rich depositional system either in detached or attached lobes from the channels (Fig. 8C) (Mutti, 1985). In this respect, the interbeds of the Bonghwajae section may represent prograding lobe on the middle and outer fan surface detached from the feeding channels (Fig. 8A). On the other hand, the overlying phyllite with fine quartzite layers (Seochangri Formation) is indicative of outer fan and semi-enclosed basinplain environments (Fig. 8).

4. GEOLOGICAL STRUCTURES

Figure 9A shows lithologic distribution along the roadcut

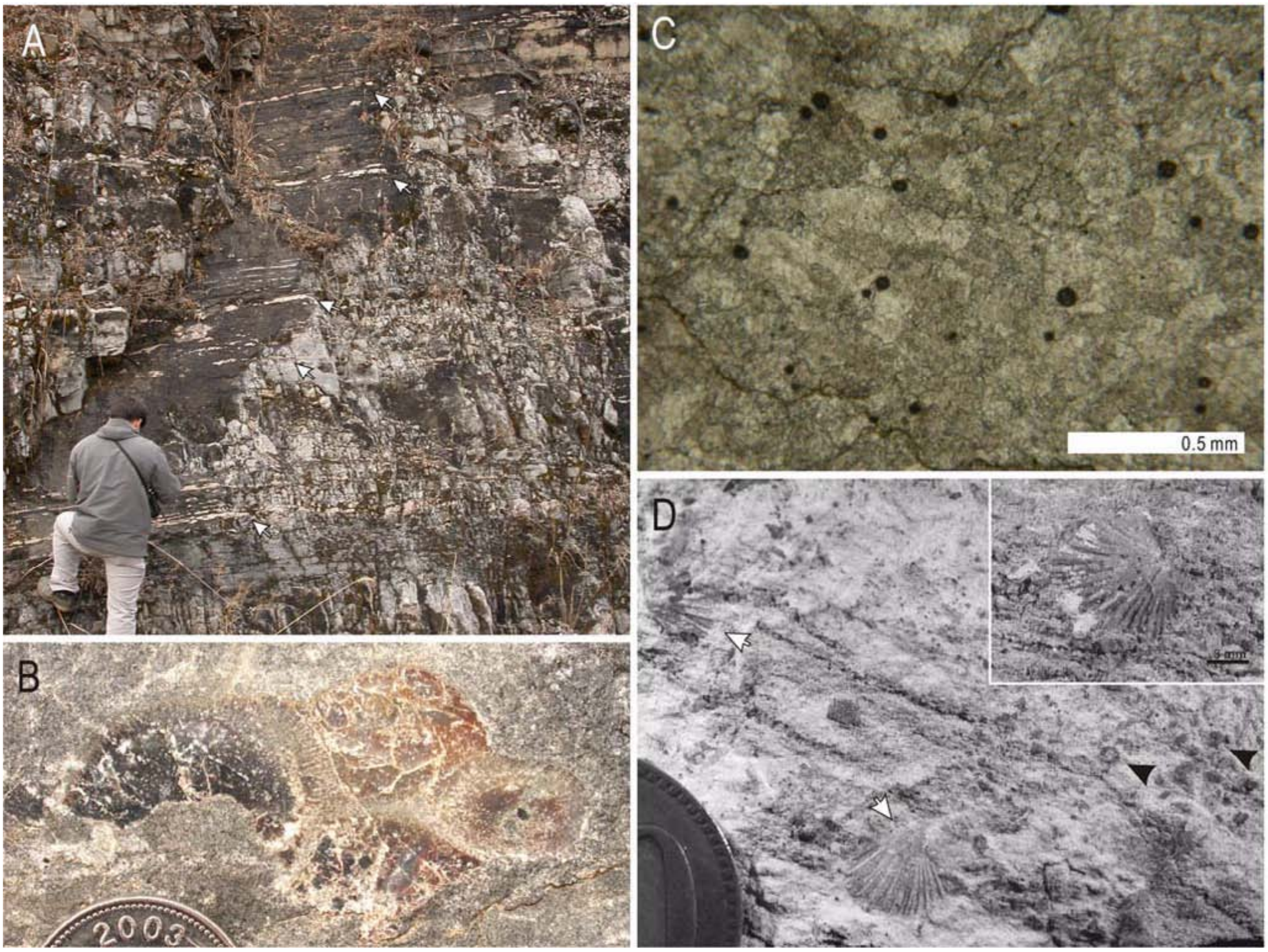

Fig. 4. (A) Photograph of the Joseon Supergroup showing relatively undeformed limestone and chert nodules (arrows). (B) Transverse cut of sponges in a chert nodule. (C) Photomicrograph of limestone showing recrystallized large calcite and dolomite crystals.(D) Ordovician brachiopods (arrows) and crinoid stems (arrow heads). For location, see Figure 2 (A, B, and C: JL02; D: JL01).

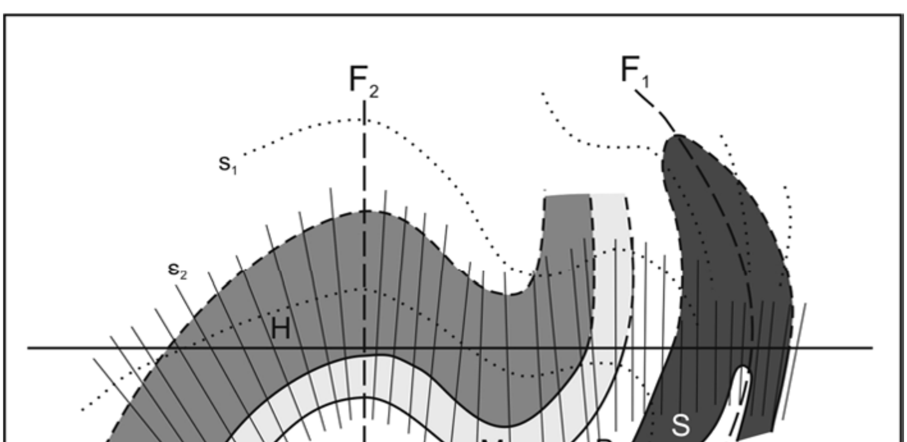

Fig. 5. A structural model of the northern Okcheon fold belt (after Reedman et al., 1973). S_1=primary foliation, S_2=secondary foliation; F_1 and F_2=fold axial planes; H=Hwanggangri Formation, M=Myeongori Formation, B=Buknori Formation, S=Seochangri Formation.

of the Bonghwajae section. On the northwest, the quartzite and shale beds are overlain by phyllite and, in turn, underalin by folded limestone beds (Fig. 10A). An undeformed mafic dyke occurs at the boundary between the quartzite and limestone beds (Fig. 9B). The limestone beds are bounded on the east by folded phyllite beds with strong intersection lineation. Further east, the deformed phyllite beds are bounded by thin-bedded, massive, and brecciated limestone beds, and are in high-angle contact with the strongly deformed phyllite and black shale beds (Figs. 9B and 10C). The phyllite beds show upright isoclinal to tight folds, sheath folds, and boudins (Fig. 10C). The fold axes of the post-major deformation (F_{m+1}) generally trend north–northeast with a low plunge angle. Further east, the phyllite beds are gently folded (axial trend of south–southwest) with a low plunge angle (Fig. 10C). On the eastern end of the roadcut, the phyllite beds are overlain by massive and brecciated limestone beds with a steep fault plane (Fig. 10B).

Three deformation events are recognized in the phyllite beds of the Bonghwajae section. The major deformation (D_m) comprises tight to isoclinal folds of the compositional layers (S_{m-1} or S_0) which formed penetrative foliation (Fig. 10D). The major foliation (S_m) strikes generally northeast–southwest and dips to the northwest or southeast (Fig. 11A). The post-major deformation (D_{m+1}) crenulated the S_m. The S_{m+1}, defined by the crenulation cleavage, generally strikes northeast–southwest and dips to the northwest (Fig. 11A). The intersection lineations of S_m and S_{m+1} planes trend northeast–southwest with a low plunge angle (Fig. 11A). The scattering of fold axes (F_{m+1}) and intersection lineations (Fig. 11A) probably resulted from the open folds, trending east-southeast–west-northwest. The predominance of the east–southeast vergence of the folds and the northeast–southwest-trending intersection lineations between the major foliation (S_m) and the crenulation (S_{m+1}) are suggestive of southeastward transport of the phyllite beds. The strikes of compositional layers (S_0) in the limestone beds vary with a north- to east-trend (Fig. 11B). The fold axes and the intersection lineation are characterized by an east–west trend with a sub-horizontal plunge angle.

The mylonite texture occurs in the clast-bearing coarse-grained rocks and quartzite bed of the Okcheon Group. The

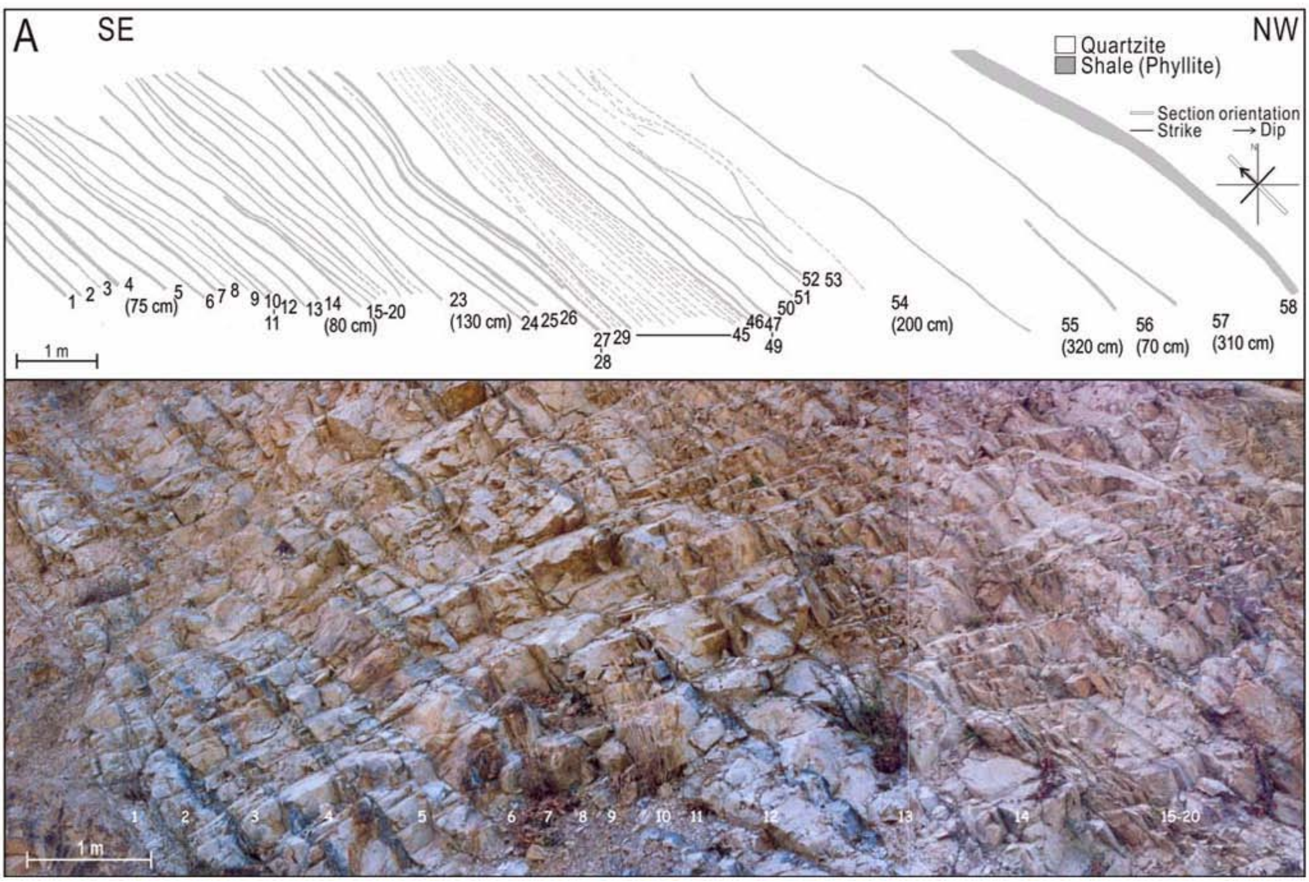

Fig. 6. (A) Photograph and line-drawing of quartzite-shale interbeds at the base of the Seochangri Formation, Bongwhajae section. For location, see Figure 9. (B) A columnar log of the quartzite-shale beds in the Bongwhajae section. (C, D) Photographs of quartzite-shale beds showing Bouma-A and -D/E divisions with erosional boundary.

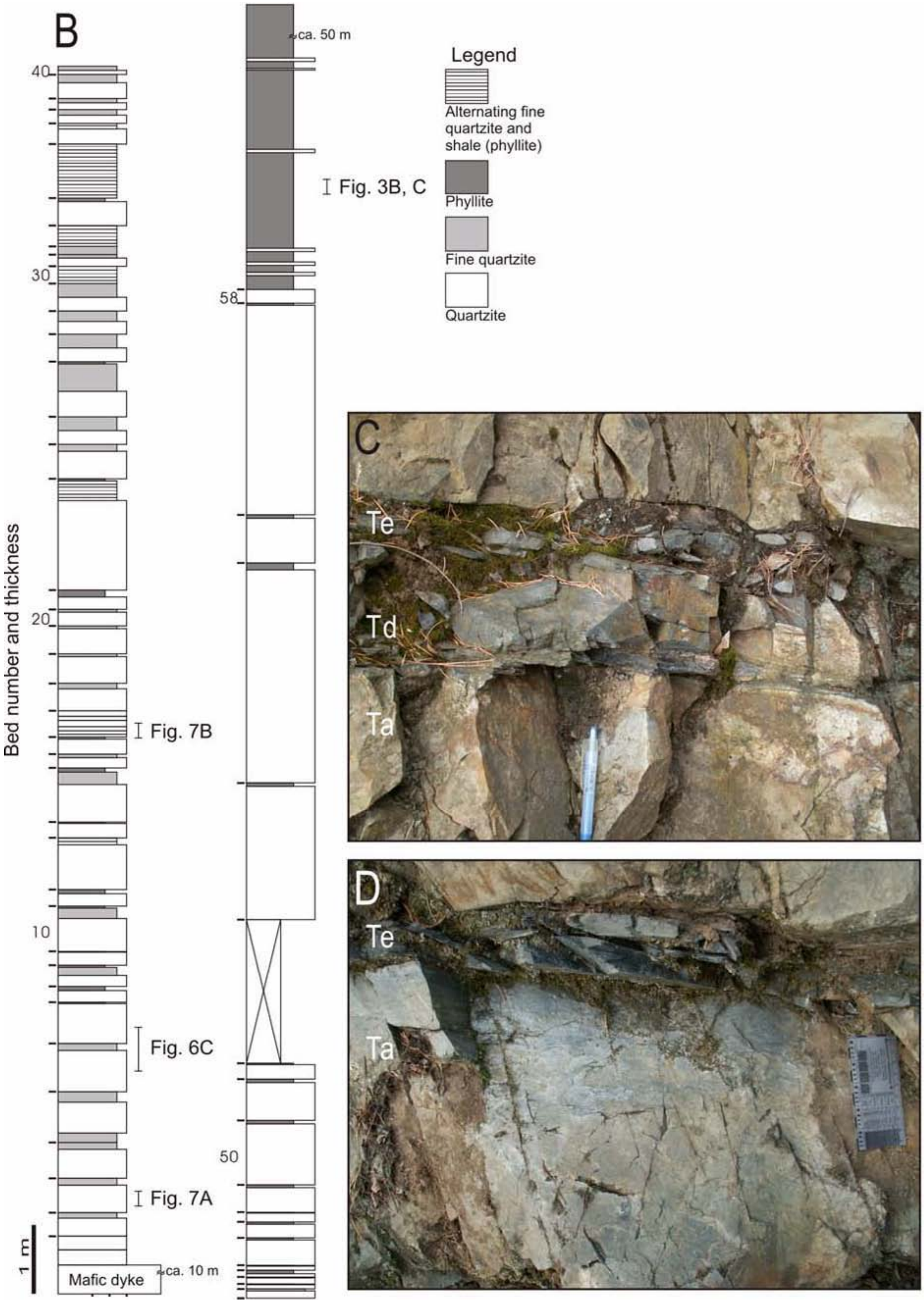

Fig. 6. (continued).

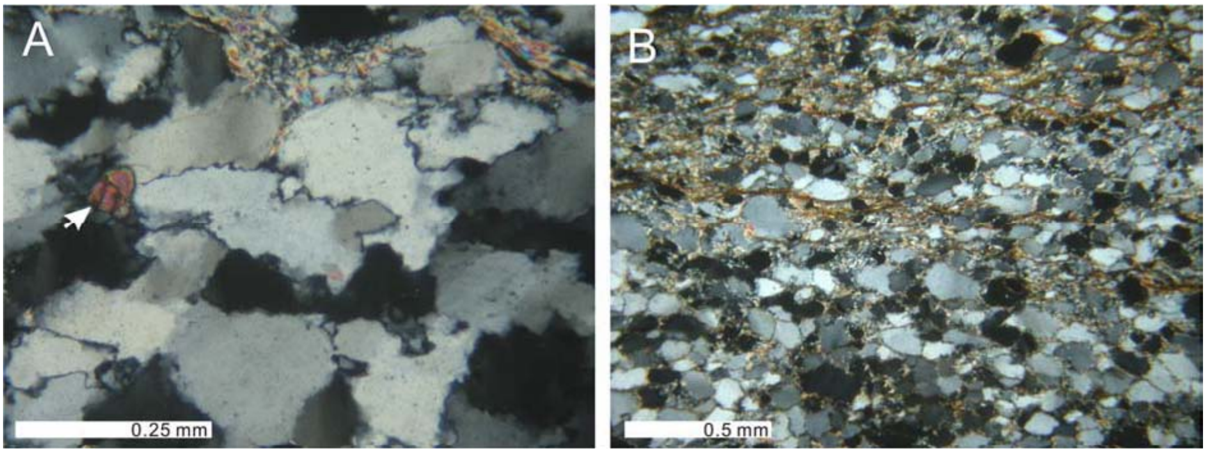

Fig. 7. Photomicrographs (cross-polarized) of quartzite in the Bonghwajae section. (A) Interlocking grains of quartzite. There are small amounts of heavy mineral grains (arrow) and micaceous minerals (in the upper right part of photograph). Quartz grains are mostly monocrystalline and show undulatory extinction. (B) Photomicrograph of the boundary between quartzite bed and the overlying shale. The transition is gradual in terms of grain size and quartz-clay ratio. For sample locations, see Figure 6B.

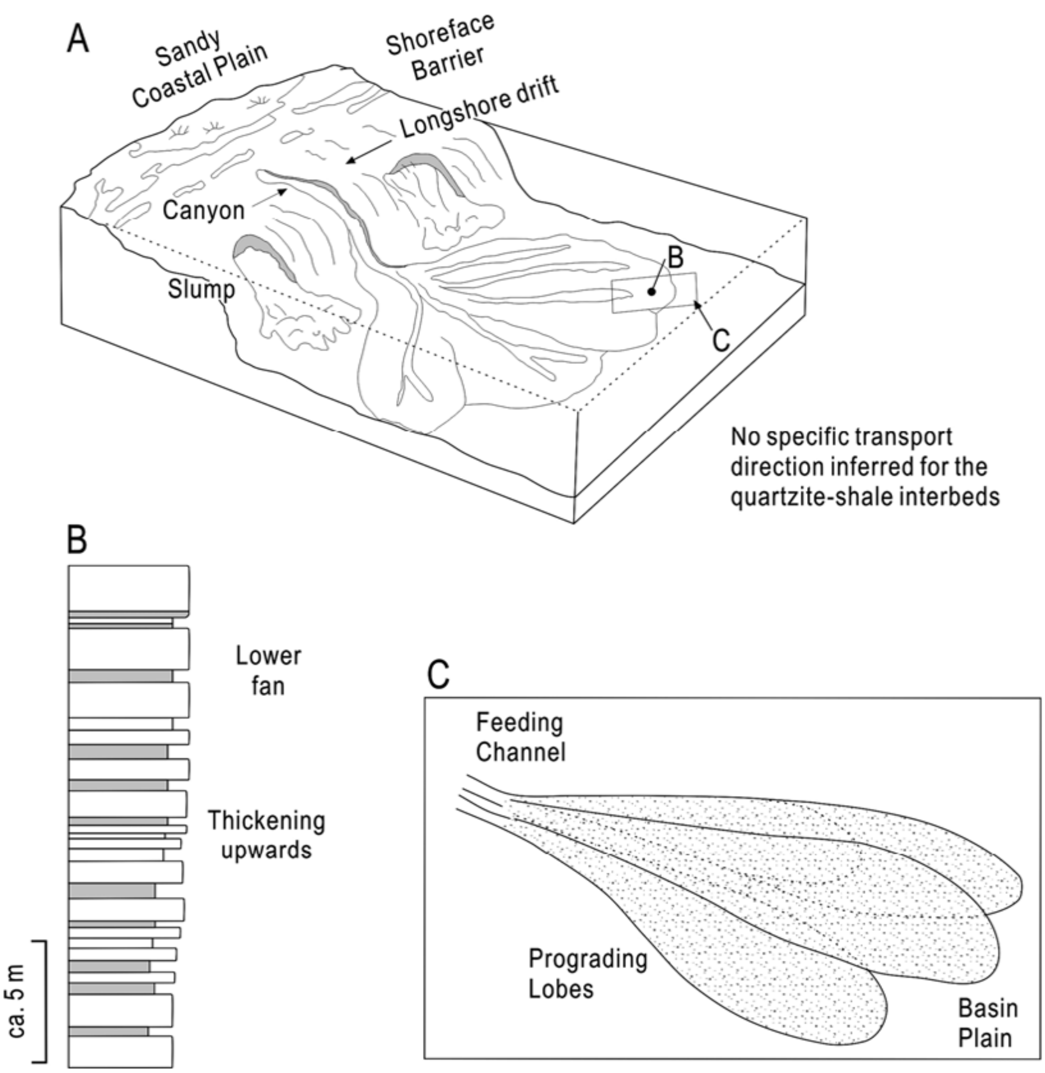

Fig. 8. Depositional model for the quartzite-shale interbeds of the Seochangri Formation. (A) The beds represent middle and lower parts of a deep-water fan, showing a thickening-upwards trend as schematically shown in (B). It formed in channel-detached sand lobes(C). (A) Modified after Reading and Richards (1994), (B) after Mutti and Ricci Lucchi (1972), and (C) after Mutti (1985).

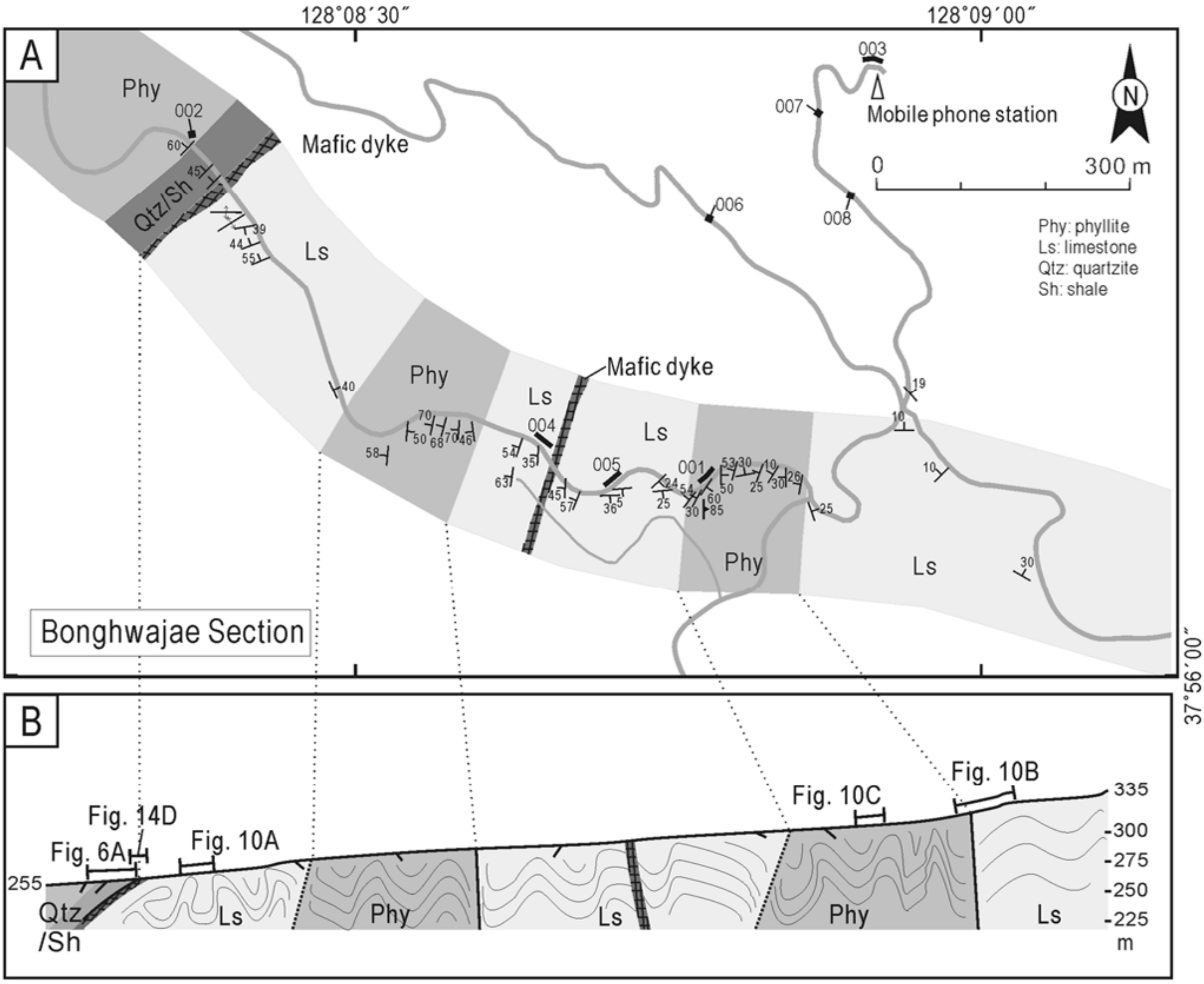

Fig. 9. Geologic description of the Bonghwajae section. (A) Lithologic distribution, attitudes of foliations, and fold axial planes of phyllite and limestone units along the roadcut. (B) Inferred cross-section.

quartz and feldspar grains show undulatory extinction and are elongated and sub-grained with a sutured boundary (Fig. 12A, B). The major foliation of the fine quartz grains was crenulated at a high angle to the major foliation and clast-stretching lineation (Fig. 12C, D). The muscovite schist, intermingled with the limestone, was strongly deformed, whereas the surrounding limestone was relatively undeformed (Fig. 12E, F).

5. DEFORMATIONAL MODEL

Radiometric age data of the Okcheon Group indicate that metavolcanic rocks of the Munjuri Formation initially formed in the Late Proterozoic (ca. 750 Ma) (Cho et al., 2004). It implicates that the Seochangri Formation, which is stratigraphically lower than the Munjuri Formation (Lee and Park, 1965; Reedman et al., 1973), formed at least prior to 750 Ma. On the other hand, the limestone beds of the Joseon Supergroup, unconformably overlying the Yeongnam massif, formed in the Cambrian–Ordovician, as manifested by the fossils of brachiopods, crinoid stems, and sponges.

Figure 13 shows a deformational model for the phyllite and limestone beds in the Bonghwajae section. The quartzite and shale beds of the lowermost Okcheon Group overrode the limestone beds of the Joseon Supergroup during the initial collision of the Gyeonggi and Yeongnam massifs (Fig. 13). A low angle thrusting occurred with an intense deformation in both groups and resulted in rootless isoclinal to tight folding of the compositional layers (Fig. 10D). Local strain concentration was responsible for the development of stretched-quartz ribbons in the quartzite beds (Fig. 14F). The continued deformation comprised open to tight folds, verging

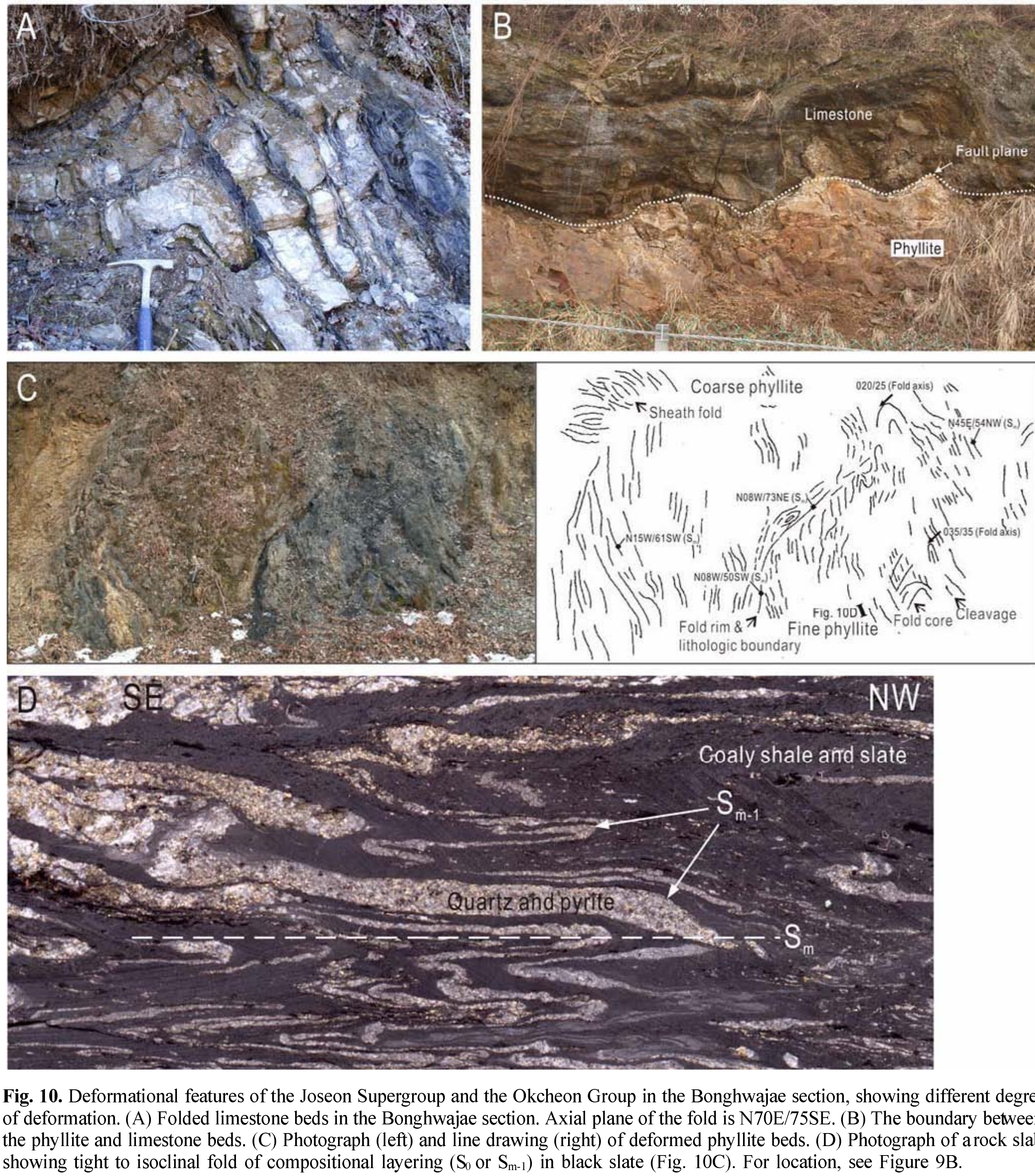

Fig. 10. Deformational features of the Joseon Supergroup and the Okcheon Group in the Bonghwajae section, showing different degree of deformation. (A) Folded limestone beds in the Bonghwajae section. Axial plane of the fold is N70E/75SE. (B) The boundary between the phyllite and limestone beds. (C) Photograph (left) and line drawing (right) of deformed phyllite beds. (D) Photograph of a rock slab showing tight to isoclinal fold of compositional layering (S_0 or S_{m-1}) in black slate (Fig. 10C). For location, see Figure 9B.

to the east to southeast. These folds formed crenulation cleavage, similar in strike, but different in dip angle to the regional foliation. The intersection lineation of the S_m and S_{m+1} and the fold axis trend northeast–southwest with a low plunge angle.

6. AMPHIBOLITES

An amphibolite body intruded limestone beds of the Joseon Supergroup as well as metasedimentary rocks of the Okcheon Group, and was, in turn, intruded by granite

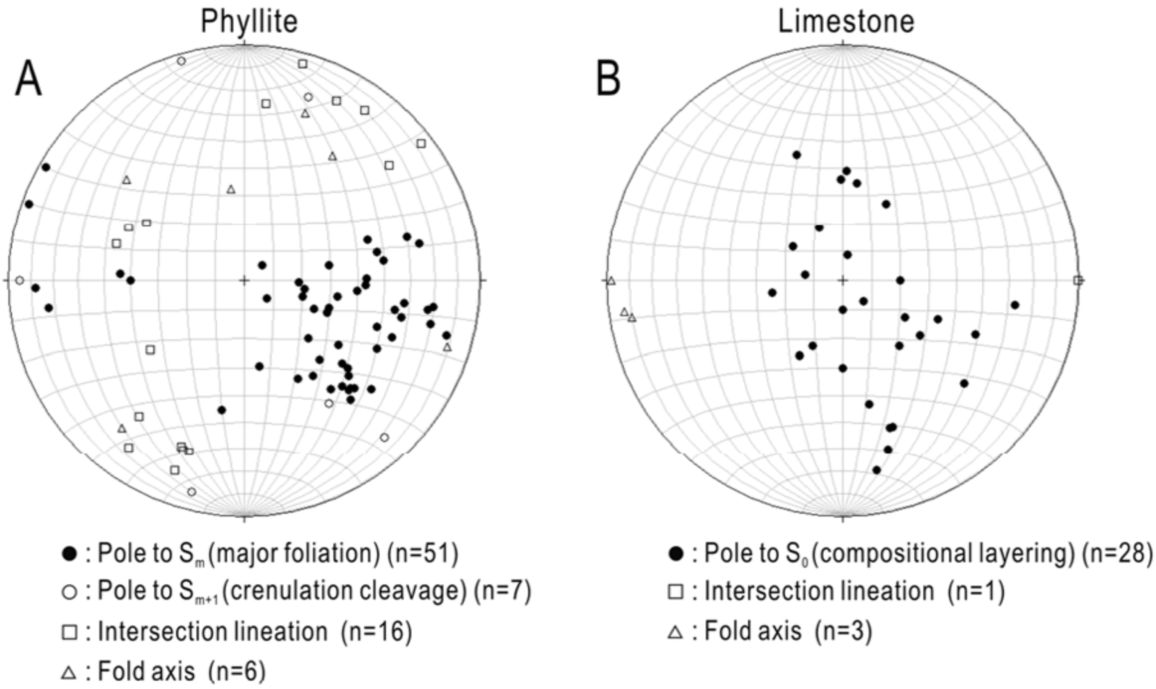

Fig. 11. Stereographic plots of structural elements measured from the phyllite (A) and limestone beds (B) in the Bonghwajae section.

of the early Cretaceous (Lee and Park, 1965). The amphibolites are fine-to coarse-grained, and the chilled margins are observed along the boundary of the sedimentary rocks. The amphibolite increases in grain size away from the chilled margin and is characterized by primary mineral assemblage of hornblende, plagioclase, sphene, magnetite, and quartz. Randomly oriented actinolite, biotite, epidote, and chlorite occur as secondary minerals. The hornblendes occur as subidiomorphic to xenomorphic phenocrysts and partly altered to actinolite, epidote, and chlorite. Actinolite neoblasts grew in matrix and armored hornblende phenocrysts near the contact of granite (Fig. 14A). The plagioclase mainly constitutes the matrix but also occurs as idiomorphic to subidiomorphic phenocryst in which actinolite neoblasts grew along the cleavages (Fig. 14B).

Some amphibolites contain fractured and undulatory-extinct hornblende phenocrysts (Fig. 14A). Faint foliation formed in some amphibolites, containing the plagioclase porphyry whose twin plane is bent (Fig. 14B). The bending of the plagioclase suggests that the amphibolite was deformed at least above 450 °C (Van der Pluijim and Marshak, 1997). It is an abnormally high temperature for the regional metamorphic conditions, since the mineral assemblage of the neighboring pelitic rocks includes biotite and muscovite. Local deformation was most responsible for the ductile deformation of the amphibolite during intrusion of the granite in the Cretaceous. This interpretation is supported by the occurrence of post-tectonic cordierite porphyroblasts in muscovite schist near the deformed amphibolite (Fig. 14C).

Fine-grained and massive amphibolite intruded the Cambrian–Ordovician limestone in the Bonghwajae area. Major foliation is partly recognized under thin section owing to the overprinting of thermal metamorphism which accompanied the growth of actinolite and biotite. On the other hand, most amphibolites are massive and devoid of deformation texture (Fig. 15). The mafic bodies in the Bonghwajae section preserve igneous texture, whereas the quartzite-shale beds are strongly deformed (Fig. 14D, E, F). The petrographic and deformational texture suggests that these dykes are younger than the amphibolites.

7. STRATIGRAPHIC AND TECTONIC IMPLICATIONS

The quartzite-shale interbeds in the Bonghwajae section conform to the stratigraphic relationship of the Okcheon Group proposed by Lee and Park (1965) and Reedman et al. (1973). The entire sequence underwent more than two phases of regional deformation (Fig. 5) (Reedman et al., 1973). The compressional deformation in the Bonghwajae section most likely formed an isoclinal fold where the phyllite sequence overlies the quartzite beds on the eastern limb (Fig. 13). The phyllite beds of the Seochangri and Buknori formations thrusted eastward and intermingled with the limestone beds (Fig. 9).

The overthrust block along the South Korean Tectonic Line, abutted on the carbonate sequence of the Joseon Supergroup, concurs that the thrust deformation was

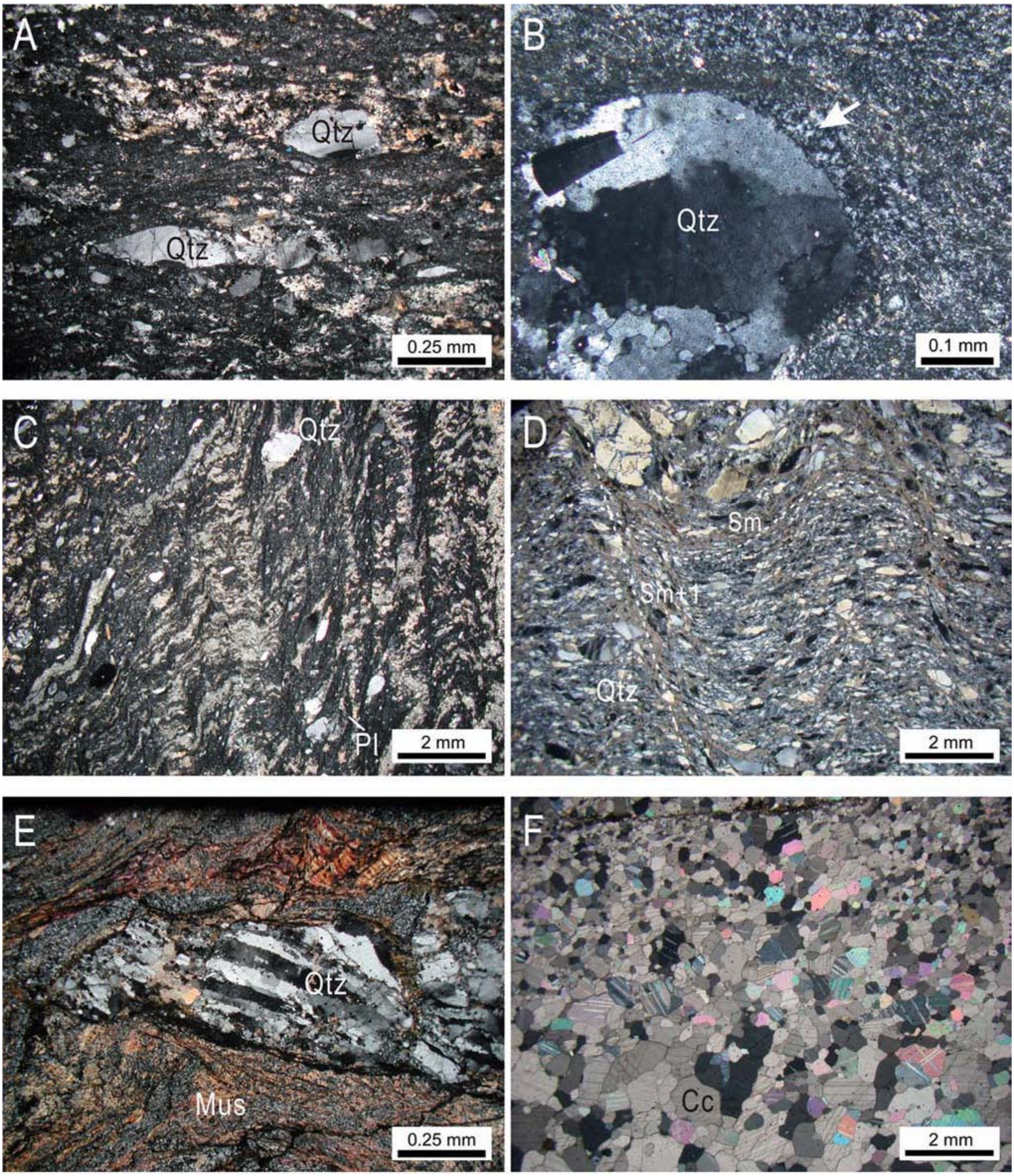

Fig. 12. Photomicrographs of clast-bearing phyllite, quartzite, muscovite schist, and limestone. (A) Clast-bearing psammitic phyllite showing stretched and undulatory extinct quartz clasts (location 006 in Figure 9). (B) Sub-grained quartz clast showing recrystallized outer part of original grain (arrow, location 006 in Figure 9). (C) Crenulation of major foliation defined by stretched clasts (location 003 in Figure 9) and (D) quartz grains (location 007 in Figure 9). (E) Strongly deformed muscovite schist showing deformed quartz grains formed parallel to major foliation (location 008 in Figure 9). (F) Crystalline limestone including muscovite schist. Calcite grains are devoid of deformation texture (location 008 in Figure 9). Qtz=quartz; Mus=muscovite; Cc=calcite; Pl=plagioclase.

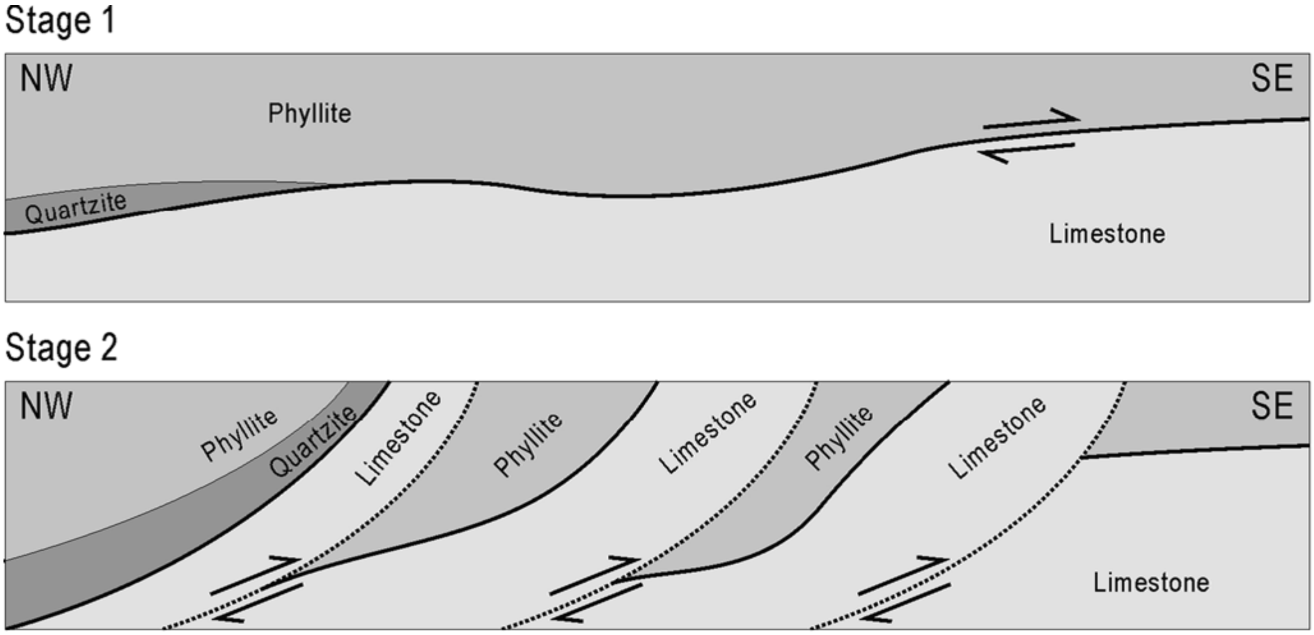

Fig. 13. Deformational model for the Bonghwajae section. Stage 1 shows phyllite beds of the Seochangri Formation that thrusted over the limestone beds of the Joseon Supergroup. Stage 2 represents subsequent high-angle thrusts.

toward the east–southeast (Fig. 11). The regional distribution of the deformational features conforms to the eastward tectonic transport (Kihm and Kim, 2003). The eastward compression was due to the collision in the restraining bend of the dextral fault, the South Korean Tectonic Line, between the Gyeonggi and the Yeongnam massifs (Chough et al., 2000). A synthesis of regional deformation features in the vicinity of the Bonghwajae section also conforms to the thrusts formed by northeast–southwestward compression (Fig. 16).

The Seochangri Formation contains two distinct deformational features (Fig. 15D). One is major regional foliation defined by an alignment of biotite and muscovite. The other is crenulation of the regional foliation without mineral growth. On the other hand, the amphibolite bodies were undeformed and show plagioclase grains that are randomly oriented (Fig. 15B, C), suggesting that emplacement of the amphibolites along the boundary was probably posterior to the deformation. These rocks were, in turn, intruded by the granite of the early Cretaceous. The foliated amphibolites in the interior of the Okcheon Basin were emplaced or metamorphosed in the Proterozoic (Kwon and Lan, 1991; Lee and Chang, 1996; Min et al., 1995).

The Bonghwajae section would represent part of the restraining bend of the collisional offset of the South Korean Tectonic Line between the Gyeonggi Massif with deep-water basin on the west and the Yeongnam Massif with carbonate platform on the east (Fig. 17). It is an overthrust front of the continent-continent collision along the offset between the Sino-Korean Block and the South China Block (Fig. 18). The collision extends from the Qinling-Dabieshan Belt on the west, offset by the Tanlu Fault, to the Sulu and Imjingang belts on the east (Fig. 17) (Cho et al., 1995; Ree et al., 1996). According to the paleomagnetic studies of the late Paleozoic sedimentary sequence in the Taebaeksan Basin (Doh and Piper, 1994), the Korean peninsula rotated clockwise (ca. 30°) in the Mesozoic. The rotation probably occurred at the eastern end of the Imjingang Belt where possible subduction of the South China Block was terminated (Fig. 18). Figure 19 shows the collisional event in stratigraphic framework. The Gyeonggi Massif, unconformably overlain by the Okcheon Group, deformed against the Yeongnam Massif, unconformably overlain by the Paleozoic sequence, and formed the Daedong Group. U–Pb age-dates of zircons in tuffaceous rocks of the Daedong (Bansong) Group using a sensitive high-resolution ion microprobe suggest that the Gongsuwon thrust, about 20 km east of the Bongwhajae section, formed in the Jurassic (171–187 Ma) (Han et al., 2006; Jeon, 2006)

A synthesis of the structural elements in the Taebaeksan Basin is suggestive of the dominance of strike-slip faults in the eastern part of the South Korean Tectonic Line, running northeast–southwest. These features most likely represent trace of the block movements and thrust deformation, i.e., rotation and lateral movement along the colliding suture between the two massifs (Fig. 18). Rotation and slip of the overriding block occurred at the end of the subducting plate, as in the Himalayan orogeny (Tapponnier et al., 1982). At

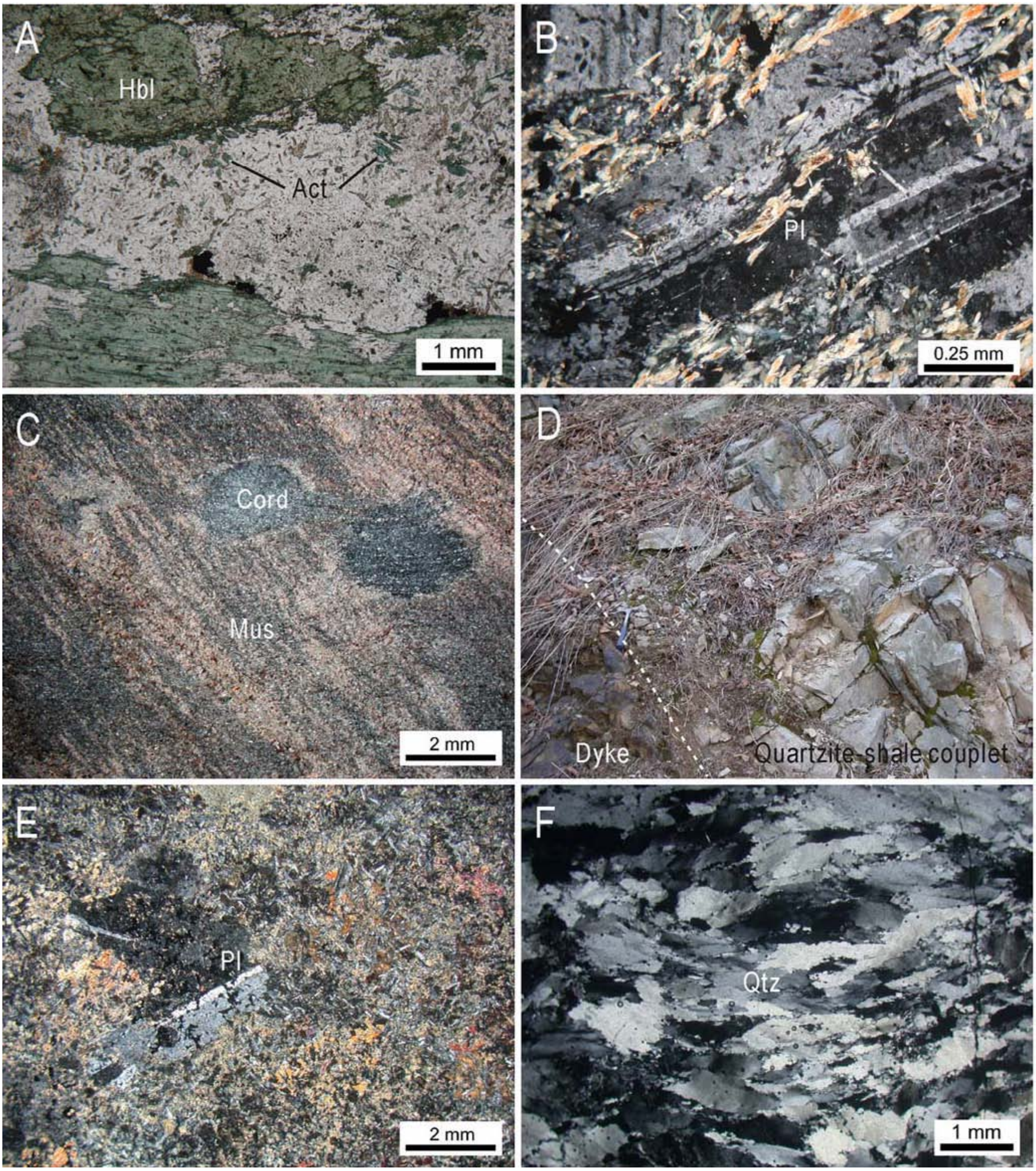

Fig. 14. (A) Photomicrograph of undeformed coarse-grained amphibolite (location OC03 in Figure 2). Actinolite neoblasts grew around the hornblende and in the matrix of plagioclase. (B) Photomicrograph of plagioclase porphyry showing a bent twin plane (location OC02 in Figure 2). Randomly oriented actinolite grew along the cleavage plane of plagioclase. (C) Photomicrograph of cordierite porphyroblasts overprinted on crenulation cleavage of muscovite schist (location OC01 in Figure 2). (D) Photograph of the boundary between the quartzite-shale beds and mafic dyke. For location, see Figure 9B. (E) Photomicrograph of undeformed mafic dyke showing igneous texture. (F) Photomicrograph of quartzite bed of quartzite-shale beds in the Bonghwajae Section. Quartz grains are elongated and show undulatory extinction. Hbl=hornblende; Act=actinolite; Cord=cordierite, Mus=muscovite; Pl=plagioclase.

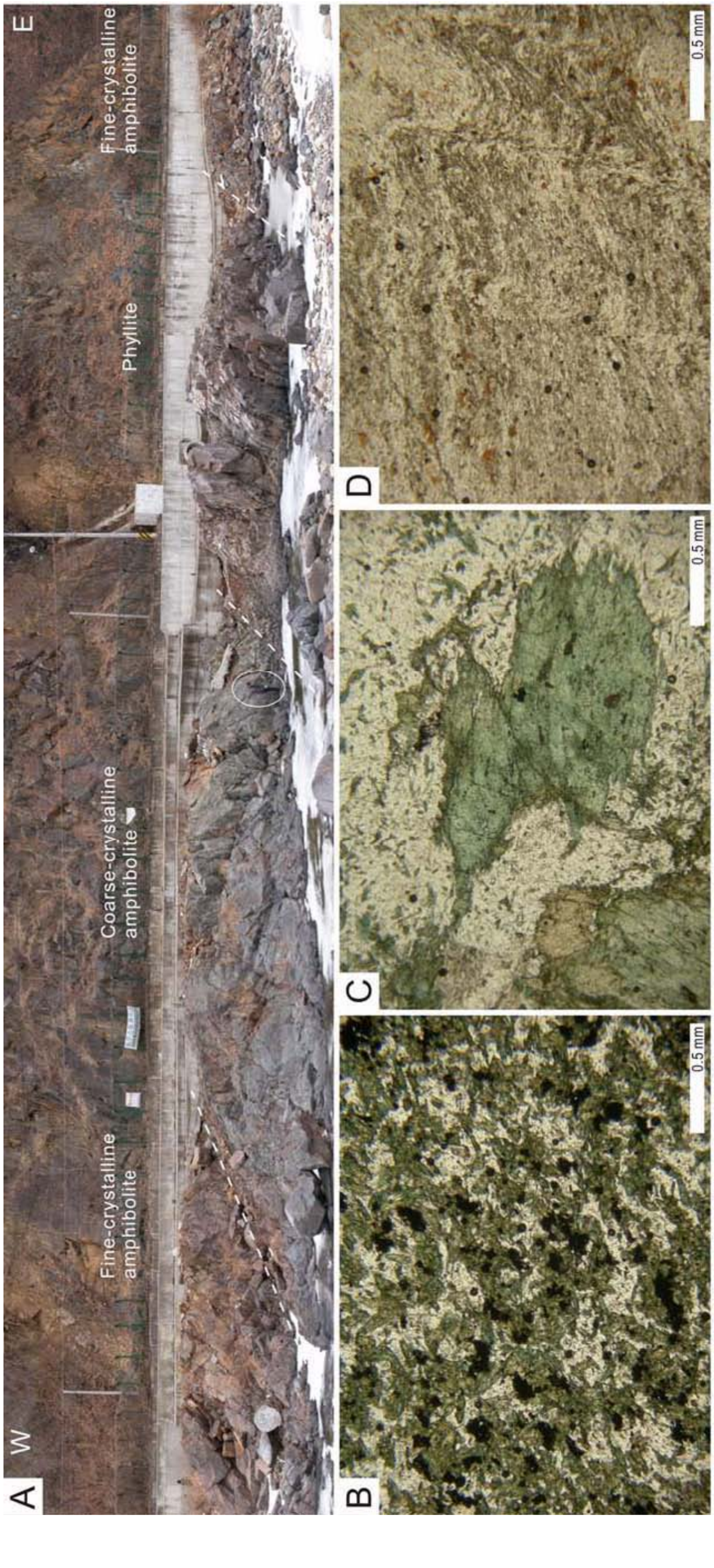

Fig. 15. (A) Photograph showing the occurrence of amphibolite and phyllite (location OC03 in Fig. 2). (B) Photomicrograph of fine-crystalline amphibolite. (C) Photomicrograph of coarse-grained amphibolite. (D) Photomicrograph of phyllite.

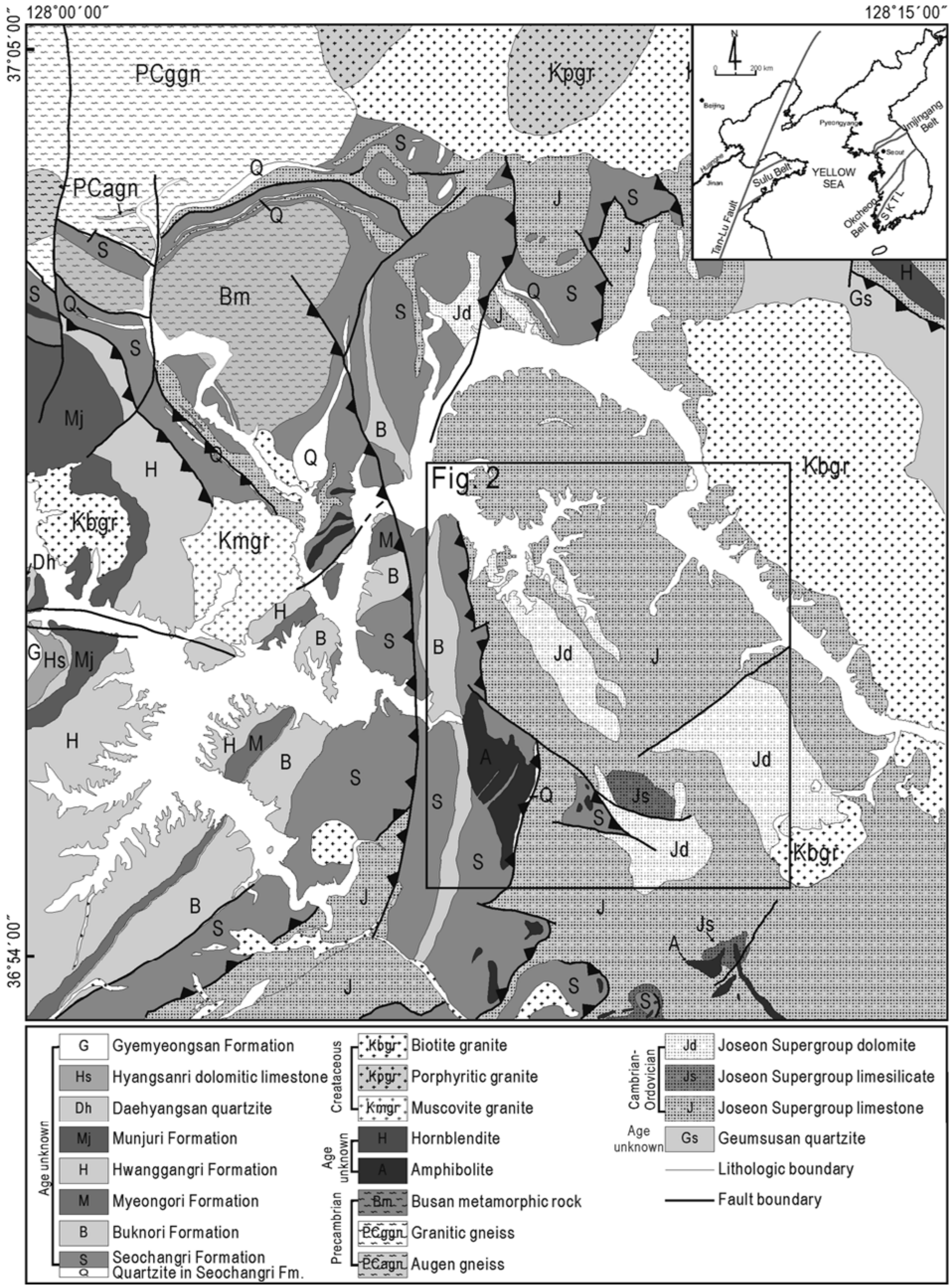

Fig. 16. Geologic map and major structural features in the vicinity of the Bonghwajae section (modified after Lee and Park, 1965; Kim et al., 1967). Inset shows major tectonic boundaries in the Korean peninsula (after Chough et al., 2000). SKTL=South Korean Tectonic Line.

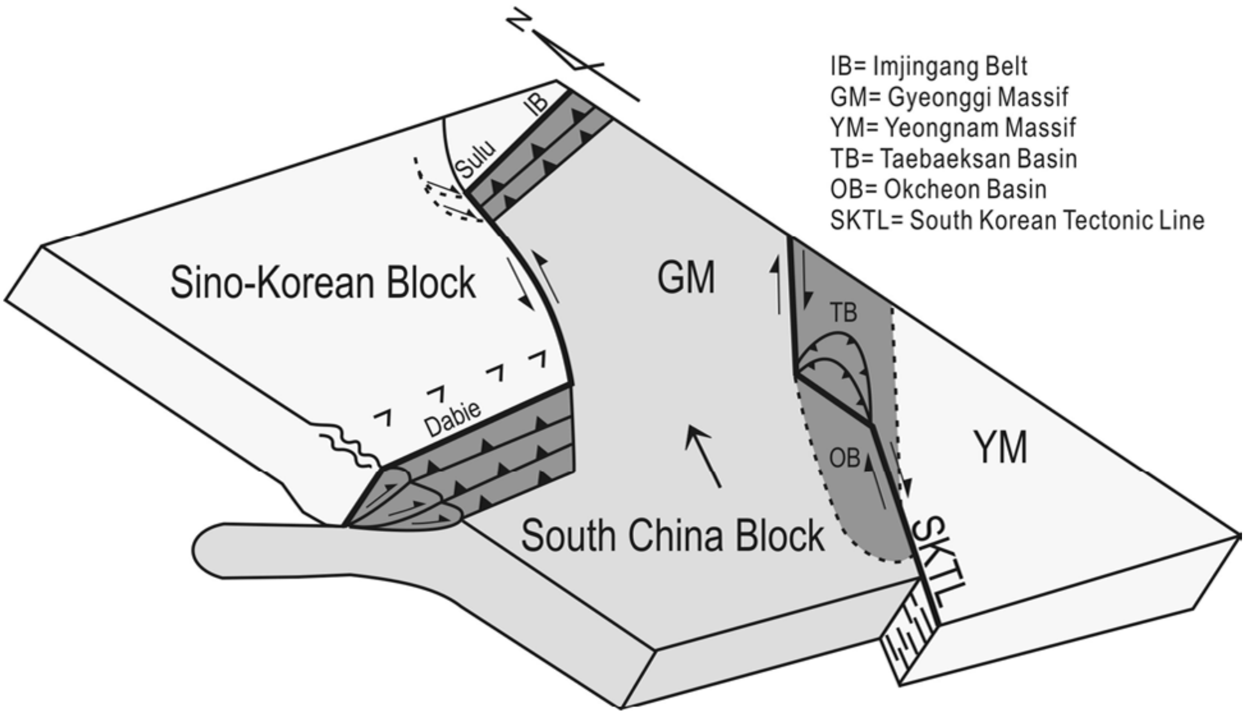

Fig. 17. Tectonic evolution of northeast Asia in the Mesozoic (after Chough et al., 2000).

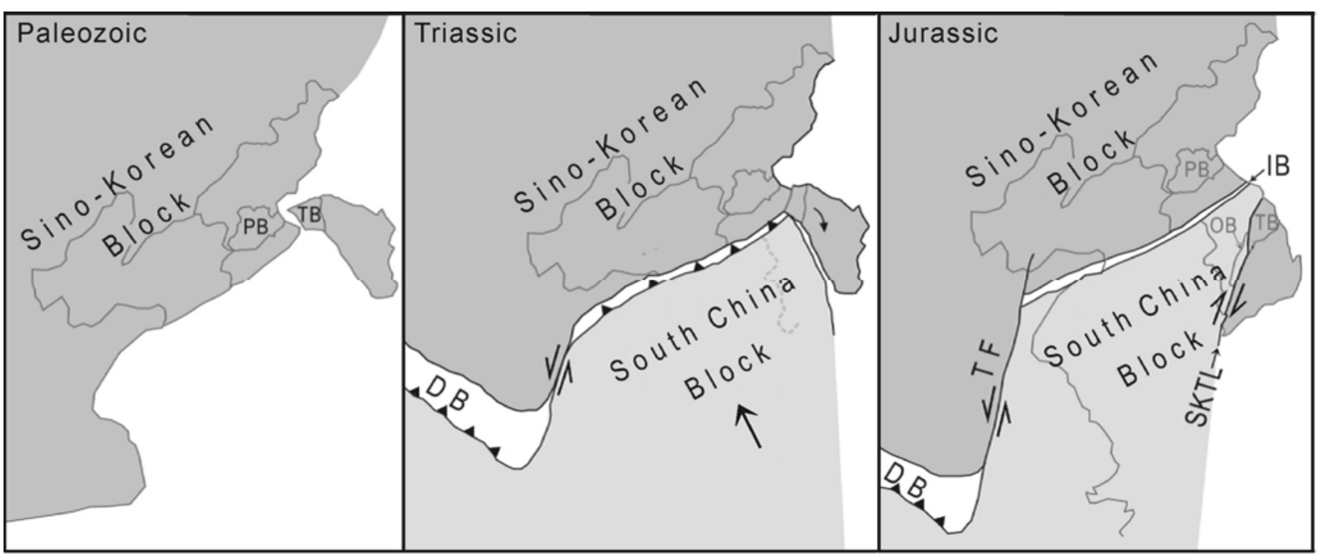

Fig. 18. Tectonic reconstruction of the Sino-Korean and South China blocks. PB=Pyeongnam Basin, TB=Taebaeksan Basin, OB=Okcheon Basin, IB=Imjingang Belt, DB=Dabieshan Belt, TF=Tan-Lu Fault, SKTL=South Korean Tectonic Line.

the eastern end of the Indian Plate, the large Asian continental block rotated clockwise and formed a series of thrust and strike-slip faults. Similar rotation of a relatively small continental block of the Yeongnam Massif was followed by a collisional offset against the Gyeonggi Massif (South China Block). The northeast–southwestward offset in the Bonghwajae section was in concert with the thrust deformation along the restraining bend of the dextral fault of the South Korean Tectonic Line, although crustal shortening occurred in the direction of the northwest and southeast.

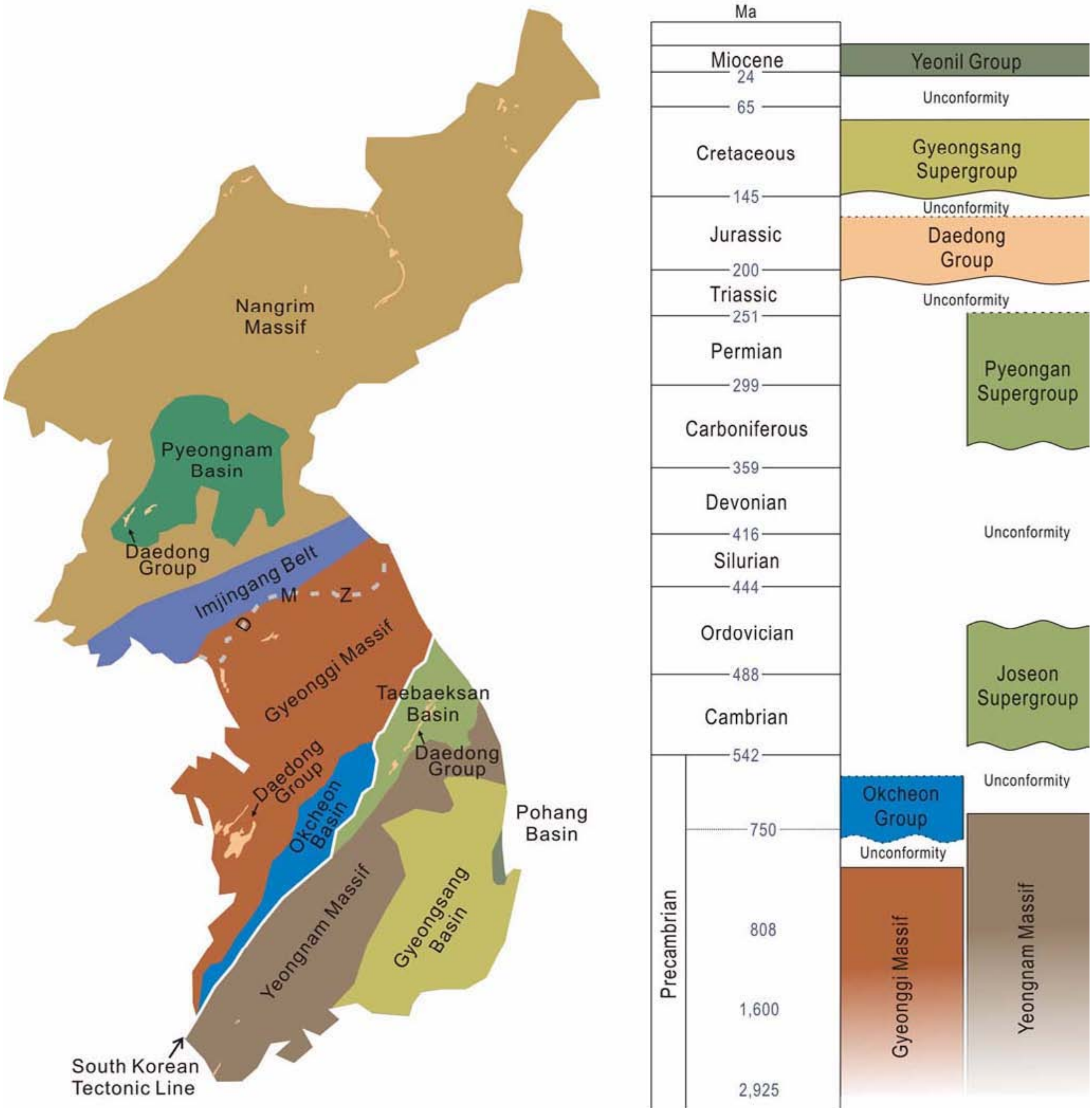

Fig. 19. Major tectonic features and stratigraphy of the Korean peninsula.

8. CONCLUSIONS

1. The quartzite-shale interbeds at the base of the Seochangri Formation, Okcheon Group represent deposition from turbidity currents in the middle-outer part of a deep-water fan.

2. The quartzite-shale interbeds are overlain by phyllite beds (Seochangri Formation) and, in turn, underlain by folded limestone beds (Joseon Supergroup). These beds were deformed by both northeast–southwest- and northwest–southeastward- compression.

3. The amphibolites of hornblende, plagioclase, sphene, magnetite, and quartz were emplaced posterior to the deformation (most likely in the Jurassic), but prior to the intrusion of the granitic body in the early Cretaceous.

4. The Seochangri Formation (late Proterozoic) forms a thrust front against the limestone beds of the Joseon Super-

group (Cambrian–Ordovician). The thrust represents collision along the restraining bend of a dextral slip, i.e., the major structural discontinuity of the South Korean Tectonic Line.

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