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YELLOW SEA TRANSFORM FAULT (YSTF) AND THE DEVELOPEMNT OF KOREAN PENINSULA

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The Yellow Sea Transform Fault (YSTF), the boundary between the Korean Peninsula and the South China Plate was a repeatedly reactivated ancient fault, extant since 1 Ga or more ago. Similarly polycyclic continental collisions along the Qinling-Dabie-Sulu (QDS) suture dispatched the lateral (vectorial) collisional effects eastwardly toward the Korean Peninsula across YSTF, the east end of the QDS belt. The Korean Peninsula, coexisted with YSTF, has been a promontory of the Sino-Korean Plate (SKP) at least since the Rodinia assembly, ca 1 Ga. The Early Paleozoic rift origin of the Okcheon Trough, a major aulacogen developed within the Korean Peninsula of the Sino-Korean Plate is attributed to the transform role of the YSTF. During the Middle Paleozoic, the Yangtze Plate, an inherent component of the South China Plate, collided SKP so mildly and enduringly that SKP had to develop the Late Ordovician-Early Carboniferous 'great hiatus' over the cratonic SKP. Contemporaneously, the clustered aulacogens were formed over an area near the YSTF. It is envisioned that during the middle Paleozoic, the compressed part of the SKP by the eastward-pushing Yangtze Plate formed an extensional upper crust where the aulacogens formed. The Yangtze sea invaded the aulacogens where the clastic sediments of the mixed environment were dominated by the supply from the Yangtze Plate as witnessed by the clastic zircon grains showing the Yangtze-akin isotope dates. The development of both the middle Paleozoic 'great hiatus' and the clustered aulacogens represents the Caledonian tectonic phase though scarcely accompanied deformations or an orogeny. The Carboniferous-Permian metamorphism recorded in the Middle Paleozoic aulacogens represents the Hercynian (Variscan) phase, but without obvious structural deformations. The deepest subduction and the most intensive collision of the Yangtze Plate along the Paleotethyan suture was made in the late Permian-mid-Triassic time, the Indosinian phase. The coeval Songnim Orogeny in Korea was similarly intensive, though it was a derived, secondary, orogeny propagated ultimately from the QDS collision belt. Because of the eastward compression derived then from the QDS collision belt, YSTF was so deformed and considerably pushed eastward that it now occurs as a deformed-dislocated fault zone called the West Marginal Fault of Korean Peninsula (WMF in Fig. 1). The location of the mid-Triassic Korean Peninsula was inserted between the eastwardly compressing marginal Yangtze Plate and the counter balancing Permian-Triassic subduction-metamorphic-accretionary complex of the Japanese Pacific. Such a sandwich tectonics effectively intensified the Indosinian Songnim Orogeny of Korea.

***Key words:* Sino-Korean Plate, Korean Peninsula, Yellow Sea Transform Fault, Indosinian Tectonism, Qinling-Dabie-Sulu Suture, Songnim (Songrim) Orogeny, Derived (Secondary) Orogeny.**

INTRODUCTION

Significance of the Yellow Sea Transform Fault (YSTF)

For the past twenty years, the geology of the Korean Peninsula (KP) has been haunted by a skepticism on the validity of the peninsula as a part of the Sino-Korean Plate [20, 22, 29, 57, 76]. Glevovitsky et al [29] suggested that the Pyeongnam Basin with the capital city of North Korea, together with the whole South Korea, are the extension of the South China blocks. A more popular assumption by Zhai [76] is that the Imjingang foldbelt of the middle part of KP is a possible extension of the Sulu UHPM zone of China. It was succeeded by Chough et al [20] who strived to figure out an indent of the South China Plate in KP. Owing to the radiometric datings, however, the KP with its Precambrian basement is now known confidently to belong to the Sino-Korean Plate (SKP) with ca 1.85 Ga orogenic dates. The Imjingang foldbelt is so oriented that

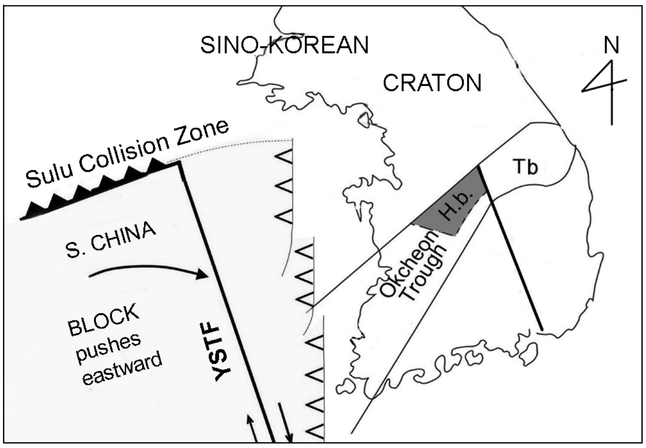

Fig. 1. The Okcheon Trough (OT), a Cambro-Ordovician aulacogen, in the southern Korean Peninsula. OT was likely opened by a transtension caused by the transpressive YSTF. OT was an embayment that mimicked a failed branch of possible triple junction with YSTF. OT is divisible into the Taebaeksan Basin (Tb) and the relatively mobile metamorphosed part MOT. It includes the Hwanggangni Basin (Hb) which was particularly mobile or unstable during the Triassic Period. In the early Triassic time, the collisional pressure of the Sulu (Shandong) collision zone (solid triangles) was likely transmitted to the northern promontory of the South China Block, which escaped toward the east as it was the east end of the Paleotethyan collision zone. Apparently, that South China part pushed YSTF rotating it clock-wisely in a certain measure. In consequence, YSTF is now found as the west marginal fault of South Korea (open triangles).

the Sulu belt appears to extend there, but the former is merely a folded Devonian aulacogen, intermediate- (to high pressure)-metamorphosed by the Triassic Songnim Orogeny; an abrupt geological discontinuity at the eastern tip of the Shandong Peninsula is obvious.

The present paper is aimed at assuring the validity of the view that the whole KP is a promontory of the SKP [6, 10, 11]. South Korea is adjacent, under its western offshore, with the South China Plate. Due to that plate boundary, the western South Korea would show some South China-akin geological features, such as some sedimentary basins as the recipients of the sedimentary material supplied from the provenance of South China. In the Devonian, a neighbored Yangtze sea invaded over the Sino-Korean land in which the Yangtze-akin marine fossils are now found.

Eastwardly migrated in the Triassic time, YSTF is now found as a submarine relict called the WMF (West Marginal Fault) zone figured out based on gravity studies [31]. It occurs near the western offshore of South Korea, but its pre-Triassic original location as YSTF, together with the accompanied ancient KP, must have been a thousand Km west-lying than present. Now that the fossilized YSTF occurs as WMF, the assumable location of the original YSTF plus the peninsula may be drawn near the eastern tip of the Shandong Peninsula.

The Songnim Orogeny well known as a local phase of the Triassic Indosinian Orogeny has its mid-Triassic paroxysm as shown by a clino-unconformity between the Carboniferous-Permian Pyeongan Synthem and the late Triassic-Jurassic Daedong Synthem. A view of the Songnim Orogeny as the result of the indentational collision of a piece of South China was once proposed [20]. But, quite contrastingly, the present writer views that the Songnim orogeny was ultimately caused by the Triassic Qinling-Dabie-Sulu (QDS) suturing in China, which dispatched the eastward compression via Yangtze Plate toward Korea, that is, the east-end blockade of the Paleotethyan suturing in China. Assumably, the energy out of plate collision could escape only toward the east because of the location of the Sulu segment of the Paleotethyan Triassic suture.

The Triassic Korean peninsula, a part of the SKP, was then sandwiched between the eastward compressing Yangtze Plate and the counter-balancing (even mildly compressing) metamorphic and accretionary zone of the Japanese Pacific, which made the sandwich tectonics of Korea quite effective during the Early-mid-Triassic Indosinian phase.

YSTF was conceived to answer the question why the Triassic QDS collision belt of China with UHPM was discontinued to Korea. YSTF as a global tectonic transform fault was required for a genetic cut-off of the QDS suture exempting the Korean Peninsula from the suturing [6, 10, 11]. The limited QDS subduction-collision zone confined to the west of YSTF connotes the accompanied presence of the KP, a promontory of the SKP.

It is a salient feature that the Triassic Songnim Orogeny of Korea is penecontemporaneous (almost time-correlated) with the Paleotethyan Indosinian tectonism in the QDS zone of China. Such a synchronism would suggest that the Songnim Orogeny is a side-effect of the QDS collision, which dispatched its collisional energy, finally transmitted to the KP as it is located in the east end of the QDS collision zone. Repeatedly throughout its lengthy life history, YSTF would change from time to time into the front blockade for the lateral, secondary, collision, which itself had to deform and migrate eastwardly as it did lastly in the Indosinian phase. The resultant fault zone, the relict of YSTF has been actually identified below the sea floor of the western offshore of South Korea based on gravity study [31]. The fault zone was called the West Marginal Fault of the Korean

Peninsula (WMF), which is preserved like the fossil of YSTF. It is the last relict of YSTF, which used to be repeatedly activated and deformed throughout the long history since more than 1,0 Ga.

KOREAN PENINSULA BELONGS TO SINO-KOREAN PLATE

Kobayashi [47] noted that the Cambrian marine fauna of the un-metamorphosed part of the Okcheon Trough bears the elements of the Yangtze faunal realm increasingly as one steps toward the west, i.e. in the Yeongweol area. However, the young students of plate tectonics misunderstood the Kobayashi's science in that they understood that a part of KP belongs to the Yangtze Plate, a block of South China. Thus the skepticism as to the validity of the Sino-Korean KP was born and reinforced. To the skeptics, Kobayashi appeared to suggest that the west part of OT may belong to the South China Plate.

Eventually, Yin and Nie [76] and Chough et al [20] figured out an in-Korea South China indent based on misunderstood Kobayashi's science and their wishful extension to Korea of the Sulu UHPM zone. But UHP minerals have never been identified in Korea except the dominant medium pressure-type mixed with some high pressure-type minerals despite intensive researches for the past many years by qualified scientists. The Imjin Group in the Devonian aulacogen was folded and metamorphosed in the Triassic but remained far below than UHPM that characterizes the Sulu zone of China. The Devonian depositional age of the Imjingang fold belt excludes the candidacy of the Sulu extension. The Sulu extension was sought even in Japan via the Imjingang fold belt of Korea, but the fold belt stops in the midway of the peninsula (Fig. 1). The concept of YSTF foretells neither possibility of the Sulu extension to Korea and Japan, nor any other zones of China across YSTF, a profound global tectonic element.

The alleged South China indent in Korea [20, 76] is not valid as the indent consists of the Precambrian Gyeonggi Massif, a typical part of SKP as shown by the thoroughly distributed ca 1.8 Ga signatures and of the Metamorphosed Okchon Trough (MOT), a part of OT that is located in SKP. The alleged South Korean Tectonic Line (SKTL) involves the strike-slip Honam Shear Zone (see figure 23 of Chough et al [20]), in which any extensive enough dextral strike slip is doubtful. SKTL is a man-made composition of available combination of faults to accommodate the wish of an in-Korea indent of an exotic plate piece. They suppose that the two sides of SKTL were parts of two different plates gathered to match in the Triassic to form the mosaic Korea. It is purely a fiction not supported by the actual geology. To them the

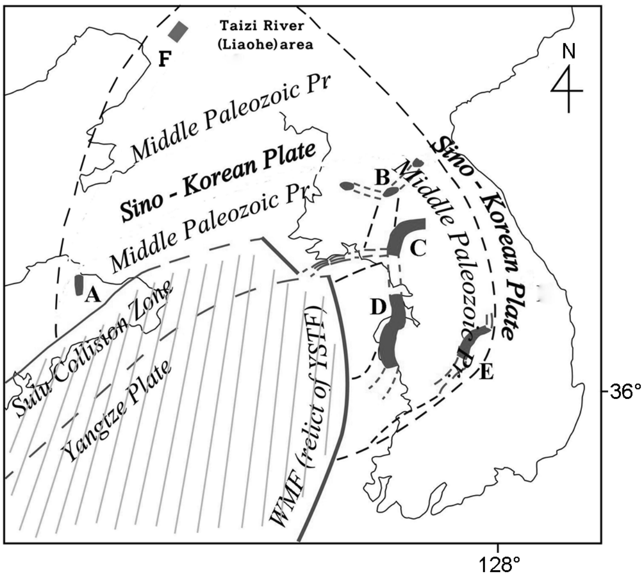

Fig. 2. Middle Paleozoic (Late Ordovician-Early Carboniferous) aulacogens are clustered in a Korea-Shandong-Taizihe area called Middle Paleozoic Sedimentary Province. A series of mild and sustained soft collision of South China Plate in the Middle Paleozoic was likely the cause both of the aulacogens and the 'Great Hiatus'.

Songnim Orogeny was the consequence of their alleged Triassic indentation, their wishful collision.

3. ORIGIN OF SINO-KOREAN PLATE, KOREAN PENINSULA AND YSTF

As a part of the Columbian Supercontinent, the SKP was formed by the collisions of the West North China, the East North China and the Korean Peninsula by the Luliang-Machollyong Orogeny, ca 1.8–1.85 Ga [52, 78, 81]. Since then, the SKP has remained a distinctive global-tectonic plate consisted of North China and KP. But notably, the southern margin of the initial SKP was obviously cut away and later substituted by the Yangtze Plate along the QDS suture. Notably, QDS and the Luliang Orogenic Belt (Trans-North China Orogen) are in an angular contact, that suggests to assume a torn-away part here called the Southern Margin of North China (SMNC).

The origin of YSTF may go back to its initial role to accommodate the leaving of SMNC. In other words the initial YSTF was the scar of the tearing out of SMNC in sometime ca ?1.4 Ga. And then the Rodinia assembly of 1-0.8 Ga made use of YSTF in accommodating the arrival of the exotic Yangtze Plate. Since then, YSTF seems to have been repeatedly active several times until the final, very intensive, collision in the Triassic. In all such polycyclic divergence and convergence of the two plates, the transform role of YSTF appears to have been critical. In every occasions, the paired YSTF and the Korean promontory acted together as a mutually compatible entity. Though YSTF was repeatedly active since the Middle Proterozoic, this paper focuses on the Phanerozoic role of YSTF on sedimentation and tectonics.

Recently the Precambrian basement of KP is known to bear widespread ca 1.85 Ga signatures proving its identity of belonging to the SKP [28, 56, 59, 60, 68, 74, 75, 77, 78, 81]. Jeon et al [35] acquired detrital zircons of several age components, among which three components are notable, namely (1) ca 1.85 Ga, (2) ca 1.0-0.8 Ga and (3) Devonian components, in that (1) seemed surely derived from the SKP, but (2) and (3) groups are said to reflect the South China location of the sample sites. But, to the present writer, the location of the sedimentary basins may possibly be in the Sino-Korean Craton. The ca 0.9 Ga (early Neoproterozoic) and the Devonian populations may have been either derived from the neighboring South China or otherwise, the Korean marginal SKP had such plutonisms in South China-akin times. Because they were repeatedly colliding each other, say during the Rodinia asssembly in ca 0.9 Ga and in the Devonian continental amalgamation, such South China-akin age groups may reflect the plutonisms in SKP. Therefore, it must be remembered that South China-akin age groups not necessarily indicate the sampled locality be the South China.

Sometimes, geologic bodies unfamiliar or alien to SKP occur over older rocks and the Precambrian basement, but Triassic deformation, metamorphism and magmatism common both to the cover and basement makes it difficult to clarify their mutual relation [41]. Because the Yangtze Craton of the South China is adjacent to the western KP, the geology of the latter bears some Yangtze-akin geologic features, such as the middle Paleozoic sedimentary basins, unusual in SKP.

Ca 900–820 Ma plutons of the west Gyeonggi Massif were likely formed at the convergent margin during the Rodinia assembly (Kim et al, 2013a). In the Hongseong area of the Gyeonggi Massif, TTG and alkali plutons have been identified, each dated the U-Pb zircon ages of ca 841–822 Ma and ca 751–746 Ma respectively. The alkali plutons of ca 750 Ma are interpreted as the anorogenic products of Rodinia disruption [42, 43]. The Precambrian block of the Korean Peninsula in contact with South China may plausibly carry such signatures; during the Rodinia assembly and disruption, the KP as a promontory of the SKP was repeatedly affected tectonically by the collisions of the blocks of South

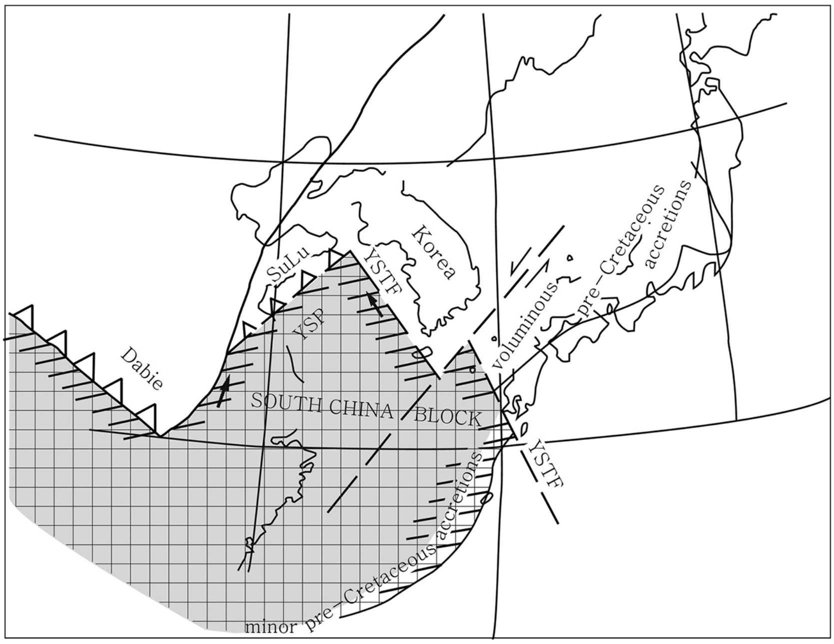

Fig. 3. Map showing the South China Plate (colored) and the adjacent Sino-Korean Plate, the boundary being the Yellow Sea Transform Fault (YSTF) now apparent as WMF (West Marginal Fault of the Korean Peninsula) as detected by gravity studies. The activity of YSTF was repeated during the pre-Rodinia (Mesoproterzoic)-Indosinian (Triassic) dispersions and assemblies of supercontinents. Its last Permian-Triassic dextral transform activity contributed to form the Triassic UHP collision zone of the Sulu Belt, China. While the Sulu collision made the YSTF to die out and become a derivative collision front, the contemporaneous accretions in the Japanese Islands by the convergent Pacific Plate resulted in the counter-compressed Korean Peninsula, which we call the Songnim Orogeny, a local phase of the Indosinian Tectonism.

China. In short, the presence in KP of the South China-akin signatures reflecting the Rodinia assembly and disruption is not strange at all for the Sino-Korean KP.

PALEOZOIC OKCHEON TROUGH: GENETIC RELATION WITH YSTF

The Okcheon Trough (OT) runs in SW-NE direction, diagonally across the southern part of the Korean Peninsula. Its global tectonic genesis has never been explained or debated. Here an aulacogenic origin is suggested as OT assumes a triple junction with YSTF. Its Early Paleozoic rifting at the junction with the Yangtze Plate must have been possible under the role of YSTF resulting in the initial OT.

The OT is geologically divided into two parts: The metamorphosed and very highly deformed half area near the junction with YSTF is called the Metamorphose Okcheon Trough (MOT). And, the remaining relatively stable but quite deformed part is called the Taebaeksan Basin. Such an increasing crustal mobility toward the YSTF may support its aulacogenic origin.

The known amalgamated state of the Yangtze Craton and the Sino-Korean Craton during the middle Paleozoic as will be discussed in the coming section of this paper renders a premise of the Early Paleozoic dextral activity of YSTF to assure the convergence of the two plates. That dextral activity may have caused a transtensional rifting of the OT in the Cambrian-Ordovician time.

OT was an extensional sedimentary basin as shown by its early Paleozoic depositional history controlled by syn-depositional normal faults of two kinds: some parallel to the axis of the trough while some pendicular to the axis. Such an extensional character of OT and it's diagonal junction with YSTF suggest its opening and development ascribable to the transform and the transfer roles of YSTF (Fig. 1).

OT was a single elongated, intra-cratonic, trough or 'geosyncline.' Kobayashi [47] called it 'Yokusen Geosyncline' in Japanese reading of the locality name. During the Mesozoic, it changed into the Okcheon fold belt. A marine embayment of ca 500 Km long, it dies out in the northeastern terminal part near the east coast of the Korean Peninsula. The northeastern half of OT is called the Taebaeksan Basin (Tb in Fig. 1) or the 'un-metamorphosed' part of OT. The southwestern half of OT is called the MOT.

The Taebaeksan Basin (Tb) of OT may be divided into two areas showing a facies contrast in the Cambrian-Ordovician stratigraphy: the northeastern part shows a typical shallow-marine near-shore facies (the Duwibong-type facies) analogous with the inland-sea facies of the central Sino-Korean Craton, i.e., the Shansi Province of China. The other part of Tb, near Yeongwol, occupying the middle part of OT, shows a relatively deeper marine facies with semi-pelagic biofacies comprising planktonic agnostids (Kobayashi, 1966). These two parts of the Taebaeksan Basin (Tb) are mutually well correlated in stratigraphy, both bearing the famous M. Ordovician-E. Carboniferous 'great hiatus' typical to the Sino-Korean Craton. Contrastingly, the basin-fill of MOT was so highly deformed and even metamorphosed by Mesozoic tectonics that its stratigraphy would be still debated. Particularly, the rarity of fossils in MOT invited efforts to find them [9, 49, 51]. The occurrence in MOT of a specimen of Archaeocyatha witnesses the Cambrian invasion of the Yangtze seawater to MOT as that fossil group was not known in the marine realm of the Sino-Korean Craton but known from the worldwide Cambrian inclusive of the Yangtze realm [49]. The areal overlapping of MOT and the MPPr (Middle Paleozoic Sedimentary Province) gives a perspective of further finding of fossils from MOT.

In the late Paleozoic (Carboniferous-Permian) time, the coal-bearing Pyeongan Synthem was well developed in Tb while its development in MOT was poor and scarce. Such a difference may support an idea that the OT development in the late Paleozoic was related with subsidence, not related with the transform activity of YSTF.

REVIEW OF MIDDLE PALEOZOIC TECTONISM IN CHINA

The collisions of the Sino-Korea and the Yangtze Plates along the Qinling-Dabie-Sulu suture zone were polycyclic or repeated [4] and left tectonic and metamorphic signatures to the Korean Peninsula. So the tectonics of the suture zone in China is understood as the ultimate source of the pre-Jurassic tectonisms in Korea. The middle Paleozoic features are also under the same context.

The terminal phase of the middle Paleozoic convergence of the Sino-Korea Craton and the Yangtze Craton has been expressed variously depending on the authors. The CAGS Inst. of Geol. [4] termed it a Caledonian amalgamation. Gao et al [26] termed it the Silurian-Devonian accretion of the Yangtze (South China) to the North China Craton based on a research on the provenance changes of South Qinling basins. And many others contributed to the consensus of the Sino-Korea-South China amalgamation in the Middle Paleozoic time [23, 24, 67]. It is the Early Paleozoic weak collision according to Wan [73].

The main suture zone of Qinling Block and Sino-Korean Plate, the Shangdan Belt comprises the rocks of the oceanic island arc and the ophiolitic blocks residual of the oceanic crust. It records the Early Paleozoic ocean that existed between Qinling Block and Sino-Korean Plate. Associated with the Shangdan Belt, in its east, is the Erlangping Ophiolitic Belt composed of basalts, sheeted dykes or sills, and siliceous rocks that contain the Ordovician-Silurian radiolarian [30, 73, 80].

Dong et al [23] concluded that the Sino-Korea and the South China Plates collided in either the Late Silurian or the Early Devonian constrained by depositional ages on both sides of Shangdan suture, and also based on the unconformity between the Middle Devonian and the pre-Devonian strata. During the Late Ordovician–Early Silurian time, the Shangdan Ocean was extant with fore-arc sedimentation, sediments being supplied from the North Qinling Belt. As the Shangdan Ocean was closed, the marine foreland basin was developed in the South Qinling belt where the Middle–Upper Devonian Liuling Group was deposited.

It is thus generalized that the Sino-Korea and the Yangtze Cratons had two sutures on both sides of the Qinling microcontinent, favorably for the soft collision of the two plates. Based on the study of the Tongbai orogen, Liu et al [55] concluded that (1) Ordovician-E Silurian oceanic subduction and arc magmatism, (2) Silurian-Early Devonian (ca 440-400 Ma) arc-continent collision, (3) Carboniferous oceanic subduction and accretion and (4) the final continental subduction and collision in the Late Permian-Triassic (ca 260-200 Ma) took place. For our purpose (2) the Silurian-Early Devonian (ca 440-400 Ma) arc-continent collision is noteworthy as a favorable situation for a soft collision. It must have been weaker than a continent-continent collision.

Wan [73] reviewed the Early Paleozoic amphibolite facies metamorphism of the North Qinling-Tongbai collision belt (of the Qinling-Dabie belt) and the Cambrian-Early Devonian (519-403 Ga) high-ultrahigh pressure metamorphism of the eclogite facies in the Dabie collision belt. A collisional orogeny reportedly occurred in North Qinling in the end of the Early Paleozoic when the oceanic crust (ophiolite suite) finally disappeared [79]. Wan [73] pointed out the deficiency of the reported intense deformation in the plate margin and near-by area in the E Paleozoic period, which disproves a major collision of the Sino-Korea and S China blocks, and also doubted any late Paleozoic deformations not recorded in the plate margin and near-by area. It, thus, remains that the Triassic Indosinian orogeny was the major collisional phase.

Wan [73] reviewed the amalgamation of N. and S. Yangtze plates in the Caledonian time. He mentioned that the Early Paleozoic Yangtze Plate and the Cathaysia Plate differ each other in the orientation of rock deformation, magmatism and metamorphism, suggesting their being separate plates. In short, no Yangtze-Cathaysia collision in the end of the E. Paleozoic [73], He stated that the compression-shortening of Cathaysia in the end of the E. Paleozoic was not the result of its collision with Yangtze. He emphasized the differing tectonic orientations: N-S in the Cathaysia while E-W in Yangtze. Wan's evidence for no colliision includes no regional metamorphism in the Yangtze. In contrast, Faure et al [25] asserts a Caledonian intracontinental subduction of Cathaysia block into the S. Yangtze block, a sort of continental collision. In summary, the Caledonian collision of South and North Yangtzes to form the Yangtze Plate seems established. Did the Cathaysia collide the Yangtze Plate to form the total South China Plate in the end of the Early Paleozoic, that is, about the end of the Silurian Period? Views are divided. It only remains certain that the Caledonian phase witnessed the collision or amalgamation of the northern South China (the Yangtze Plate) with the Sino-Korean Plate.

CLUSTERED AULACOGENS IN SINO-KOREAN PLATE: GENETIC RELATION WITH YSTF

For a long time, the Late Ordovician-Early Carboniferous ('middle Paleozoic') Great Hiatus has been a reliable criterion of the Sino-Korean Craton. The Precambrian basement of the Korean Peninsula is showing abundant ca 1.8 Ga signatures and carries cratonic Paleozoic basins that bear the characteristic middle Paleozoic great hiatus, which altogether proves the peninsula as a part of the Sino-Korean Craton [5, 60].

Some scattered middle Paleozoic part-time depositions recently observed in the medial part of the Korean Peninsula and the adjacent part of China raised a skepticism as to the validity of the whole Korea belonging to SKP. But, the present author, trusting the validity of the Sino-Korean Korea, conceived the Middle Paleozoic Sedimentary Province (MPPr) within the Sino-Korean Plate, where aulacogens are clustered as a feature proper to SKP [8].

The various Middle Paleozoic sequences in MPPr, so far known, are: (1) the Late Ordovician Sangseori Series and the Silurian Goksan Series in the Pyeongnam Basin, N Korea [48, 61]; (2) Silurian-Devonian Ungyori Formation and Devonian Daehyangsan Formation in the Metamorphosed Okcheon Trough; (3) Devonian Taean Formation, Middle Devonian-Early Carboniferous Imjin Group and Yeoncheon Group [14, 17, 18], and the western extension of the Imjin Group in the southern Ongjin Peninsula (i.e. its Yellow Sea coastal area) [53, 54], (4) Early Carboniferous strata with abundant and well-preserved vascular plants in the Taizi River (a tributary of the Liao River)-Liaodong area, China [58], (5) M. Devonian-Early Carboniferous Yannan Group, near Yantai, Shandong Peninsula, China [36, 69, 82], and (6) the middle Paleozoic strata of the Hwanggangni basin such as the Daehyangsan Formation of the early Devonian age [8, 63]. Prior to those discoveries of in-situ strata, abundant middle Paleozoic fossils were collected from the pebbles of the Mesozoic conglomerates [64, 65].

The above list of the Middle Paleozoic sequences excluded a controversial conodont-based Silurian unit, Hoedongri Formation in the Tb of the Okcheon Trough [12, 50]. Exclusion has been made according to An [1, 2, 47], who are judged by the present author as reliable.

The Devonian-Carboniferous Imjin Group (3000 m thick) of the Ongjin-Gangnyong area (Ongjin Peninsula) is reported to carry in its upper part (1000 m thick) some volcanic strata in addition to the dominant sedimentary strata [5, 8, 53, 60]. The effusives (lavas and tuffs) are spillite and Keratophyre series of mafic, intermediate and subalkaline compositions [53, 54].

The time span of the total middle Paleozoic depositions in MPPr well corresponds with the U Ordovician – L Carboniferous hiatal interval of SKP (see Table). Now the hitherto recognized Middle Paleozoic gap in the geologic column of Korea is certainly filled out.

The Caledonian tectonism has been well documented in the Qinling-Dabie-Sulu suture between SKP and the Yangtze Plate. On the other hand, the SKP in general, remote from the suture, is shown with a special Caledonian phase as represented by the middle Paleozoic hiatus and the aulacogen genesis during the hiatal time. Such a coincidence suggests that the suturing with mild and enduring collision may have caused the hiatus and the coeval genesis of the aulacogens.

Notably the MPPr's aulacogens are densely clustered near the YSTF, that is, the medial-west Korean Peninsula. Why the aulacogens were clustered in the near-Korea part of the Sino-Korean Craton while the soft and enduring collisional state between the Sino-Korean and the Yangtze Cratons formed the cosmopolitan 'Middle Paleozoic Hiatus' all over the Paleozoic basins of the Sino-Korean Craton? During the soft and enduring collisional state between two plates, the medial Korean Peninsula near YSTF and also the Chinese area near the junction of YSTF with Sulu (Shandong) Collision Belt were particularly clustered with aulacogens to form the MPPr. Here, the aulacogens were formed here and there from time to time during the Late Ordovician-Early Carboniferous interval.

The east end of the Qinling-Dabie-Sulu Suture, YSTF was to become the eastward front of the collision during the Caledonian time; at the same time, the area of MPPr was to form aulacogens in the upper crust above the compressed and heated lower crust. Apparently, MPPr was developed around the juncture of YSTF and the east end of the Sulu suture. The MPPr appears to be mimical of an area of potential triple junction above a hot spot [3, 8].

Among MPPr, the aulacogens were most densely clustered in the middle part of the KP. The geographic overlapping of the MPPr and MOT predicts that the age-unknown stratigraphic units of MOT may comprise some middle Paleozoic strata. Such occurrences of the middle Paleozoic strata there was foreseen by Son [70a, 70b], the pioneering worker on MOT.

MIDDLE PALEOZOIC AULACOGENIC DEPOSITS CONTAIN S CHINA-AKIN CLASTS AND FOSSILS

Clastic zircons studied in Korea have shown that they were derived from both the Sino-Korean Craton near depositional site and also from the Yangtze Craton as manifest in the radiometric zircon ages characteristic of the tectonic and magmatic ages proper to the Yangtze Craton [19]. Such a dual provenance is also shown in case the invaded Yangtze sea water was spread over the Sino-Korean Craton by the marine fossils proper to the Yangtze Craton that occur mixed with plant fossils endemic to the Sino-Korean Craton [28].

Notably, the Middle Devonian-Early Carboniferous Imjin Group, N. Korea, and the Yannan Group, Shandong Peninsula of China, contain faunas that bear the marine taxa of the Yangtze Sea around the northern South China Plate [7]. The aulacogenic deposits in MPPr witnessed occasional on-land volcanisms as examplified by the Imjin Group of Korea.

During the middle Paleozoic soft collision of the two plates in the central China, their adjacency with KP was just like the situation of today. The middle Paleozoic Yeoncheon Group, the lateral extension of the Imjin Group, contains clastic zircons with radiometric ages characteristic of the South China Plate from which the clastics were derived. The Taean Formation also contains the South China-derived clastic grains, all reflecting the adjacently located South China Plate as the source area. The Middle Paleozoic Great Hiatus is now understood to reflect such a long-held adjacency of the South China Plate to the Sino-Korean Plate.

Notably, multiple (Caledonian, Hercynian and Indosinian) regional metamorphisms as shown in the radiometric signatures were recorded in the basin-fills of MPPr in Korea, such as the Imjin Group of the medial Korea and the middle Paleozoic sediments of the MOT, where the alleged peak-metamorphism of the Early Permian age may fall under the Hercynian phase [13].

The Middle Paleozoic sedimentations in MPPr were either continued upon the earlier Paleozoic sedimentary sequences or took place anew on the Precambrian rocks. But the total time span of the Middle Paleozoic sedimentations in various sedimentary basins of MPPr corresponds to the Middle Paleozoic Hiatus. Therefore the total composite sedimentary sequences form an unconformity-bounded stratigraphic unit that may be called the Sino-Korean Middle Paleozoic Hiatal Synthem.

EARLY TRIASSIC HWANGGANGNI RIFTING: RELATION WITH YSTF

In the Early Triassic, a northeastern part of MOT was abruptly rifted to form the graben-like Hwanggangni Basin (Hb in Fig. 1) in which the basin-fill underwent metamorphic deformations just after or even during deposition. Its semi-plastic deformation and low- to medium-grade metamorphisms suggest that they were done while the sediment was still watery after speedy deposition.

In about the mid-Triassic, the contact of two subbasins of OT (Tb and MOT) was changed into an east-directed thrust fault over Tb. MOT, particularly the part Hb, was intensely deformed and even underwent low- to medium-grade metamorphisms during the paroxismal mid-Triassic Songnim Orogeny. Such a differential sedimentation and tectonism made MOT, particularly Hb, highly contrasty with the Taebaeksan Basin (Tb) despite the Mesozoic tectonisms common to the whole OT.

The age of the sedimentary deposits of MOT has been debated mainly because of rarity of fossils and structural complexity [15, 16, 39, 40]. But, its pre-mid-Triassic depositional age is certain as it underwent the mid-Triassic Songnim Orogeny. Its post-Permian age is certain as its deposition, deformation and metamorphism differ entirely from the Paleozoic strata of the Korean Peninsula characterized by crustal stability. Its post-Ordovician age is constrained by the discoveries of limestone pebbles that contain the Ordovician fossils and also ca 370 Ma granitic gneiss clast from the Hwanggangni Formation [51, 72]. The same formation contains sedimentary matrix of the early Triassic isotope ages [21, 62].

The early Triassic rifting of the Hwanggangni Basin (Hb in Fig. 1) was just succeeded by the compressive disturbance of the Songnim Orogeny suggesting the basin genesis as the initial phase of the same orogeny. Apparently, a tectonic phase was composed of coeval quick extensional phase and the uplifting of the neighboring Yangtze Craton and its eastward pushing against the Korean Peninsula. Such a motion of the Yangtze Craton was ultimately motivated by the Sulu collision in the present Shandong Peninsula, China.

Regarding the cause of the rifting of the Hwanggangni Basin, I suppose that the last dextral action of YSTF in the Permian-Triassic border time may have transpressed via YSTF for MOT to initiate the Hwanggangni rifting. And then the eastward compression by the Yangtze Plate stopped the transform action of YSTF and at the same time closed and deformed the Hwanggangni Basin. The closure and the deformation of the basin was the result of the maximum eastward compression derived from the Sulu orogen.

The sedimentary deposits of the Hwanggangni Basin are of the mass-waste fluvial origin and are divided into two parts, the lower and the upper. The lower part is a dark-gray sandy-silty fluvial deposit, several hundred meters thick, that contains in its lower part the lentils of the Late Proterozoic volcanites with radiometric age of ca 750 Ma. Solely based on the contained Neoproterozoic clast, the investigators regard the Neoproterozoic age of the basin-fill. The ca 750 Ma clasts were deposited in the Triassic sediments, but ca 750 volcanisms were erupted in the Hwanggangni Basin in the occasion of the Rodinia supercontinent disruption.

The upper part of the basin-fill is composed mainly of the tillite-looking fluvial debris-flow deposits often called the pebble-bearing phyllitic rocks, about one thousand meters thick. Those two parts form an unconformity-bounded stratigraphic unit Suanbo Synthem that corresponds to the so-far known Early Triassic gap in the geologic column of the Korean Peninsula. According to the Geological Society of America Geological Time Scale [27], the Suanbo Synthem was approximately the product of 252-247 Ma interval.

A rapid rifting of the early Triassic Hwanggangni Rift (Hb in Fig. 1) was filled first by the Suanbo Synthem's lower part, the clastic strata of which record a swampy fluvial low-land where flat mass-waste chunks of Late Proterozoic volcanic rocks were gravitationally slided into the swamp deposit. The upper part of the basin-fill, the debris-flow deposits, is a fault scarp slope deposits, all deformed extremely; the pebbles (limestone, gneiss, quartzite etc.) were elongatedly deformed several times of the original diameters (Fig. 4 and 5). The Early Triasssic age and the debris-flow origin for the Hwanggangni deposits are certain despite the rheomorphic deformation and metamorphism of the Triassic deposits.

In short, the ultimate cause seems to be the Sulu collision; the Hwanggangni rifting must have been an initial syn-collisional extensional feature. Soon, the YSTF became a reverse fault in the early Triassic due to the compression; after the Hwanggangni deposition, the paroxismal Songnim Orogeny followed. Notably, the early Mesozoic geology of Korea was prevailed by an alternated block movement of MOT and Tb: MOT (Metamorphosed Okcheon Trough) lacks the Jurassic basinings with coal-bearing strata, in contrast, the Jurassic coal-fields were scattered in Tb where the early Triassic basin was lacking. Therefore, the basin genesis depended on the block movement of MOT and Tb, two crustal blocks of the OT.

RECENT DISCOVERIES OF EARLY TRIASSIC SEDIMENTARY DEPOSITS

Recently, the detrital zircons from the Sangnaeri Formation of the lower basin-fill of Hb have been studied to get the SHRIMP U-Pb ages [62]. The youngest zircon population of the Sangnaeri Formation had the concordia age of ca 260 Ma indicating the late Permian or earliest Triassic depositional age of the Sangnaeri Formation. The age data appear to support the present writer's Early Triassic depositional age of the basin-fill of the Hb. Another result of Park et al [62] was a zircon population with the Paleoproterozoic ages of ca 1860 Ma, which appears to support that Hb is located in SKP. The South Korean Tectonic Line (SKTL) by Chough et al [20] was so conceived that Hb belongs to the South China Block. But the provenance data of Park et al [62] appears to disprove SKTL as the plate boundary.

Until recently, the occurrence of the Early Triassic deposits (the Suanbo Synthem) was known only as the basin-fill of Hb. But, recently, another early Triassic sedimentary deposit (Deokjeok Formation) has been identified in a westernmost area of the medial Korean Peninsula [44]. This is the first discovered occurrence of the Suanbo Synthem elsewhere of MOT.

A metasandstone cobble in the Deokjeok Formation (a deformed conglomerate deposit) yielded detrital zircons that have given the metamorphic overgrowth dates of 255 Ma and 263 Ma. Besides, the clastic zircons gave 400 Ma, 1 and 2.5 Ga age populations; 400 Ma and 1 Ga populations suggest that the ultimate source area of the zircons was the near-by South China block beyond YSTF. As Kim et al [44] suggested, the cobble was reworked probably from the Devonian Taean Formation, where the crystal overgrowth was made. The Deokjeok Formation was metamorphosed slightly, which is a

Fig. 4. Outcrop photos of the non-marine debris-flow deposits named the Hwanggangni Formation, the upper part of the Early Triassic basin-fill of the Hwanggangni Basin in the Metamorphosed Okcheon Trough (Table 1). It has dark-gray sandy-silty matrix scattered with light-gray cobbles of the Ordovician limestone and quartzite. The rock is highly deformed showing foldings and the elongated cobbles. The texture suggests its rapid and repeated slump depositions. The hammer head is for scale (photos taken by K-H Chang near Hwanggangni village, South Korea).

Fig. 5. *Archaeocyatha* sp. collected from a talus of the so far age-unknown Hyangsanri Dolomite, which is accordingly believed to be the Early Cambrian unit. It is interpreted this Yangtze-proper fossil animal (*Archaeocyatha* sp.) was living in a seaway transgressed upon the Sino-Korean Craton.

Table 1. Paleozoic-mid-Mesozoic geologic column of Korea with particular reference to the sedimentary formations of MPPr as an unconformity-bounded unit that corresponds in age to the Great Hiatus of the Sino-Korean Craton.

Late Triassic-Jurassic
Early JURASSIC **DAEDONG SYNTHEM**
Late TRIASSIC
^^
mid-TRIASSIC Indosinian Orogeny (Songrim Tectonism)
'SUANBO Hwanggangni Fm.
Early TRIASSIC Deokjeok Fm. **SYNTHEM'** Munjuri Fm, Seochangni Fm.
252 ^^
PERMIAN Carboniferous-Permian
299----------- **PYEONGAN**
CARBONIFEROUS **SYNTHEM**
(U)
318----------- *Upper Limit of Great Hiatus*
(L) ^^
E. Carboniferous strata, Taizi River area, Liaodong, China
359--M. Devonian-E. Carboniferous Yannam Gp., Shandong, China
DEVONIAN (U) M. Devon.-E. Carbon. Imjin Gp./Yeoncheon Gp.
Devonian Taean Formation
385-----------Devonian Daehyangsan Quartzite
(M) Silurian-Devonian Ungyori Formation
397.5----------
(L)
416----------- Ordovician-Carboniferous
SILURIAN (U) **'MIDDLE PALEOZOIC**
423----------- **HIATAL SYNTHEM'**
(M) Silurian Goksan Series
428-----------
(L)
443.7----------
ORDOVICIAN (U) Late Ordovician Sangseori Series
^^
461----------- *Lower Limit of Great Hiatus*
(M)
472-----------
(L) Cambrian-Ordovician
488-----------
CAMBRIAN **JOSEON SYNTHEEM**

post-depositional metamorphism. Afterward, a granitic dyke with 225 Ma age intruded the deposit. Therefore, the age of the Deokjeok Formation (metaconglomerate) is constrained as the Early Triassic.

The Deokjeok deposition in Korea of the Sino-Korea Craton was coevally done in the Early Triassic when the Suanbo Synthem was deposited in the Okcheon Trough (see section 7). Though Kim et al [44] called the deposit post-orogenic, a metamorphism already affected the Taean Formation. The present writer reviews that the Deokjeok deposit underwent the Indosinian Songnim orogeny prior to the dyke intrusion. Therefore the age of the deposit is constrained as after the late Permian and before the Late Triassic. So, the depositional age is constrained as the Early Triassic. Only the Late-Triassic granitic dyke (225 Ma) should be really post-orogenic.

YSTF, A PROFOUND GLOBAL TECTONIC ENTITY

Prior to the recognition of YSTF, it was a fashion to try to delineate various geologic zones of China via Korea to Japan. But, not only the QDS suture but also other zones of China do not extend beyond YSTF. Ishiwatari and Tsujimori [34] extended the QDS suture to Japan. But the Yangtze Plate itself does not extend beyond YSTF. It only appeared that the QDS suture extends to the Sangun Belt, the initial Paleopacific subduction zone with the Permo-Triassic accretionary complex accompanied by high-pressure metamorphites.

Table 2. The alternated vertical movement of crustal blocks before and after the mid-Triassic transition from the Indosinian-Songnim-Akiyoshi regime to the Yanshanian-Daebo-Sakawa regime.

crustal block	Tb(Taebaeksan Basi n)	MOT(Metamorphosed OT)
Late Triassic -Jurassic Daebo Tectonic cycle *(Post-YSTF new regime)*	Sedimentary basins formed	--- ***Unconformity*** ---- (No sedimentary basi ns)
---***Unconformity*** ---^^^^**mid-Triassic**	SongnimOrogeny^^^^	---***Unconformity*** --
Early Triass ic Songnim Tect. Cycle	--- ***Unconformity*** --- (No sedimentary basins)	sedimentary basins(Hb) formed

YSTF has been so profound a transform fault that two different continental drift systems were there on both sides of YSTF; Chang and Park (2001) pointed out that YSTF was passing at the contact of the Kyushu Island and the Ryukyu Island. The geological zones of both sides of YSTF drastically differ though somewhat common; it is suggested that the circum-Pacific zonal developments were quite affected by the presence of YSTF.

Along the Paleotethyan Qinling-Dabie-Sulu suture, the occurrence of the Late Paleozoic oceanic deposits and accretionary prisms are scarcely heard. It means only a narrow, if any, Late Paleozoic opening (seaway) between the Sino-Korean and the Yangtze Plates. And soon the seaway, if any, was closed, when was the termination of the life of YSTF of the Indosinian time.

After the collisional phase of QDS zone, the post-Indosinian Mesozoic world of the East Asia appeared, an entirely new tectonic regime. In China, it was the beginning of the serial Yanshanian Movements [75, 73]. In Japan near Korea, it was the beginning of the Sakawa orogenic cycle of T. Kobayashi.

After the mid-Triassic Songnim Orogeny of Korea, the post-YSTF (that is the post-Songnim) Yanshanian regime was opened in East Asia. The post-Songnim Korea witnessed several Late Triassic-Jurassic molassic coal-bearing basinings place to place over the Precambrian basement and over the Taebaeksan Basin [38, 37]. Notably, such molassic basins were absent over MOT where, in the Early Triassic, the unique debri-flow-dominated Hwanggangni Trough was formed (shown Hb in Fig. 1).

The succeeded Late Triassic-Jurassic Korea met a new tectonic age typified by Jurassic Daebo Orogeny and the associated Daebo granite intrusions. The Early to mid-Triassic granites were typified by the syn-tectonic gneissose structures but the end-Triassic-Jurassic Daebo granites saliently lack such gneissosity.

The Indosinian-Yanshanian transition in China was controlled by the change of the global tectonic regime from the Paleotethyan suturing along the East-West collision belt into a new subduction-related tectonics in the wide East Asian continental margin facing the Pacific domain.

In the Japanese area of the Pacific, the subduction-related tectonics was already in process during the Late Paleozoic and earlier [33, 45, 32]. The Hida-Sangun metamorphic belt was formed in the Late Paleozoic, and the associated Akiyoshi accretionary complex and Yakuno ophiolite of the Late Paleozoic age were emplaced. But, what event does represent the Akiyoshi-Sakawa transition over the whole Southwest Japan is obscure, suggesting their own special geological order proper to the Asia-Pacific border regime [33, 45]. In short, the Indosinian-Akiyoshi tectonic domain was most vividly represented by the Korean Peninsula. Japanese area may have been separately a Pacific domain in the Paleozoic and thereafter. In other words, only the Hida-Sangun belt may be compared, merely nominally, to the Sulu suture zone of China [34]. In radical verse, no real extension of the QDS zone occur beyond the YSTF in Japan, just as the South China Plate no more extend to Japan beyond YSTF. So profound a global tectonic YSTF!

The mid-Triassic Songnim-Daebo transition was clear in Korea. But the Akiyoshi-Sakawa transition in the Southwest Japan was only possible at the clino-unconformity between the Sangun metamorphic zone and the overlying clastic sequence of the Late Triassic age. Such a similarity of Korea and Japan was caused probably by the geographic adjacency of the Korean Peninsula and the Hida-Sangun zone. Generally over the Southwest Japan, to draw any boundary equivalent to the Indosinian-Yanshanian transition over the Late Paleozoic accretaionary complex and the ophiolite complex is obscure.

The Sangun-Yamaguchi zone of the Akiyoshi-Honshu cycle in the Southwest Japan is nominally comparable with the QDS zone of China. It comprises the Late Paleozoic Sangun high-pressure metamorphic belt, the Late Paleozoic Akiyoshi accretionary complex and Yakuno ophiolites, but no occurrence of UHPM rocks and abundance of accretionay complex symbolize the difference with the QDS zone of China. Rather, the Japanese zone may be regarded as an initial circum-Pacific subduction zone adjacent to East Asian margin. Incidentally, the geology of the Korea-Japan strait area may have been considerably destroyed and carried away northeastwardly by the extensive Cretaceous sinistral faults.

In conclusion, YSTF was so profound a global tectonic entity that the South China Plate and the associated Qinling-Dabie-Sulu zone were confined to occur only to the west of YSTF. Obviously YSTF was passing at the contact between the Kyushu Island and the Ryukyu Island but the tectonic zones are laterally continuous but differentially, suggesting that they were totally under an independent Pacific order despite the intervention of YSTF [10]. The present writer trusts that the science of YSTF should draw more attention in pursuing the global tectonic history of East Asia.

SUMMARY

The Yellow Sea floor occupied by the South China Plate suggests its great fault boundary with the Korean Peninsula (KP) of the Sino-Korean Plate (SKP). Based on the fact of the confined Sulu suture that abruptly discontinued to KP, the Yellow Sea Transform Fault (YSTF) was conceived, which genetically made KP exempted from being extended from the Sulu suture. The geometry of YSTF is suggestive of KP as a promontory of SKP. The history both of YSTF and the Korean promontory has been traced in this study to probe their probable mid-Proterozoic origin.

YSTF explains why the Qinling-Dabie-Sulu (QDS) ultrahigh-pressure metamorphic (UHPM) zone does not extend to KP. After the Triassic syn-orogenic eastward dislocation, some clock-wise rotation (ca 30 degrees as shown in Fig. 1.) and deformations, YSTF is now found as WMF (West Marginal Fault), a submarine fault zone off the west coast of South Korea [31].

The Indosinian Songnim Orogeny of Korea and the Sulu collision as manifest in the Shandong Peninsula of China were neatly coincided in ca 240–220 Ma suggesting their genetic relation. The agent of their coevality was the eastward compression of the northern margin of the South China Plate. Apparently, the collisional energy of the Dabie-Sulu orogen was released eastwardly via Yangtze Plate because YSTF was in the east end of the Paleotethian suture zone. In short, the N-S compression was partly transferred to the E-W compression released toward the South Korean side. That was a derived, secondary, collisional orogeny, the Songnim Orogeny. The orogeny was a confined orogeny, KP being inserted between the eastwardly compressed YSTF and the counter-balancing subduction-related Hida-Sangun pair and the associated pre-Jurassic accretionary prism of the Pacific Japan. Because of a mild counter compression from the Japanese side, the Korean Peninsula suffered the Triassic Songnim Orogeny quite effectively.

A review of the reports on the QDS suture zone of China has convinced the writer to assume the multiple QDS suturing-collision as the ultimate source for the polycyclic tectonics of the Korean Peninsula. The repeated plate collisions in China from the Proterozoic Rodinia Supercontinent assembly to the Triassic Indosinian collision left geologic records and radiometric signatures in Korea across YSTF.

Because of YSTF, the Korean Peninsula has been a promontory of the SKP since the time of the dispersion of the Columbia supercontinent in about 1.4 Ga ago. The YSTF, a long-lived transform fault, is envisioned to have had the repeated role of the post-transform collisional front: in ca 1 Ga (Rodinia assembly), in Silurian-Devonian (Caledonian soft collision), in Permo-Carboniferous (Hercynian/Variscan phase) and finally in the intensive Indosinian collision during the early to mid-Triassic time.

In the Southwest Japan, Kobayashi (1941) defined his Akiyoshi orogenesis based on the angular unconformity of the mid-Triassic age and correlated it with the Songnim Orogeny of Korea. As geological investigations advanced, a wide occurred Late Paleozoic-early Triassic accretionary complex of the Akiyoshi reef limestone and the ophiolitic Yakuno ultrabasic rocks has been known to be associated with the Late Paleozoic Hida-Sangun metamorphic belts, which altogether would be only nominally the extension of the QDS Suture-collision zone [34]. But the Japanese zone appears to be the early tectonic phase of the circum-Pacific subduction-related tectonic series along the East Asian margin. To the present writer, YSTF was so profound an active fault that no South China Plate nor extension of the Chinse QDS zone could occur beyond YSTF.

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REFERENCES

1. An, T. S. and Zheng, Z. C. The conodonts around the Erduoshi Basin: Science Press, Beijing, 1990. 201 p.
2. An, T. S. and Ma, W. P. Middle Ordovician-Lower Carboniferous of Sino-Korean Platform and its paleogeography and structural significance // Earth Science. 1993. 18 (6). P. 777–791.
3. Burke, K. C. and Wilson J. W. Hot Spots on the Earth's Surface // Scientific American. 1976. V. 235. P. 46–57.

4. CAGS Inst. of Geol. Explanatory Text of Geologic Map of Dabie-Sulu Orogenic Zone. Geol. Publishing Co., Beijing, 1993. 77 p.
5. Chang K.-H. Aspects of Geologic History of Korea // Journal of Geological Society of Korea. 1995. V. 31. P. 72–90.
6. Chang K.-H. Paleozoic Yellow-Sea Transform Fault and Mesozoic Korea // Geosciences Journal. 2000. V.4. P. 4–6.
7. Chang K. H. Metamorphic Okcheon Zone: Fossil Discoveries and Geologic History // Journal of Paleontological Society of Korea. 2008. V. 24. P. 149–164.
8. Chang K. Middle Paleozoic Sedimentary Province within Sino-Korean Plate: Paleogeographic Implication for Okcheon metamorphic Zone // Journal of the Geological Society of Korea. 2013. V. 49, N. 4. P. 437–452.
9. Chang K. H. and Park B. S. Occurrence and Significance of Trace Fossil *Chondrites* from Age-debated Dark Gray Low-grade Metamorphic Argillaceous Rock of Ogcheon Supergroup, Southern Korea // Journal of Geological Society of Korea. 1977. V.13 P. 263–266.
10. Chang K.-H. and Park S.-O. Paleozoic Yellow Sea Transform Fault // Its Role in the Tectonic History of Korea and Adjacent Regions: Gondwana Research. 2001. V. 4. P. 588–589.
11. Chang K.-H. and Zhao X. North and South China Suturing in the east end // What happened in Korean Peninsula?: Gondwana Research. 2012. V. 22. P. 493–506.
12. Cheong C. H., Lee H. Y., Koh I. S. and Lee J. D. Lower Paleozoic Stratigraphy and Sedimentary Environment // Korean Academy Proceedings. 1979. V. 18. P. 123–169.
13. Cheong C. S., Jeong G. Y., Kim H., Lee S. H., Choi M. S. and Cho M. Early Permian peak metamorphism recorded in U-Pb system of black slates from the Ogcheon metamorphic belt // S. Korea, and its tectonic implication: Chemical Geology. 2003. V. 193. P. 81–92.
14. Cho D.-L., Kwon S.-T., Jeon E.-Y. and Armstrong R. SHRIMP U-Pb ages of metamorphic rocks from the Samgot unit, Yeoncheon complex in the Imjingang belt, Korea: implications for the Phanerozoic tectonics of East Asia. Geol. Soc. America Abstracts with Programs, Salt Lake City, 2005. 388 p.
15. Cho M. and Kim H. Metamorphic evolution of Middle Okcheon Metamorphic Belt // Review of recent study and remaining problems: Journal of Petrological Society of Korea. 2002. V. 11. P. 121–137.
16. Cho M., Kim T. and Kim H. SHRIMP U-Pb zircon age of felsic tuff of Metamorphic Okcheon Belt: Neoproterozoic volcanismca 0.75 Ga // Journal of Petrological Society of Korea. 2004. V. 13. P. 119–125.
17. Cho M., Cheong W. and Kim J. Geochronologic vs. lithotectonic subdivision of central Ogcheon Metamorphic Belt, Korea: Correlation with the Taean Formation and detrital zircon ages of the Hwanggangri Formation: 2010 Joint Conference of Geological Sciences Societies Abstract. 2010a. 61 p.
18. Cho M., Na J. and Yi K. SHRIMP U-Pb ages of detrital zircons in metasandstones of the Taean Formation, western Gyeonggi massif, Korea: Tectonic implications // Geosciences Journal. 2010b. V. 14. P. 99–109.
19. Cho M., Cheong W., Ernst W. G., Yi K. and Kim J. SHRIMP U-Pb ages of detrital zircons in metasedimentary rocks of the central Ogcheon fold-thrust belt, Korea: Evidence for tectonic assembly of Paleozoic sedimentary protoliths // Asian Earth Sciences. 2013. V. 63. P. 234–249.
20. Chough S.K., Kwon S.-T., Ree J.-H. and Choi D. K. Tectonics and sedimentary evolution of the Korean peninsula: a review and new view // Earth-Science review. 2000. V. 52. P. 175–235.
21. Cliff R.A., Jones G., Choi W.C. and Lee T.J. Strontium Isotope Equilibrium during Metamorphism of Tillites from the Okcheon Belt, South Korea // Contributions to Mineralogy and Petrology. 1985. V. 90. P. 346–52.
22. Cluzel D., Cadet J.-P. and Lapierre H. Geodynamics of the Ogcheon Belt South Korea // Tectonophysics. 1990. V. 183. P. 41–56.
23. Dong Y., Liu X., Neubauer F., Zhang G., Tao N. and Zhang Y. Timing of Paleozoic amalgamation between the North China and South China Blocks: Evidence from detrital zircon U-Pb ages // Tectonophysics. 2013. V. 586. P. 173–191.
24. Faure M., Lin W., Monie P., Meffre S. Paleozoic collision between the North and South China blocks, Triassic intracontinental tectonics, and the problem of the unltrahigh-pressure metamorphism. C. R. Geoscience. 2007. V. 340. P. 139–150.
25. Faure M., Shu L., Wang B., Charvet J., Choulet F. and Monie P. Intracontinental subduction: a possible mechanism for the Early Paleozoic Orogen of SE China // Terra Nova. 2009. V. 21. P. 360–368.
26. Gao S., Zhang B., Gu X., Xie Q., Gao C., Guo X. Silurian-Devonian provenance changes of South Qinling basins: implications for accretion of the YangtzeSouth China to the North China craton // Tectonophysics. 1995. V. 250. V. P. 183–197.
27. Geological Society of America. Geologic Time Scale. compiled by Walker et al., 1 sheet. 2012.
28. Geological Society of Korea. Geology of Korea. Sigma press, Seoul. 1998. 802 p.
29. Glebovitsky V.A., Sedona I.S., Buchmin S.A., Vapnik Ye.A. and Buiko A.K. Granulites of Northern Korea // Journal of Petrological Society of Korea. 1994. V. 3 P. 196–219.
30. Hacker B.R., Wang X., Aide E.A., Ratschbacher L. , The Qinling-Dabie UHP collisional orogen. in Tectonic Evolution of Asia ed. by A. Yin and T.M. Harrison pp. 345–370, Prentice-Hall. 1996.
31. Hao T.-Y., Suh M., Liu J., Xu Y., Zhang L., Xu Y. and Liu G. Geophysical study of the location of boundary between Sino-Korean and Yangtze Blocks in Yellow Sea and adjacent area: 2005 Conf. Ser. Intern. Assoc. Gondwana Research, China. 2005. P. 1–3.
32. Hashimoto M., ed. Geology of Japan. 249 pp, Terra Scientific Publ. Co. Tokyo, 1991.
33. Ichikawa K., Mizutani S., Hara I., Hada S., Yao A. ed. Pre-Cretaceous Terranes of Japan. Publication of IGCP No 224Pre-Jurassic Evolution of Eastern Asia., Osaka, 1990.
34. Ishiwatari A., and Tsujimori T. Paleozoic ophiolites and blueschists in Japan and Russian Primoriye in the tectonic framework of East Asia // A synthesis. The Island Arc. 2003. V. 12. P. 190–206.
35. Jeon H., Cho M., Kim H., Horie K. and Hidaka H. Early Archean to Middle Jurassic Evolution of the Korean peninsula and Its Correlation with Chinese Cratons: SHRIMP U-Pb Zircon Age Constraints // The Journal of Geology. 2007. V. 115. P. 525–539.
36. Ji Z. and Zhao H. New evidence for the age of the Penglai Group in eastern Shandong // Journal of Stratigraphy. 1992. V. 16, N 3. P. 237–238.

37. Kim D. S. Geology of Korea // Science Encyclopedia Publishing Company. 1987. P. 58–85.
38. Kim Jeong Hwan. Mesozoic Tectonics in Korea // Jour. SE Asian Earth Sci. 1996. V. 13. P. 251–265.
39. Kim Jong Hwan. Caledonian Ogcheon Orogeny of Korea with special reference to the Ogcheon uraniferous marine black slate: Doctoral thesis, University of Tokyo, 1987. 208 p.
40. Kim M.J., Park G.H., Park Y.J. and Choe J.E. SHRIMP U-Pb zircon ages of Gyemyeongsan Formation, Chungju, Korea: Mineralogical Society of Korea and Petrological Society of Korea, Joint Meeting Proceedings. 2011. 51 p.
41. Kim S.W., and Kee W.S. Geochronology and Geochemical characteristics of metavolcanics from the Weolhyeonri tectonic complex in the Hongseong area, SW Gyeongg Massif // Journal of Geological Society of Korea. 2010. V. 46, N 5. P. 453–471.
42. Kim S.W., Kee W.S., Lee S.R., Santosh M., Kwon S. Neoproterozoic plutonic rocks from the western Gyeonggi massif, South Korea: Implications for the amalgamation and break-up of the Rodinia supercontinent. Precambrian Research. 2013a. V. 227. P. 349–367.
43. Kim, S. W., S. Kwon, K. Yi, M. Santosh, 2013b, Arc magmatism in the Yeongnam Massif, Korean Peninsula: Imprints of Columbia and Rodinia Supercontinents. Gondwana Research
44. Kim Y., Aum H., Cheong W., Kim T., Yi K. An occurrence of the post-orogenic Triassic strata on Deokjeok Island, western Gyeonggi Massif, Korea // Geosciences Journal. 2014. V. 18, N 2. P. 135–147.
45. Kimura T., Hayami I., Yoshida S. Geology of Japan. Univ. of Tokyo Press, 1991. 287 p.
46. Kobayashi T. The Sakawa orogenic cycle and its bearing on the origin of the Japanese Islands // J. Fac. Sci., Univ. of Tokyo. 1941. Sec. 2. P. 219–578.
47. Kobayashi T. Geology of South Korea with special reference to the Limestone Plateau of Kangwondo // Jour. Fac. Sciences, Univ. Tokyo. 1953. Section II, V. III, part 8. P. 145–293.
48. Kobayashi T. The Chosen Group of South Korea: The Cambro-Ordovician Formations and Faunas of South Korea. Part X. Section A // Jour. Fac. Sci. University of Tokyo. 1966. Section II, V. XVI, part 1. 84 p.
49. Lee D. J., Un J. G. and No H.P. Silurian System of the Sino-Korean Craton // Global Geology. 2006. V. 25, N. 4, P. 323–331.
50. Lee D.J., Choi Y.M., Lee D.C., Lee J.G., Kwon Y.K., Cao L. and Chou S.J. Upper Ordovician and Silurian deposits in the Pyeongnam Basin: Songnim Conglomerate and its paleogeographic implication // Journal of Geological Society of Korea. 2013. V. 49, N. 1. P. 5–15.
51. Lee D.S., Chang K.H. and Lee H.Y. Discovery of Archaeocyatha in the Hyangsanri Dolomite of the Okcheon Supergroup and its significance // Journal of Geological Society of Korea. 1972. V. 8, N 4. P. 191–197.
52. Lee H.Y. Discovery of Silurian conodont fauna from South Korea // Jour. Geol. Soc. Korea. 1980. V. 16. P. 114–123.
53. Lee J., Lee H., Yu K., Lee B. Discoveries of microfossils from limestone pebbles of the Hwanggangni Formation and their significance // J. Geol. Soc. Korea. 1989. V. 25, N 1. P. 1–15.
54. Lee Y., Cho M., Cheong W. and Yi K. A massif-type 1.86 Ga. anorthosite complex in the Yeongnam Massif, Korea: late-orogenic emplacement associated with the mantle delamination in the North China Craton // Terra Nova. 2014. P. 1–9.
55. Li Juknam, and Won Hyongchan. Volcanism and Mineralization of the Devonian Rimjin Group, Gangnyeong area, North Korea: Geological Sciences. 1992. V. 162, N 2. P. 5–9. Science Publisher.
56. Li Juknam. On the Rimjin Group developed in the central part of Korea: Geological Sciences, 1993. N 5. P. 2–9.
57. Liu X., Jahn B., Li S., Liu Y. U-Pb zircon ages and geochemical constraints on tectonic evolution of the Paleozoic accretionary orogenic system in the Tongbai orogen, central China // Tectonophysics. 2013. V. 599. P. 67–88.
58. Lyang, T. J., Liu Y., Yang J. H., Kim H., Han R. Y., and Kim J. N., 2009, Precambrian crustal evolution in Rangrim Massif, Korean Peninsula. Global Geology 122., 57–63.
59. Metcalfe, I., ed., 1999, Gondwana Dispersion and Asian Accretion. Balkema Co., 361 pp.
60. Mi Jiarong, Jin Jianhua, Gao Lianda. Research on the Paleoecology and Paleoenvironment of Early Carboniferous Flora from the Taizi River Valley in Eastern Liaoning Province, Geological Publishing House, Beijing, 2001. 124 p. and XVl Plates.
61. Na J., Kim Y., Cho M. and Yi K. SHRIMP U-Pb Ages of Detrital Zircons from Metasedimentary Rocks in the Yeungheung-Seonjae-Daebu Islands, Northwestern Gyeonggi massif // Petrological Society of Korea. 2012. V. 21, N 1. P. 1–45.
62. Paik Y. J. ed. Geology of Korea: Foreign Language Publisher, Pyeongyang, 1993. 619 p.
63. Pak Y.S. and Kang J.G. On Fauna of Koksan Series Lower-Early Upper Silurian // Chijilkwahak. 1991. N 6. P. 35–40.
64. Park K.-H., Yang Y.-S. and Yi K. Formation ages of the Sangnaeri Formation and Baekhwari amphibolites of the Okcheon metamorphic belt, Mungyeong area: evidence from SHRIMP U-Pb zircon ages// Jour. Geol. Soc. Korea. 2011. V. 47, N 2. P. 155–164.
65. Park K.-H., Lee T.H. and Yi K.U. SHRIMP U-Pb ages of detrital zircons of Daehyangsan Quartzite, Okcheon Metamorphic Zone // Jour. Geol. Society of Korea. 2011. V. 47, N 4. P. 423–431.
66. Park Y.S. On brachiopod fossils discovered from pebbles of the Songrim Conglomerate // Geology and Geography. 1966. V. 2. P. 12–20.
67. Park Y.S. On brachiopod fossils discovered from pebbles of the Songrim Conglomerate and their geologic age. Geology and Geography. 1967. V. 3. P. 26–33.
68. Park U.K. Characteristics of the Sedimentary Rocks of the Rimjin System Distributed in the Kumchon-Tosan-Kaesong Areas // Chijilkwahak. 1993. N 5. P. 17–22.
69. Ren J., Baogui N. and Zhigang L. Microcontinents, Soft Collision and Polycyclic Suturing // Continental Dynamics. 1996. V. 1, N 1. P. 1–9, Institute of Geology, CAGS.
70. Sagong H., Cheong C.-S., Kwon S.-T. Paleoproterozoic orogeny in South Korea: evidence from Sm-Nd and Pb step leaching garnet ages of Precambrian basement rocks // Precambrian Research. 2003. V. 122. P. 275–295.
71. Shandong Geological and Mineralogical Survey. Lithostratigraphy of Shandong Prefecture. China University of Geology Press, 1996. 328 p.
72. Son C.M. On Geologic Age of the Okcheon Group // Journal of Korean Inst. of Mining Geology. 1970a. V. 3, N 1. P. 9–16.
73. Son C.M. Discussion on Geologic Age of the Okcheon Group // Journal of Korean Inst. of Mining Geology. 1970b. V. 3, N 4. P. 231–244.
74. Suzuki K., Dunkley D., Adachi M., Chwae U. Discovery of a

c.370 Ma granitic gneiss clast from the Hwanggangri pebble-bearing phyllite in the Okcheon metamorphic belt, Korea // Gondwana Research. 2006. V. 9. P. 85–94.
75. Wan T. F. The Tectonics of China. Higher Education Press, Beijing, 2010. 501 p.
76. Wang H. ed. Atlas of Paleogeography of China: Cartographic Publishing House, Beijing, 1985. 143 sheets and explanations.
77. Yang Z., Yuqi C. and Wang H. The Geology of China. Oxford University Press, 1986. 303 p.
78. Yin A. and Nie S. An indentation model for the North and South China collision and the development of the Tan-Lu and the Honam Fault Systems, Eastern Asia // Tectonics. 1993. V. 124. P. 801–813.
79. Zhai MingGuo, Guo J., Li Z., Chen D., Peng P., Li T., Hou Q., Fan Q. Linking the Sulu belt to the Korean Peninsula: Evidence from eclogite, Precambrian basement, and Paleozoic sedimentary basins // Gondwana Research. 2007. V. 12. P. 388–403.
80. Zhai MingGuo. The main old lands in China and assembly of Chinese unified continent. Science China // Earth Sciences, 2013. doi: 10007/s11430-013-4665-7.
81. Zhai X.M., Day H.W., Hacker B.R. et al. Paleozoic metamorphism in the Qinling orogen, Tongbai Mountains, Central China // Geology. 1998. V. 264. P. 371–374.
82. Zhang GW, Zhang BR, Yuan XC et al. Qinling Orogenic Belt and Continental Dynamics. Beijing: Science Press, 2001. 1-855in Chinese with English abstract..
83. Zhao Guochun, Cawood P.A., Sangjhong Li, Wilde S.A., Sun M., Zhang J., Y. He, Yin C. Amalgamation of the North China Craton: Key issues and discussion // Precambrian Research. 2012. P. 222–223, 55–76.
84. Zhu G., Xu J., Fitches W.R. and Fletcher C.J.N. Isotopic Ages of the Penglai Group in the Jiaobei Belt and Their Geotectonic Implications // Acta Geologica Sinica. 1994. V. 7, N 4. P. 417–433.

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Трансформный разлом Желтого моря (ТРЖМ) и эволюция Корейского полуострова

Трансформный разлом Желтого моря, являющийся границей между Корейским полуостровом и Южно-Китайской плитой, представляет неоднократно реактивированный древний разлом, существовавший более 1 млрд лет назад или более. Аналогичным образом полицикличные континентальные коллизии по Циньлин-Дабе-Сулу (ЦДС) сутуре ограничивали (латеральное) векторное влияние коллизии к востоку от Корейского полуострова по трансформному разлому Желтого моря, восточной оконечности Циньлин-Дабе-Сулу пояса. Корейский полуостров, существовавший вместе с трансформным разломом Желтого моря, являлся мысом Сино-Корейской плиты (СКП), по крайней мере, с ассамблеи Родиния, приблизительно 1 млрд лет. Раннепалеозойское рифтогенное происхождение прогиба Окчеон, главного авлакогена, развитого в пределах Корейского полуострова Сино-Корейской плиты, объясняется трансформной ролью ТРЖМ. В среднем палеозое плита Янцзэ, составная часть Южно-Китайской плиты, смещала Сино-Корейскую плиту столь мягко и продолжительное время, что Сино-Корейская плита образовала позднеордовик-раннекаменноугольный большой перерыв на всей кратогенной Сино-Корейской плите. В это же время на территории около трансформного разлома Желтого моря образовались кластерные авлакогены. Предполагается, что в среднем палеозое сжатая часть Сино-Корейской плиты движущейся на восток плитой Янцзы образовала протяженную верхнюю кору, на которой возникли авлакогены. Море Янцзы заполнило авлакогены, в обломочных осадках смешанной обстановки которых преобладал привнос осадков плиты Янцзы, о чем свидетельствуют обломочные зерна циркона, показывающие сходные с плитой Янцзы изотопные датировки. Развитие среднепалеозойского большого перерыва и кластерных авлакогенов представляет каледонскую тектоническую фазу, хотя она вряд ли сопровождала деформацию или орогенез. Каменноугольно-пермский метаморфизм в среднепалеозойских авлакогенах представляет герцинскую (варисцийскую) фазу орогении, но без видимых структурных деформаций. Самая глубокая субдукция и интенсивная коллизия плиты Янцзы по палеотетической сутуре произошли в конце перми – середине триаса, в индосинийскую фазу. Одновозрастная орогения Соним в Корее была так же интенсивна, хотя и была дериватной, вторичной, орогенией, окончательно распространившейся от Циньлин-Дабе-Сулу пояса коллизии. В результате сжатия с востока, вызванного Циньлин-Дабе-Сулу поясом коллизии, трансформный разлом Желтого моря был так деформирован и значительно продвинут на восток, что в настоящее время он представляет деформированную дислоцированную зону разлома, называемую Западным окраинным разломом Корейского полуострова (ЗОР, рис. 1). Расположение Корейского полуострова в среднем триасе было определено между сокращающейся к востоку окраинной плитой Янцзы и противоуравновешивающим пермо-триасовым субдукционно-метаморфическим-аккреционным комплексом японской Пацифики. Такая многослойная тектоника практически усиливала индосинийскую Соним орогению в Корее.

Ключевые слова: **Сино-Корейская плита, Корейский полуостров, траснформный разлом Желтого моря, Индосинийский тектонизм, Циньлин-Дабе-Сулу сутура, Соним орогения, привнесенный (вторичный) орогенез.**