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Doctorate Degree Dissertation

The Evolution of the Cretaceous Basins in the Korean Peninsula

Graduate School of Chosun University

Department of Advanced Energy Resource Engineering

Lujia Pan

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한반도 백악기 분지의 진화

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Advisor: Prof. Seongseung Kang

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Department of Advanced Energy Resource Engineering

Lujia Pan

반로가의 박사학위논문을 인준함

위원장 한국교원대학교 부교수 최 태 진 (인)

위 원 조선대학교 부교수 장 일 식 (인)

위 원 조선대학교 조교수 박 준 규 (인)

위 원 광주전남연구원 연구원 노 정 두 (인)

위 원 조선대학교 교 수 강 성 승 (인)

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조선대학교 대학원

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ABSTRACT

The Evolution of the Cretaceous Basins in the Korean Peninsula

Lujia Pan
Advisor: Prof. Seongseung Kang
Dept. of Advanced Energy Resource Engineering
Graduate School of Chosun University

The detrital zircon geochronology of the Cretaceous basins was analyzed to elucidate their response to the oceanic plate subduction to the East Asian continental margin. These four basins are the nonmarine subbasins located in the marginal Okcheon Belt of the Korean Peninsula, formed by its sinistral strike-slip movement due to the oblique subduction of the Paleo-Pacific plate. The Cretaceous subbasins deposited sediments in terrestrial environments with associated volcanism until they were closed in the late Cretaceous due to the orthogonal subduction of the oceanic plate. A total of 1357 ages obtained from 1901 zircon grains reveal that the maximum depositional ages of the Eumseong, Gongju, Haenam, and Yeongdong basins are ca. 103 Ma, 108 Ma, 79 Ma, and 107 Ma, respectively. The detrital zircon age spectra of the Eumseong, Gongju, and Yeongdong basins indicate that their basin fills were mainly derived from the adjacent basement rocks comprising Paleoproterozoic metamorphic rocks and Jurassic, Triassic granitoids with a minor supply from the Paleozoic metasedimentary rocks in the of the western Gyeonggi Massif and Okcheon Metamorphic Belt. On the contrary, the Haenam Basin sediment was derived from syn-sedimentary porphyritic rock and the adjacent basement rock comprising Paleoproterozoic metamorphic rocks and Jurassic and Triassic granitoids. The conglomerates in the uppermost parts of the Eumseong and Gongju basins were supposed to be deposited in the Late Cretaceous to Paleogene time, suggesting the reactivation of the boundary faults of the Okcheon Metamorphic Belt in the latest stage of the basin evolution; the tuff and arkose in the upper part of the Haenam and Yeongdong basins, indicating sudden intensification of basin volcanism in late Cretaceous, probably influenced by the changes in the subduction of the Paleo-Pacific plate.

Key words: LA-MC-ICPMS, Korean Peninsula, Cretaceous basins, detrital zircon age, U-Pb dating

초 록

한반도 백악기 분지의 진화

반로가

지도교수: 강성승

첨단에너지자원공학과

조선대학교

본 연구는 한반도 백악기 퇴적분지의 쇄설성 저어콘 연대 측정을 통해 당시 동아시아 대륙 연변부에 대한 해양판 섭입에 따른 이들의 반응을 규명하였다. 연구 대상인 4개의 분지는 한반도 옥천변성대에 위치한 육상 소분지로 고태평양 판이 대륙 경계에 비스듬한 방향으로 섭입함에 따라 발생한 좌수향 주향이동운동에 의하여 형성되었다. 이들 소분지는 육상 퇴적환경에서 화산활동을 수반하며 백악기 후기에 해양판의 섭입 방향이 경계에 직각방향으로 바뀔 때까지 퇴적물이 충진되었다. 1901 개의 저어콘 입자에 대하여 측정한 1357점의 연령을 통해 추정한 음성, 공주, 해남, 영동 소분지의 최대 퇴적시기는 각각 130 Ma, 108 Ma, 79 Ma, 107 Ma이다. 음성, 공주, 영동 소분지에서 얻은 쇄설성 저어콘 연령 스펙트럼에 따르면 분지 충전물은 주로 인접한 기반암인 고원생대 변성암과 쥐라기, 트라이아스기 화강암, 그리고 서부 경기육괴와 옥천 변성대에서 유래한 고생대 변성 퇴적암으로부터 유래하였다. 이에 반해, 해남 소분지 충전물은 주로 퇴적동시성 반상화산암과 인접한 기반암인 고원생대 변성암과 쥐라기 및 트라이아스기 화강암으로부터 유래하였다. 음성과 공주 소분지 최상부 역암은 백악기 후기부터 고제3기

사이에 퇴적된 것으로 추정되며, 이는 옥천 변성대의 경계 단층이 분지 진화의 최후 단계에서 다시 활성화되었음을 시사한다. 해남과 영동 소분지 상부에서 보이는 응회암과 장석사암은 이들 퇴적분지가 백악기 후기에 고태평양 판의 섭입방향 변화에 영향을 받아 화산 활동이 발생하며 형성된 것으로 추정된다.

핵심주제어: LA-MC-ICPMS, 한반도, 백악기 소분지, 쇄설성 저어콘 , U-Pb 연대

I. Introduction

The development of the Cretaceous sedimentary basins in East Asia is interpreted to have been a response to the Paleo-Pacific (Izanagi) plate subduction beneath the Eurasian continent. In the Chinese continent, the extensive rifting after the Jurassic regional contraction developed rift basins of various types with sporadic volcanism migrating eastward (Meng et al., 2022 and references therein). On the contrary, the Cretaceous basins in the East Asian continental margin are known to be formed as strike-slip basins associated with the oblique (northwestward) subduction of the Izanagi Plate. The development of these basins was well elucidated as three stages of formation, sedimentation with volcanism, and basin closing (Kim et al., 2015; Kwon et al., 1994; Ryang, 2013a, b; Song et al., 1990). They were formed by the reactivation of the pre-existing faults in the Korean Peninsula during the Early Cretaceous and the sediments were accumulated in nonmarine depositional environments with volcanism in an active continental margin setting (Chough, 2000; Chough and Sohn, 2010; Lee, 2002). The sedimentation continued until these basins were closed due to basin inversion caused by the changes in the subduction direction of the Paleo-Pacific plate in the Late Cretaceous (Choi and Lee, 2011; Lee, 1992a; Lee, 1992b; Liu et al., 2017; Peng et al., 2021 amongst others).

The Eumseong, Gongju, Haenam, and Yeongdong basins are the Cretaceous nonmarine subbasins located in the marginal Okcheon Metamorphic Belt of the Korean Peninsula. The depositional ages and the changes in their provenance can provide information of the timing of their development stages, which are essential to the changes in the tectonic environment of the East Asian continental margin. Thus, I analyzed the U-Pb ages of the detrital zircon grains in the sediments of four basins using LA-MC-ICPMS (Laser Ablation Multicollector Inductively Coupled Plasma Mass Spectrometer) to constrain their depositional period and to elucidate their provenance. The U-Pb isotope system of zircon crystal is essentially stable, and they resist physical and chemical degradation. Detrital zircon grains also survive sediment transport (Bruguier et al., 1997). Consequently, zircon age populations can be used to trace provenance and reconstruct Paleotectonic evolution that has resulted from sedimentary rocks (Leier et al., 2007; Ross et al., 1992).

II. Geological setting

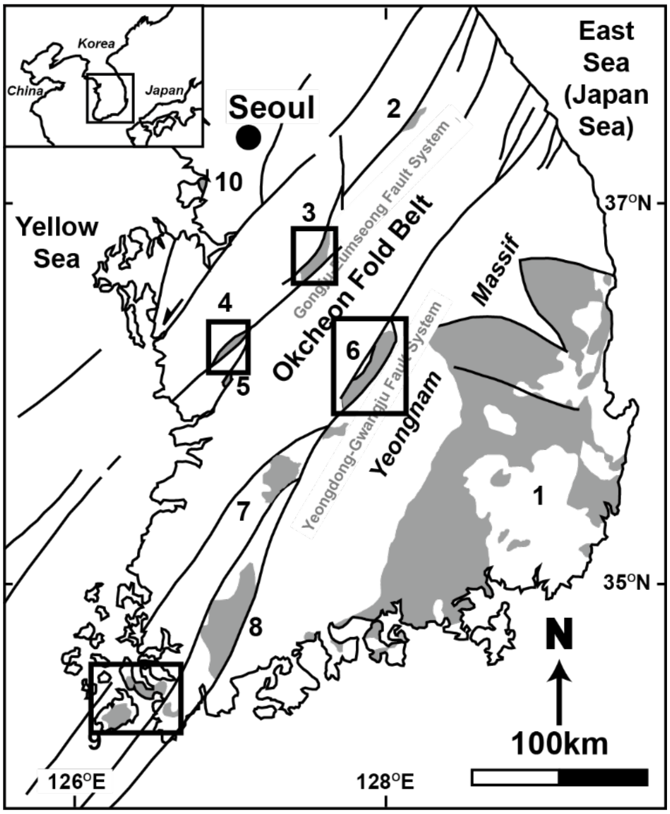


Figure 1 The distribution of the Cretaceous basins in the southern Korean Peninsula modified from Lee (2002). 1, Gyeongsang basin; 2, Pungam Basin; 3, Eumseong Basin; 4, Gongju Basin; 5, Buyeo Basin; 6, Yeongdong Basin; 7, Jinan Basin; 8, Neungju Basin; 9, Haenam. Black squares from top to bottom represent Figure. 2, Figure. 3, Figure. 4 and Figure 5.

The Korean Peninsula is located at the East Asian continental margin. It comprises three Precambrian Massifs (Nangrim, Gyeonggi, and Yeongnam Massifs from north to south), two metamorphic belts (Imjingang and Okcheon fold belts, respectively) between the Massifs, and several small nonmarine sedimentary basins formed in the southwest of the peninsula, while a large nonmarine sedimentary basin named Gyeongsang Basin formed in the southeast (Fig. 1). As a result of sinistral, brittle shearing along several strike-slip fault bends and stopovers, these small basins were formed in the late Cretaceous when the Izanagi plate changed direction of motion, leading to orthogonal subduction against the Asian continent (Chough, 2000; Chun, 1992; Lee, 2002; Okada, 2000; Ryang, 1997). In terms of the formation of the Cretaceous basins in east of the Eurasian Plate, some researchers attribute it to the activity of the plume and subduction-related magmatism (Kim et al., 2012; Okada, 2000; Safonova and Santosh, 2014; Yarmolyuk et al., 2019). During the early Cretaceous, the subduction of the paleo-Pacific plate to the north and northwest led to the formation of the pull apart basins and the generation of large-scale magmatism related to the plume activity, while the orthogonal subduction of the Pacific Plate in the Late Cretaceous caused island arc magmatism, which closed the Cretaceous back arc basin on the East Asian continental margin.

The Okcheon Metamorphic Belt is distributed to the northwest of the Yeongnam Massif, which is further divided into the Taebaeksan Basin, a Paleozoic sedimentary basin in the northeast, and the Okcheon Metamorphic Belt in the southwest. The sedimentary sequences of the Taebaeksan Basin consist of the Cambrian–Ordovician Joseon Supergroup and the Carboniferous–Permian Pyeongan Supergroup. On the other hand, the Okcheon Metamorphic Belt is composed of Neoproterozoic metavolcanic rocks, Paleozoic and age-unknown metasedimentary rocks (Cho et al., 2013; Kim et al., 2006; Lee et al., 1998; Park, 2011). To the northwest of the Okcheon Belt, a Jurassic granite belt, and the Gyeonggi Massif composed mainly of Paleoproterozoic metamorphic rocks are distributed. Recently, rocks of Paleozoic and Neoproterozoic ages similar to the Okcheon Metamorphic Belt have been reported several times (Han et al., 2017; Kim et al., 2017b; Park et al., 2017) from inside and around Gyeonggi Massif.

The Gyeonggi Massif is mainly composed of Paleoproterozoic ortho-and paragneisses formed at ca. 1.9-1.8 Ga (Lee et al., 2014; Oh et al., 2015). Recent studies (Cho, 2007; Kim et al., 2013; Kim et al., 2019; Park et al., 2017 amongst others) reported Neoproterozoic and Paleozoic metasedimentary and metaigneous rocks in the Gyeonggi Massif. The Okcheon Fold Belt is known to be formed as an intraplate rift comprising Neoproterozoic metavolcanic and Paleozoic metasedimentary rocks (Cho et al., 2013; Cho and Kim, 2005). The Yeongnam Massif is a Paleoproterozoic metamorphic terrane bounded by the Okcheon Fold Belt to the northwest. The Massif is consisting of gneiss complexes metasedimentary rocks, granite gneiss, schist, quartzite, and calc-silicate rocks, which were metamorphosed up to granulite facies (Lee et al., 1986). Triassic, Jurassic, and Cretaceous granitoids were widely intruded to the Yeongnam Massif throughout the whole Mesozoic time.

2.1 Gyeongsang Basin

The Gyeongsang Basin is a Cretaceous non-marine sedimentary basin and is located in the southeastern part of the Korean peninsula. In the west and north, this basin is bounded by Precambrian metamorphic rocks (Yeongnam Massif) and Jurassic granitoids, while in the east it is overlain by calc-alkaline volcanic successions of the Early Tertiary. Sedimentary rocks of the Cretaceous Gyeongsang Supergroup deposited in the Gyeongsang Basin are divided into Sindong, Hayang, and Yucheon Groups in ascending order (Chang, 1977; Chang, 1975). Sandstone, shale, conglomerate, and marl dominate the Sindong and Hayang Groups, while volcanic rocks dominate the Yucheon Group (Chang, 1975).

Paleontological studies (e.g., Choi and Park, 1987; Choi, 1989; Park and Chang, 1998; Park et al., 2003b) suggest that ages from the Sindong and Hayang Groups are middle Early Cretaceous and the late Early Cretaceous. Overlying the Yucheon Group are volcanic layers (lavas and pyroclastics) and volcaniclastic layers (tuffs). The Yucheon Group fossils have not been found so far. The Gyeongsang Basin has been divided into three smaller crustal segments, called the Milyang, Uiseong, and Yeongyang subbasins, due to the uneven distribution of the three lithostratigraphic units (Sindong, Hayang, and Yucheon Groups). There are three distinct lithostratigraphic units in the Milyang and Uiseong subbasins, exhibiting the traditional tripartite scheme of the Gyeongsang Basin. In contrast, the northern Yeongyang subbasin consists mostly of the middle Hayang and upper Yucheon Groups without the lower Sindong Group. It may be due to differential movement of the three lithostratigraphic units during basin formation or deformation that they are distributed unevenly in the basin (Chang et al., 2003).

The results of estimating the maximum depositional ages of the Sindong Group by the U-Pb dating of the detrital zircons seem to be somewhat different among researchers. Lee et al. (2010a); Lee et al. (2010b); Lee et al. (2010c) proposed a maximum deposition time of 118 Ma, 108 Ma, and 106Ma for the Nakdong, Hasandong, and Jinju Formations of the Sindong Group from the U-Pb age of the detrital zircons. However, based on U-Pb zircon ages as well, Lee et al. (2010a) suggested about 128 Ma for the Nakdong Formation and Lee et al. (2010b) suggested about 113 Ma for the Jinju Formation. The results of previous studies that seem to be somewhat different are discussed along with the results of this study.

The Bulguksa granitoids consist of subvolcanic magmatic bodies, are found mostly in the Gyeongsang Basin, but also some parts of the Okcheon Metamorphic Belt. The syndepositional igneous activity is rarely found in the lowest layers of the Gyeongsang Supergroup, but it gradually increased to the upper level and became very active in the Yucheon Group and eventually led to the closure of the basin (Cheong and Kim, 1996; Choi, 1986b; Okada, 2000).

2.2 Pungam Basin

The Pungam Basin s is located in the eastern central Korean Peninsula. It is ca. 7 km wide and 20 km long in the NE-SW direction, and has sediment thickness of 300~500 km. Its evolutionary history is very different from the rest of the basins along the fault system. It is a transpressional basin formed at a gentle restraining bed developed along the Gongju fault system, resulting in the uplift of one margin and the descent of the basin, as one block moves past the restraining bend of the fault zone (Lee, 1986). Alluvial fan, fluvial and lacustrine deposits filled the basin. Then, it underwent deformation process. The upper part of the basin fill is mostly denuded now by uplift (Cheong and Kim, 1999). The Cretaceous sedimentary strata of the Pungam Basin are in contact with Precambrian biotite gneiss and two-mica granite by the Geumwang fault. The basin fills mainly consist of arkose, purple sandstone and mudstone, or siltstone and conglomerate (Cheong and Kim, 1999). The stratigraphy and depositional ages of the Pungam Basin are not yet established. Radiogenic isotope age data (84-70 Ma) of the intruded andesite and volcaniclastic pebbles from the sedimentary rocks (K-Ar whole-rock dating) indicate that volcanic activities in the Pungam Basin occurred continuously from pre-depositional to post-depositional period (Kim, 1998).

2.3 Eumseong Basin

The Eumseong Basin contains the Cretaceous Chopyeong Formation (＞8km thick), comprised of seven lithologic units: volcanics (including andesite, basalt, and tuffaceous sediments), conglomerate, conglomerate/purple mudstone, purple mudstone, green mudstone, greenish-gray mudstone/gray sandstone, and dark-gray mudstone (Ryang, 2013b). These nonmarine deposits were formed in alluvial-fan, alluvial-plain, and lacustrine environments. Minor Cretaceous calc-alkaline magmatic rocks are scattered in the middle of the southern part along the margin, many Paleoproterozoic and Archean gneisses from the basement and Jurassic granites (174.6±1.8 Ma) (Kim et al., 2009), formed by Daebo Orogeny, are exposed immensely around the basin (Fig. 2). According to Chun (1992) and Song et al. (1990), the various fossil assemblages of plants (Conifers and Ginkgoales), invertebrates (Estherids), and microfossils (Charophyta) all relate to a temperate climate and a fresh-water lacustrine environment. In the southern part of the basin, Charophyta fossils in the green mudstone were dated as Hauterivian-Aptian age (Choi, 1995). According to Kim et al. (2015; SHRIMP U-Pb geochronology), the maximum depositional age of the basin is 108.3±2.0 Ma.

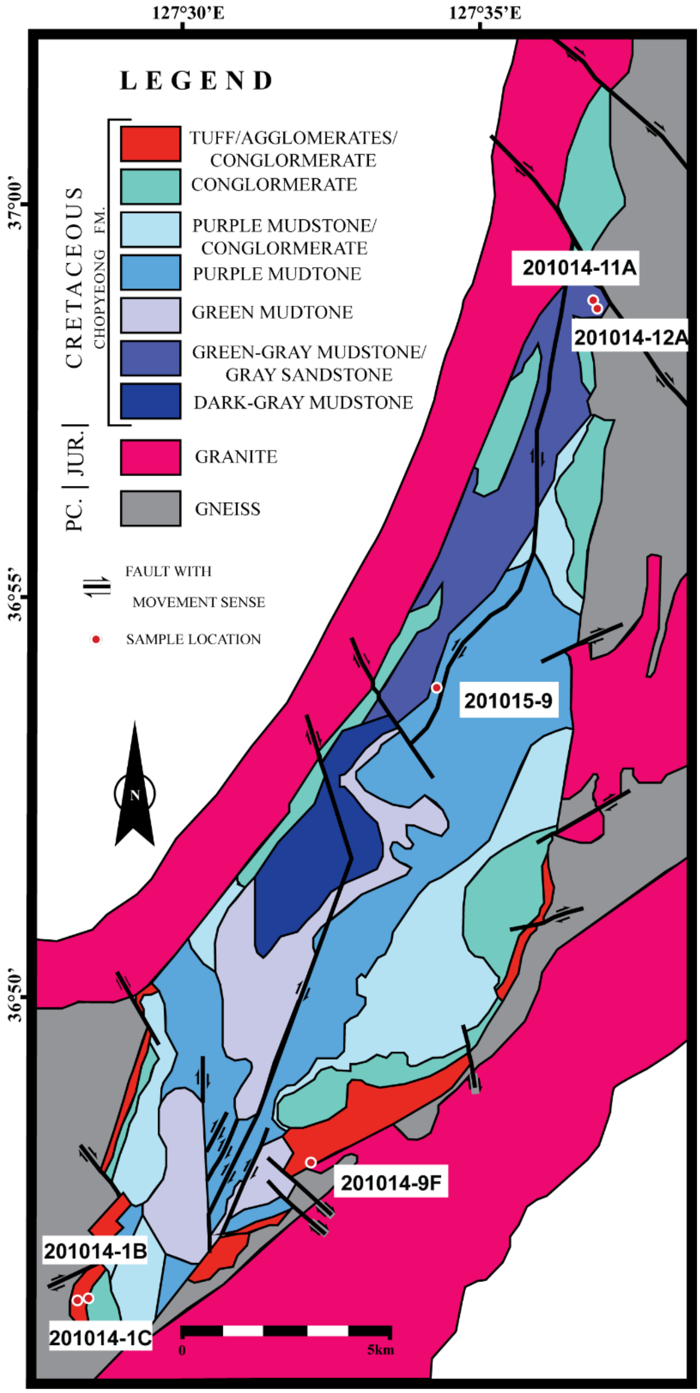


Figure 2 Geological map of Eumseong basin modified after Doh et al., (1996); Jonghyuk et al., (1971); Ryang (2003).

2.4 Gongju Basin

The Gongju Basin shows a fining-upward sequence underlain by volcanic sediments, suggesting that the depositional settings evolved from alluvial fan through alluvial plain to lacustrine environment in ascending order (Fig. 3). Sedimentary facies show a symmetric distribution along the longitudinal basinal axis. brecciated conglomerates and gravel stones are developed along both longitudinal margins of the basin (Kim et al., 1977). Toward the center of the basin, the grain size of sediments gradually deceases from gravel to silt size. Sediments are gravel stone, arkose, and siltstone, which were deposited mainly in alluvial fan systems and partly in fluvial systems (Chang, 1982). Based no gravity data, Kwon et al. (1994) proposed the depth and geometry of the basinal basement. the depth to the basement of the basin was suggested to be ~ 400-700m, and the central area is shallower than the marginal part, suggesting block tilting in the basement.

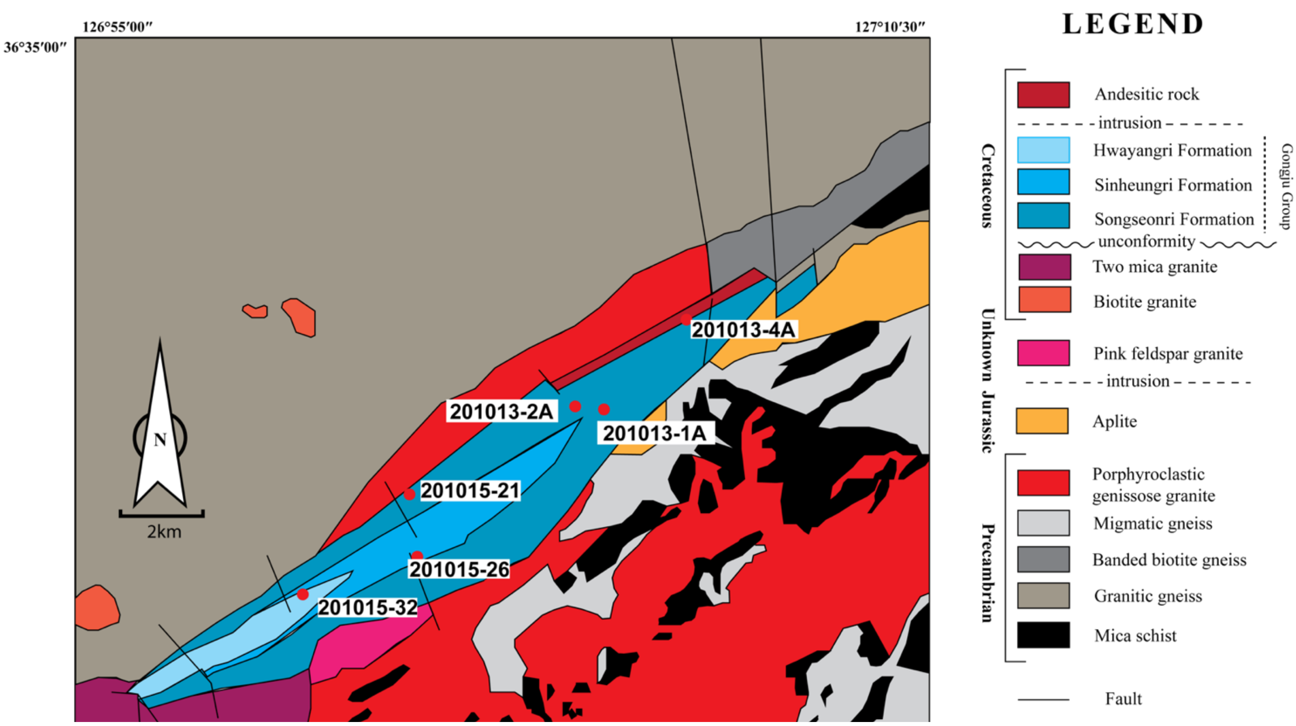


Figure 3 Geological map of Gongju Basin modified after Cheong et al. (2007); Kang (1974).

2.5 Yeongdong Basin

The Yeongdong Basin is located in the central part of the southern Korean peninsula and occupies area of ca. 40 km in length and 12. Km in width and has ca. 3,500 m thick sediment. The basin is bounded by strike-slip faults in the southeast and contact with Precambrian gneiss and schist of the Yeongnam massif, intruded by Mesozoic granitic rocks (Fig. 4). Kim and Hwang (1986) divided it as the Mangyeri, Saniri, Dongjeongri, Baekmasan, Wonchonri and Myeongyundong formations. Alluvial fan deposits were formed along the southeastern fault, and provenance of sediments are inferred from Precambrian basement and Yeongnam massif in eastward direction of basin (Kim, 1996a; Kim et al., 1997). Chun (1994) subdivided the Yeongdong Group into two zone based on the fossil type and forms. The lower Dongjeongri, Saniri, and Mangyeri formations are suggestive of Neocomian age, while the upper fossil type zone consists of the upper Dongjeongri, Baekmasan, Wonchonri, and Myeongyundong formations and is Aptian to Albian in age.

As a pull-apart basin, lateral motions along the two major strike-slip faults were different. The Yeongdong Fault acted more intensely than the northwestern fault and has extended the basin towards the northwestern fault and has extended the basin towards the northeast, making two depocenters. It produced asymmetric facies distribution and basin depth. The stratal architecture was obviously controlled by the fault movements as evidenced by the deposition of two different sedimentary sequences, indicating that the basin experienced extensional regime twice. In the lower sequence, alluvial sediments developed along the basin margin and lacustrine sediments in the basin center, whereas alluvial sediments are predominant in the upper sequence. Paleoflow analyses indicate that the clastic materials were derived from the south (Kim et al., 1997).

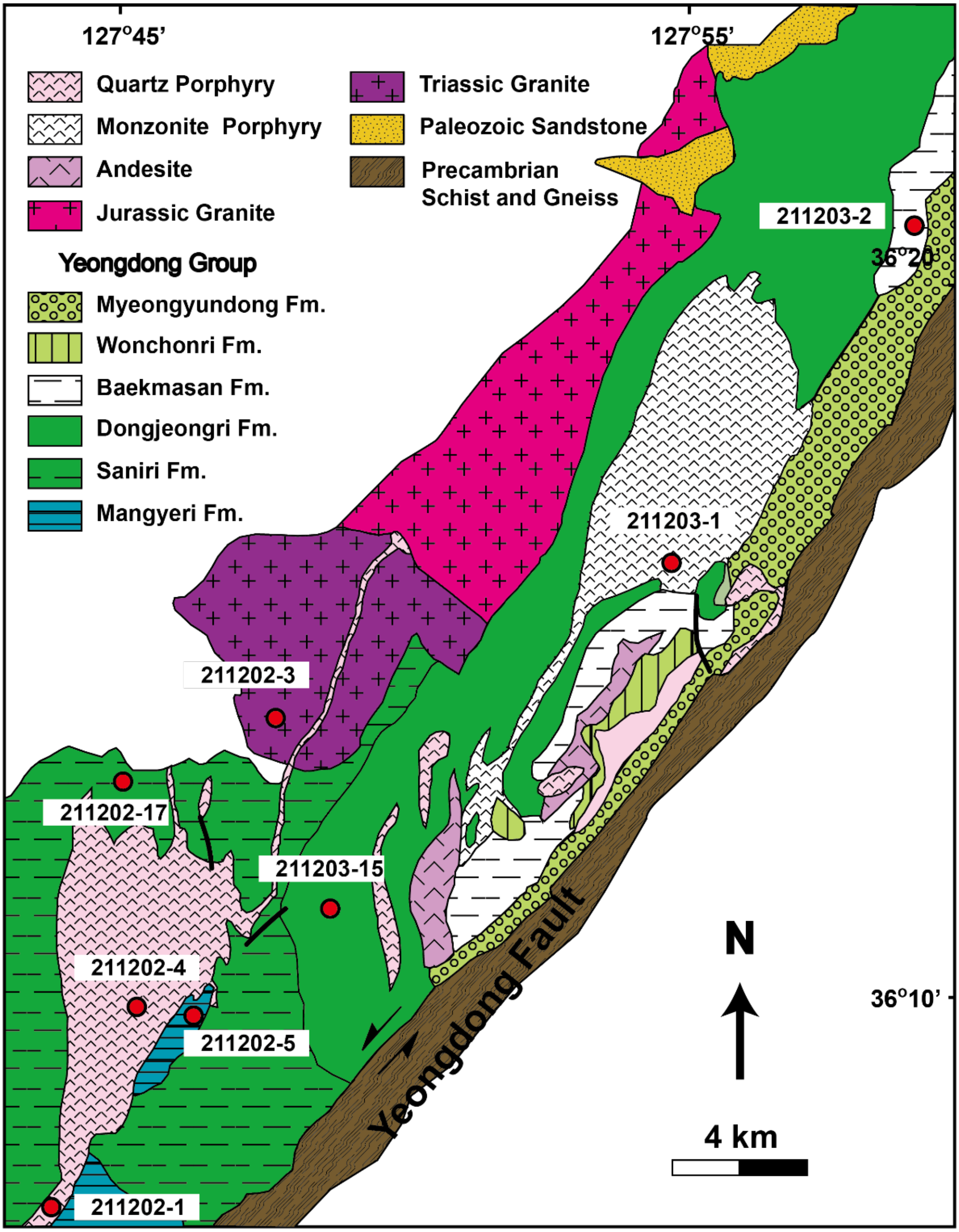


Figure 4 Geological map of the Yeongdong Basin modified after Doh et al. (1996); Kim and Hwang (1986); Yang et al. (2012).

2.6 Jinan Basin

The Jinan Basin is located in the southwestern Korean Peninsula along the southern boundary (Yeongdong-Gwangju fault system) of the NE-trending Okcheon Belt which was presumably formed by closing of a Late Precambrian failed continental rift during Permian-Triassic time (Cluzel, 1992). The Jinan Basin is ca. 18 km wide and 32 km long in the NE-SW direction and occupies an area of ca. 580 km^2 (Lee, 1992b). The basinfill of the Jinan Basin, the Jinan Group, is underlain by Precambrian gneiss and Jurassic granite, and was intruded by Upper Cretaceous andesite after the closing of the Jinan Basin (Lee, 1992b). Isotopic ages of the intrusive andesite are 69-76 Ma (whole rock K-Ar: 73-76 Ma, zircon FT: 70 Ma, and apatite FT: 69 Ma) (Shin and Jin, 1995). The depth to the basement in the southeastern part of the basin is deeper than that in the northwestern part and thickness of the sedimentary rock reaches up to 1.5 km (Baag, 1994). The Jinan Group consists of four stratigraphic units: the Mandeoksan, Dalgil, Sansudong, and Maisan formations. The Mandeoksan Formation (ca. 800 m thick) comprises mainly sandstones, whereas the Dalgil and Sansudong formations (ca. 600 m thick each) are mostly composed of shale. The Maisan Formation (ca. 1500-2000 m thick) consists of clast-supported conglomerates (Lee, 1992b).

Lee (1992b) interpreted that four lithostratigraphic units of the Jinan Group were deposited coevally. The depositional age of the Jinan Group was reported to be Barremian (ca. 120 Ma) (Yi et al., 1998). Lee (1992b) interpreted that the Jinan Group was deposited in alluvial fan, fan delta, alluvial plain and lacustrine settings, and was uplifted in the Late Cretaceous by transpression due to the northwestward subduction of the Izanagi Plate. The present altitude of the Jinan Basin sediment is higher (ca. 400 m) than that of its surrounding basement rocks, and flower structures are well observed in the Jinan Group (Lee, 1992b).

2.7 Neungju Basin

The Neungju basin is located east of Mudeung Mountain, which was formed by volcanic eruptions during the late-stage development of the Neungju Basin (Ahn et al., 2014). The western and eastern basin margins remain unclear because pyroclastic deposits (the Mudeungsan Tuff) associated with the formation of Mudeung Mountain covers most of the basin margins.

The basin fill was deposited in nonmarine environments including alluvial fan, alluvial plain, sandflat, and shallow lacustrine systems, punctuated by intermittent volcanism (Paik et al., 2007; Son and Kim, 1966). Based on lithology, the basin fill is subdivided into the Oyeri Formation, Manwolsan Tuff, Jangdong Formation (Jangdong Tuff), Jeokbyeok Formation (Jeokbyeok Tuff), Mudeungsan Tuff, and Ongam Conglomerate in ascending order (Kim and Park, 1966; Jung et al., 2014). It is evident that synsedimentary volcanism is continuing owing to all formations contain volcano sediments associated with terrigenous clastic rocks.

Most of the previous studies focused on dinosaur track-bearing sites in the Jangdong Formation and Jeokbyeok Tuff, suggestive of their deposition in sandflat to mudflat environments (Huh et al., 2003; Huh et al., 2006; Paik et al., 2007). The Yeonhwari Formation has also been interpreted as an alluvial fan environment (Yu et al., 1998). Arid to semi-arid climate conditions during the development of the Neungju Basin were suggested based on the occurrence of evaporite casts in mudstones.

2.8 Haenam Basin

The basement rocks of the Haenam Basin (including Jindo island) Precambrian gneiss and is intruded by massive and relatively undeformed Daebo Series granitoid and foliated Triassic plutons (Kim, 1991; Koh, 1996) (Fig. 5). They are unconformably overlain by Hwawon, Uhangri Hwangsan tuff and Jindo tuff (Chun and Chough, 1995; Koh, 1996; Yang et al., 2012). The Hwawon Formation is an inter-layered sequence of andesitic lapilli tuff and crystal-lithic tuff, fine-grained trachyandesite, basalt and andesite lavas and red-brown siltstone (Bowden, 2007). Crystallization age through $^{40}K/^{40}Ar$ whole-rock dating of basalt from the Hwawon Formation indicates of 103.4 ± 2.5 Ma (Kim and Nagao, 1992; Moon et al., 1990), sedimentary age through SHRIMP U-Pb dating of andesitic tuff from the Hwawon Formation shows 85.08 ± 0.79 Ma (Ko et al., 2021). The Uhangri Formation consists of 250– 450 m of black shale, laminated siltstone and mudstone, tuffaceous sandstone, chert and calcareous siltstone and minor intercalated volcanogenic units (Kim, 1991; Koh, 1996). Sedimentary age through SHRIMP U-Pb dating of tuff from the Uhangri Formation shows 79.4 ~ 86.0 Ma. The formation locally contains plant fossils as well as trace fossils of dinosaurs, pterosaurs, birds and arthropods (Chun and Chough, 1995; Hwang et al., 2002). $^{40}K/^{40}Ar$ whole-rock dating of andesite from the Uhangri Formation indicates a crystallization age of 95.4 ± 2.9 Ma (Hwang et al., 2002). The Hwangsan tuff conformably overlies the Uhangri formation. Reworked deposits and volcaniclastic debris-flow deposits occur dominantly in the transition zone between the Uhangri formation and Hwangsan tuff, sedimentary age through SHRIMP U-Pb dating shows 83.81 ± 0.82 Ma. Jindo tuff and rhyolite, the uppermost part of the Haenam Group, is mainly exposed in southern coastal areas. It conformably overlies the Hwangsan tuff. Most rhyolites show flow and pearlitic structures (Chun and Chough, 1995).

The NE-trending Gongju–Eumseong and Yeongdong– Gwangju fault systems and spatially associated transtensional strike-slip basins are the dominant structural features of the central and south-western parts of the Korean peninsula (Choi et al., 2005). The strike-slip basins (including the Haenam–Jindo Basin) are interpreted to have formed during the Late Jurassic to Early Cretaceous in response to the northward subduction of the Izanagi plate beneath the Eurasian plate (Chough, 2000; Lee and Paik, 1990). Alluvial fans and fluvial channel networks formed along the margins of the opening basins, and ephemeral lacustrine systems developed in the basin centers (Choi, 1996). A change to northwestward subduction of the Izanagi plate at the beginning of the Late Cretaceous is interpreted to have resulted in more extensive volcanism in the southwestern part of the peninsula (Park et al., 2003a). Haenam–Jindo Basin fill consists of non-marine sedimentary rocks, overlying andesitic to felsic pyroclastic and flows and high-level intrusions (Bowden, 2007; Yang, 1992). Transtensional basin development ceased by the Early Tertiary and was followed by widespread contractional deformation.

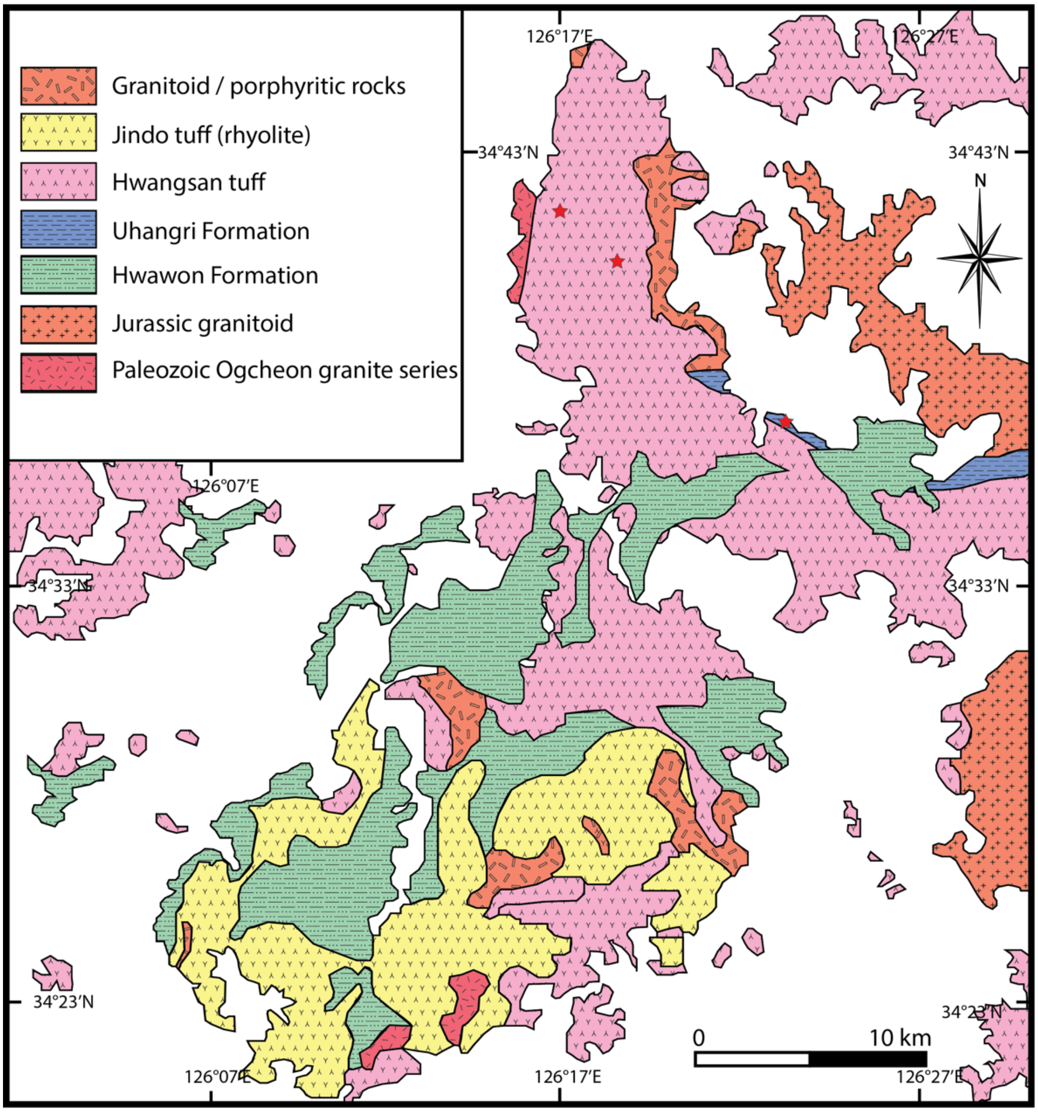


Figure 5 Geological map of Haenam basin modified after Chough (2000); Yang et al. (2012). The sampling points of the samples are identified by five pointed stars, which are HN-211201-14, HN-211201-11 and HN-211201-2 respectively from north to East.

III. Method

Seventeen clastic sedimentary rocks and four igneous rocks collected from the Eumseong, Gongju, Haenam, and Yeongdong basins. The petrographic observation was carried out to understand the composition and textural maturity of framework grains and decipher geological history using an optical microscope.

Detrital zircon U-Pb geochronology tests of clastic sedimentary rock samples from the Eumseong Basin and Gongju Basin were completed in Korea Basic Science Institute (KBSI) Ochang Center, South Korea. Conventional heavy mineral separation was used to collect the detrital zircon grains from the samples. Cathodoluminescence (CL) and backscattered electron images (BEIs) were collected at KBSI, before being analyzed for isotopes. At the KBSI Ochang Center, Pb-Th-U isotope analysis was performed with a Nu Plasma II multi-collector inductively coupled plasma mass spectrometer and a 193-nm ArF excimer laser ablation system (LA-MC-ICP-MS). The measurement parameters were 15~20 μm diameter of spot size, 5 Hz repetition rate, and energy density of 3.6~4.0 J/cm2. The carrier gas was helium (650 mL/min). Background signals, dwell duration, and washout time were all 30 seconds. A Time-Resolved Analytical (TRA) analysis was conducted to investigate the measured isotope ratio. Signal intensities for each collector were acquired every 0.2 seconds. Background, laser-induced elemental fractionation, mass discrimination, and drift in ion counter grains were all corrected in the raw data. Following analytical sessions, zircon standards of 91500 and Plesovice were measured at regular intervals to calibrate U-Pb isotope ratios, following protocols (Andersen, 2002). The statistical analyses were performed using the Iolite (Paton et al., 2011) and DetritalPy programs (Sharman et al., 2018). Isotopic ages were estimated using a 2s error level. Age probability curves were plotted using $^{206}Pb/^{238}U$ ages for <1000 Ma and $^{207}Pb/^{206}Pb$ ages for > 1000 Ma, respectively. Discordance (< 10%) of the zircon ages were calculated as [1-($^{207}Pb/^{238}U$ age) / ($^{207}Pb/^{235}U$ age)] * 100 and [1-($^{206}Pb/^{238}U$ age) / ($^{207}Pb/^{206}Pb$ age)] * 100 with ages younger and older than 1000 Ma, respectively.

Zircon U-Pb geochronology tests of clastic sedimentary rock and igneous samples from the Haenam Basin and Yeongdong Basin were completed in Sample Solution in China, Zircon grains were collected from the samples by conventional heavy mineral separation. Zircon Cathodoluminescence (CL) images were obtained using an Analytical Scanning Electron Microscope (JSM-IT300) connected to a Delmic sparc system. The imaging condition was 0.5-30 kV voltage of electric field and 72 μA current of tungsten filament.

Laser sampling was performed using a GeolasPro laser ablation system that consists of a COMPexPro 102 ArF excimer laser (wavelength of 193 nm and energy of 80 mJ, 5 Hz repetition, 32 μm diameter of spot size) and a MicroLas optical system. An Agilent 7700e ICP-MS instrument was used to acquire ion-signal intensities. Agilent standard tuning solution was used to auto-tune the best conditions of the instrument including intensity, oxide production and stability. Helium was used as carrier gas and argon as make-up gas and mixed with the carrier gas via a T-connector before entering the ICP. A “wire” signal smoothing device is included in this laser ablation system, by which smooth signals are produced even at very low laser repetition rates down to 1 Hz (Hu et al., 2012). Each analysis incorporated a background acquisition of approximately 20-30 s (gas blank) followed by 50 s data acquisition from the sample. Zircon 91500 and NIST610 were used as external standards for U-Pb dating and trace element analysis, respectively. The above experiments are completed at Wuhan sample solution analytical technology co., ltd., Wuhan. Time-dependent drifts of U-Th-Pb isotopic ratios were corrected using a linear interpolation (with time) for every six analyses according to the variations of the 91500 (Sláma et al., 2008) zircon standard (Liu et al., 2010) and preferred U-Th-Pb isotopic ratios used for 91500 are from Wiedenbeck et al. (1995) Zircon standards GJ-1 (Jackson et al., 2004) and Plesovice (Sláma et al., 2008) were used as unknown samples to monitor the stability and accuracy of acquired U-Pb data. The obtained Concordia U-Pb ages of GJ-1 and Plesovice are consistent within error with the recommended values. Trace element composition analysis of zircon was calibrated with Si as internal standard. Except for those elements with low concentrations (e.g., La, Pr and/or Nd), the results of trace elements in GJ-1 are consistent within error with the recommended values. Off-line selection and integration of background and analyzed signals, time-drift correction and quantitative calibration for trace element analysis and U-Pb dating were performed by ICPMSDataCal (Liu et al., 2010; Liu et al., 2008). Concordia diagrams of zircon grains were made using IsoplotR (Vermeesch, 2018). Isotopic ages were estimated using a 1s error level, age probability curves were plotted in DetritalPy programs (Sharman et al., 2018) using $^{206}Pb/^{238}U$ ages for <1000

Ma and $^{207}Pb/^{206}Pb$ ages for > 1000 Ma, respectively. Discordance (< 10%) of the zircon ages were calculated as [1-($^{207}Pb/^{238}U$ age) / ($^{207}Pb/^{235}U$ age)] * 100 and [1-($^{206}Pb/^{238}U$ age) / ($^{207}Pb/^{206}Pb$ age)] * 100 with ages younger and older than 1000 Ma, respectively.

IV. Results

4.1 Eumseong Basin

Six samples were collected in this basin, and petrographic and geochronological analyses were conducted on clastic zircon uranium and lead isotopes (Table 1). From 536 detrital zircon grains collected, 447 concordant to slightly discordant (±10%) ages were obtained, ranging from Campanian to Archean (Fig. 11). Cretaceous and part of Jurassic detrital zircon grains show angular and euhedral prismatic crystal morphology, while Precambrian grains in subangular to rounded shapes. Most of the zircon have oscillatory growth or patchy zoning (Fig. 10), which are indicative of a magmatic origin. As a result, the following results were obtained.

Table 1 Sample information sheet of the Eumseong Basin.

Formation	Name	Latitude (°)	Longitude (°)	Lithology
Chopyeong Formation	201014-1B	36.768748	127.474173	Purple-Grey Conglomerate
	201014-1C	36.7700675	127.4771459	Purple-Grey Conglomerate
	201014-9F	36.7959883	127.534192	Greenish Tuffaceous Siltstone
	201015-9	36.89646461	127.5627685	Greenish-Grey Quartz Siltstone
	201014-11A	36.97654045	127.60458397	Greenish Tuffaceous Quartz Siltstone
	201014-12A	36.97446983	127.60479385	Arkose

4.1.1 Petrographic analysis

201014-1B (Purple-Grey Conglomerate)

This sample is purple-grey conglomerate, cryptocrystalline matrix-supported, included plagioclase and quartz particles, angular-subrounded clasts including granular chert, sorting in bad, iron cement is visible in some areas of observation.

201014-1C (Purple-Grey Conglomerate)

This sample is purple-grey conglomerate. Clast-supported, cryptocrystalline matrix. Grains are mainly composed of quartz phenocrysts (undulating extinction, obviously eroded, decomposed and broken), andesitic detritus with volcanic glasses and chert (Fig. 6). Sorting is bad, roundness of chert is round, AD and QP is subangular. A large amount of strip plagioclase in andesite debris is an obvious indicator of volcanic origin.

201014-9F (Greenish Tuffaceous Siltstone)

This sample is greenish tuffaceous siltstone, good sorting and high roundness of quartz indicate the long transport distance. Channel pores are filled with layered chert.

201015-9 (Greenish-Grey Quartz Siltstone)

The sample is greenish-grey quartz siltstone, clast-supported, composed of quartz, chert, the grain of quartz has bad sorting and low roundness show the close transport distance (Fig. 6). The cataclastic fabric of quartz shows that the rocks have suffered metamorphism. The pressure solution joints surrounding the particles show that they are subjected to a high degree of compaction.

201014-11A (Greenish Tuffaceous Quartz Siltstone)

The sample is greenish tuffaceous quartz siltstone, matrix-supported, the grain of quartz shows bad sorting and low roundness show the close transport distance.

201014-12A (Arkose)

The sample is poorly sorted arkosic wacke, clast-supported, large primary intergranular pores are obviously visible, most of the particles are broken feldspar.

4.1.2 Zircon U-Pb analysis

201014-1B

A total of 100 zircons were analyzed in this sample, and 50 grains show concordant U-Pb ages ranging from 104.2 ± 0.87 ~ 3356 ± 6.6 Ma, youngest group of Concordia age is 106.57 ± 0.33 Ma (n=4) (Fig. 9). Age distributions shows zircon age peaks at ca. 108 Ma, 177 Ma, and 1873 Ma (Fig. 12). Age proportions consist of Cretaceous (6%), Jurassic (8%), Triassic (6%), Paleozoic (8%), Meso ~ Neoproterozoic (8%) and Archean ~ Paleoproterozoic (64%).

201014-1C

In total, 73 grains show concordant U-Pb ages 104.7 ± 1.8 Ma ~ 3208 ± 14 Ma, youngest group of Concordia age is 108.93 ± 0.52 Ma (n=2). This zircon age population contains zircon age peaks at ca. 111 Ma, 172 Ma, and 1877 Ma (Fig. 12). Age proportions include Cretaceous (3%), Jurassic (4%), Paleoproterozoic (86%), and Archean (7%).

201014-9F

Among the analyzed 93 zircons from this sample, 78 grains have concordant U-Pb ages ranging from 72.4 ± 6.2~ 2739 ± 7 Ma, the youngest group of Concordia age is 114.59 ± 0.39 Ma (n=21). Age groups were identified in: Cretaceous (26%), Jurassic (5%), Triassic (8%), Paleozoic (11%), Neoproterozoic (20%), Mesoproterozoic (6%), Paleoproterozoic (20%), and Archean (4%). The most prominent age peak occurs at 118 Ma (Fig. 12).

201014-11A

Overall, 54 grains exhibit concordant U-Pb ages 102.8 ± 1.5 Ma~ 2253.3 ± 5.9 Ma, weighted mean age of two youngest grains is 103 ± 0.45 Ma (Fig. 9). Two dominant age peak occurs at 104 Ma and 173 Ma (Fig. 12). Age groups were established at Cretaceous (3%), Jurassic (69%), Triassic (2%), Neoproterozoic (3%), Mesoproterozoic (2%), Paleoproterozoic (19%) and Archean (2%).

201014-12A

Among 99 grains analyzed, 62 grains show concordant U-Pb ages varying from 113.8 ± 1.7 Ma~ 3158 ± 3.1 Ma. Age peak occurs at 114 Ma, 174 Ma, and 1873 Ma (Fig. 12). Age groups were established in Cretaceous (2%), Jurassic (44%), Paleoproterozoic (48%), and Archean (12%).

201015-9

It was found that 75 grains have concordant U-Pb ages ranging from 105.6 ± 3.2 Ma~ 3438 ± 1.9 Ma, the youngest group of Concordia age is 108.76 ± 0.46 Ma (n=4). The zircon age population exhibited zircon age peaks at ca. 109 Ma, 175 Ma, and 1875 Ma (Fig. 12). Age groups were founded: Cretaceous (5%), Jurassic (12%), Triassic (3%), Paleoproterozoic (68%), and Archean (12%).

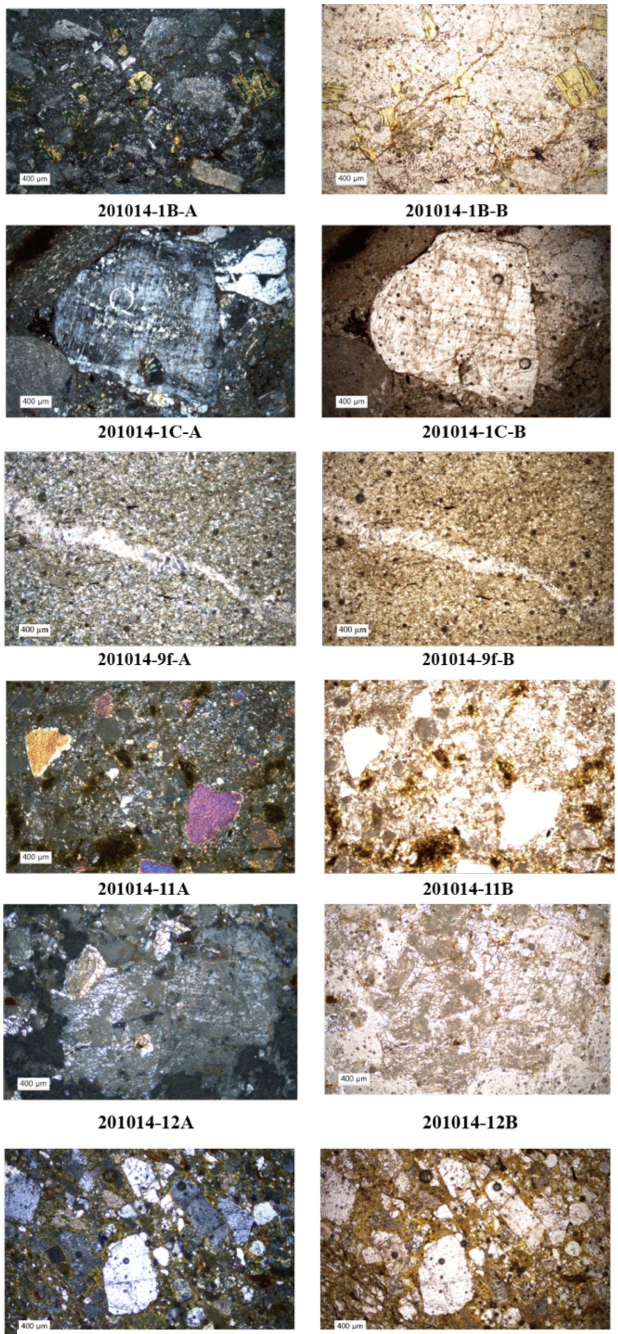


Figure 6 Thin-section microphotographs in plane- and cross-polarized light of sedimentary rock from the Eumseong Basin (cross [left and open [right] nicols]). Q, quartz; VRF, volcanic fragments.

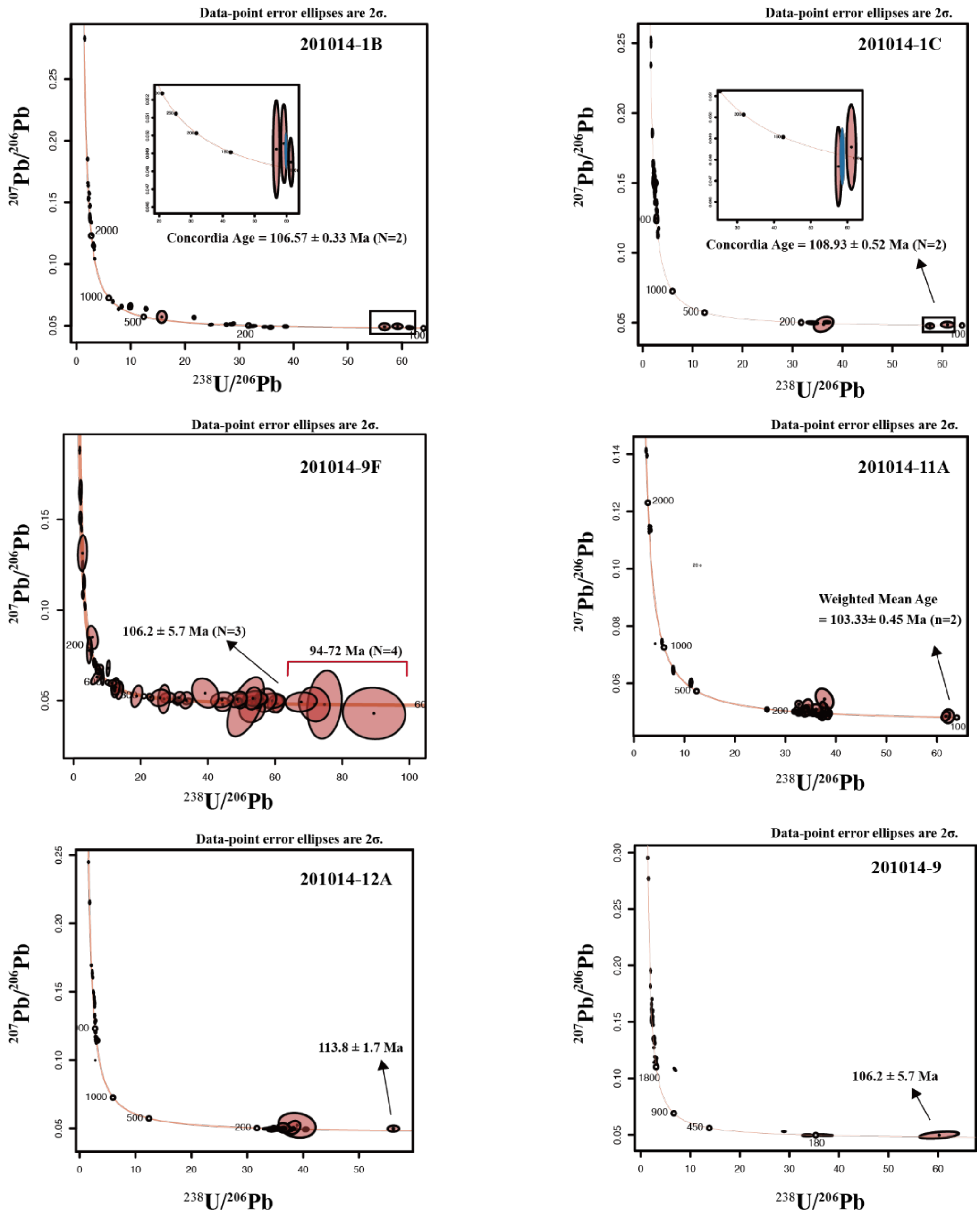


Figure 7 Terra-Wasserburg diagrams of LA-MC-ICPMS U-Pb for detrital zircon ages in the Eumseong Basin.

4.2 Gongju Basin

From 593 detrital zircon grains collected, 482 concordant to slightly discordant (±10%) ages were obtained, ranging from Paleocene to Archean (Fig. 11). Cretaceous, Triassic and part of Jurassic detrital zircon grains show angular and euhedral prismatic crystal morphology, while Precambrian grains in subangular to rounded shapes. Most of the zircon have oscillatory growth or patchy zoning (Fig. 10), which are indicative of a magmatic origin.

Table 2 Sample information sheet of the Gongju basin.

Formation	Name	Latitude (°)	Longitude (°)	Lithology
Songseonri Formation	201013-1A	36.4708459	127.111230	Purple Polymictic Conglomerate
Songseonri Formation	201013-2A	36.4683892	127.103376	Purple Conglomerate
Songseonri Formation	201013-4A	36.487881	127.130259	Gray Conglomerate
Songseonri Formation	201015-21	36.4122154	127.0232518	Reddish Clast-Supported Conglomerate
Sonheungri Formation	201015-26	36.3992201	127.0170573	Reddish Matrix-Supported Conglomerate
Hwayangri Formation	201015-32	36.39113551	126.98468833	Greenish Conglomerate

4.2.1 Petrographic analysis

201013-1A (Purple Polymictic Conglomerate)

The sample is a purple polymictic conglomerate composed of green tuff and rhyolite fragments with a sand-sized matrix and iron cement (Fig. 8). Quartz phenocrysts are significantly altered to hydromica and sericite by metasomatism. There are fractures and undulatory extinction in quartz grains, showing that the parent rock has undergone metamorphism.

201013-2A (Purple Conglomerate)

The sample is a purple conglomerate consisting of green rhyolite rock fragments and matrix in sand size and iron cement (Fig. 8). The metasomatism altered quartz phenocrysts in rhyolite to hydromica and sericite. The quartz grains have fractures and show undulatory extinction and polycrystalline state (>3 subcrystals), which means that the parent rock has undergone low-rank metamorphism.

201013-4A (Gray Conglomerate)

The sample is gray conglomerate, phenomenon of containing a large number of rhyolite rock fragments indicates the origin of its effusive rocks.

201015-21 (Reddish Clast-Supported Conglomerate)

The sample is a red clast-supported conglomerate. Composed of quartzite chert and sphene debris and cryptocrystalline and red tuffaceous matrix.

201015-26 (Reddish Matrix-Supported Conglomerate)

The sample is a red matrix-supported conglomerate composed of volcanic breccia, quartz, feldspar, and mica. The feldspars are large, fresh, and angular in shape, indicative of arid climate.

201015-32 (Greenish Conglomerate)

The sample is a greenish conglomerate composed of red tuffaceous matrix, quartz and feldspar grains (Fig. 8). The phenomenon of granular crystalloblastic structure in quartzite detritus and sericite bands indicate metamorphism.

4.2.2 Zircon U-Pb age analysis

201013-1A

There were 38 grains with concordant U-Pb ages in 239.3 ± 2.9 ~ 2680 ± 14 Ma (Fig. 9). This zircon age population shows zircon age peaks at ca. 1866 Ma. Age proportions consist of Jurassic (5%), Triassic (3%), Paleozoic (3%), Neoproterozoic (3%), Paleoproterozoic (70%), and Archean (17%).

201013-2A

I selected 115 zircons and analyzed 100 grains of zircons; 87 grains show concordant U-Pb ages ranging from 107 ± 1.4 Ma ~ 2525.5 ± 6.4 Ma, the youngest group of Concordia age is 107.68 ± 0.34 Ma (n=3) (Fig. 9). This population of zircon age contains zircon age peaks at ca. 108 Ma, 169 Ma, and 1841 Ma (Fig. 12). Age proportions include Cretaceous (4%), Jurassic (13%), Triassic (6%), Neoproterozoic (1%), Mesoproterozoic (1%), Paleoproterozoic (70%), and Archean (4%).

201013-4A

In total, 93 zircons were selected and 93 grains analyzed, 81 grains with matching concordant U-Pb ages ranging from 57.6 ± 6.1 Ma ~ 2615 ± 18 Ma, youngest group of Concordia age is 121.68 ± 0.95 Ma (n=3) (Fig. 9). Age groups were identified in: Paleocene (2%), Cretaceous (24%), Jurassic (20%), Triassic (5%), Paleozoic (11%), Neoproterozoic (9%), Mesoproterozoic (1%), Paleoproterozoic (24%), and Archean (5%). The most prominent age peak occurs at ca. 115 Ma.

201015-21

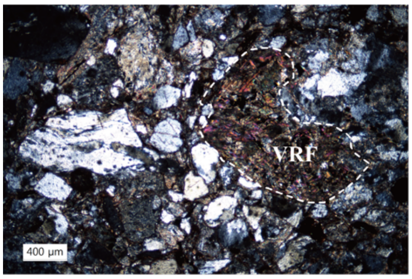
The U-Pb ages of 214 zircons were measured, and 83 grains showed concordant results 225.7 ± 4.8 Ma~ 3468 ± 11 Ma, youngest group of Concordia age is 234.34 ± 1.12 Ma (n=3). The most prominent age peak occurs at ca. 1882 Ma (Fig. 12). Age groups were established at Triassic (4%), Paleozoic (1%), Neoproterozoic (1%), Paleoproterozoic (87%), and Archean (7%).

201015-26

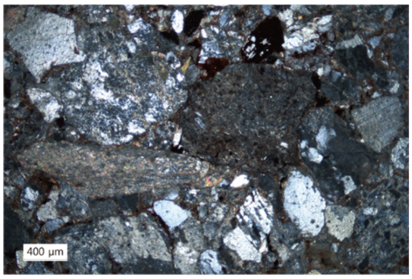
A total of 154 zircons were selected, and 100 grains were tested; 82 grains show concordant U-Pb ages varying from 1888.5 ± 5 Ma~ 3438 ± 1.9 Ma. The most prominent age peak occurs at ca. 1855 Ma. Age groups were established Paleoproterozoic (85%) and Archean (15%).

201015-32

I selected 243 zircons and analyzed 100 grains; 56 grains have concordant U-Pb ages ranging from 214.3 3.7 Ma to 2715.6 3 Ma (Fig. 9). The population of zircon age exhibited zircon age peaks at ca. 1916 Ma (Fig. 12). Age groups were founded: Triassic (6%), Permian (8%), Carboniferous (2%), Neoproterozoic (2%), Paleoproterozoic (62%), and Archean (20%).



201013-1A-1



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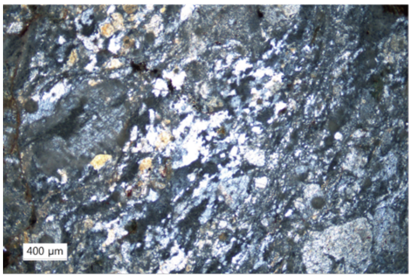

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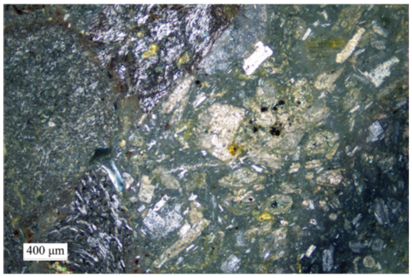

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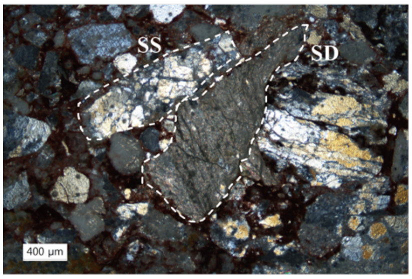
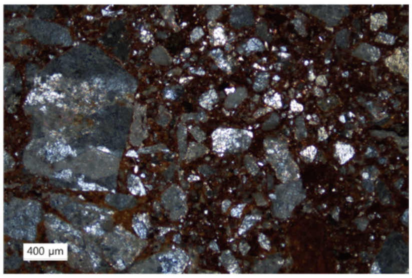
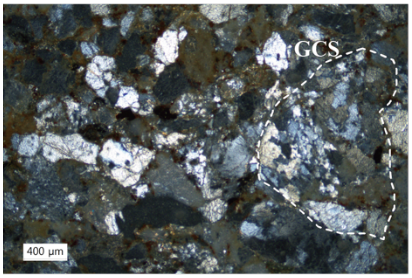


201015-21



201015-26



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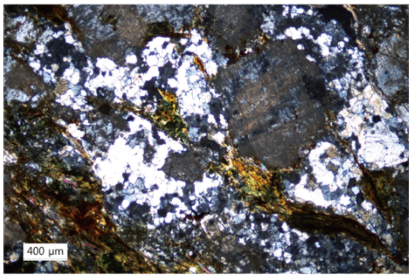

201015-32-2

Figure 8 Thin-section microphotographs in plane- and cross-polarized light of sedimentary rock from the Gongju Basin. VRF, volcanic fragments; SD, sphene detris; GCS, granular crystalloblastic structure.

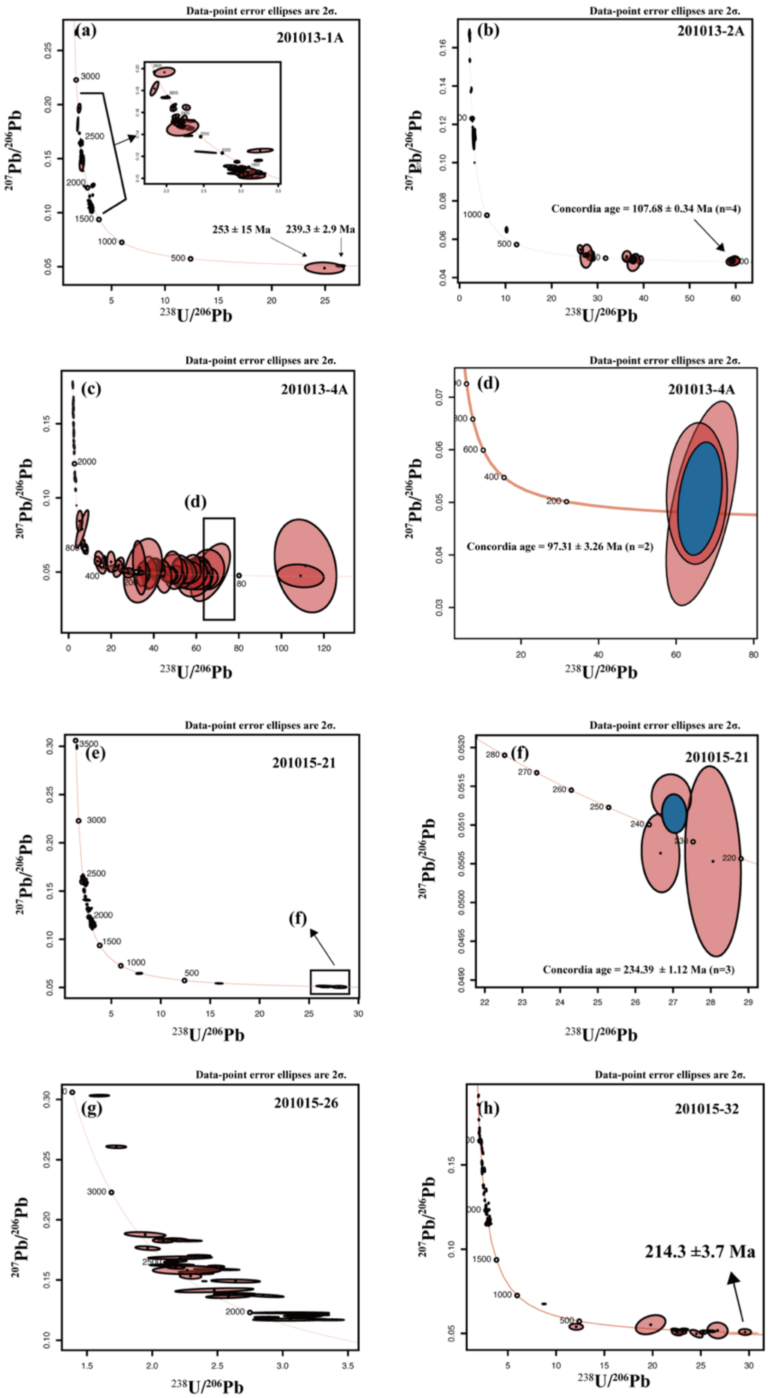

Figure 9 Terra-Wasserburg diagrams of LA-MC-ICPMS U-Pb for detrital zircon ages in the Gongju Basin.

Figure 10 Typical Cathodoluminescence (CL) images of detrital zircon grains of the Eumseong and Gongju Basins. CL imaging has been used to recognize the zircons' internal textures and target coherent domains within grains for laser spots. Circles show laser analyze.

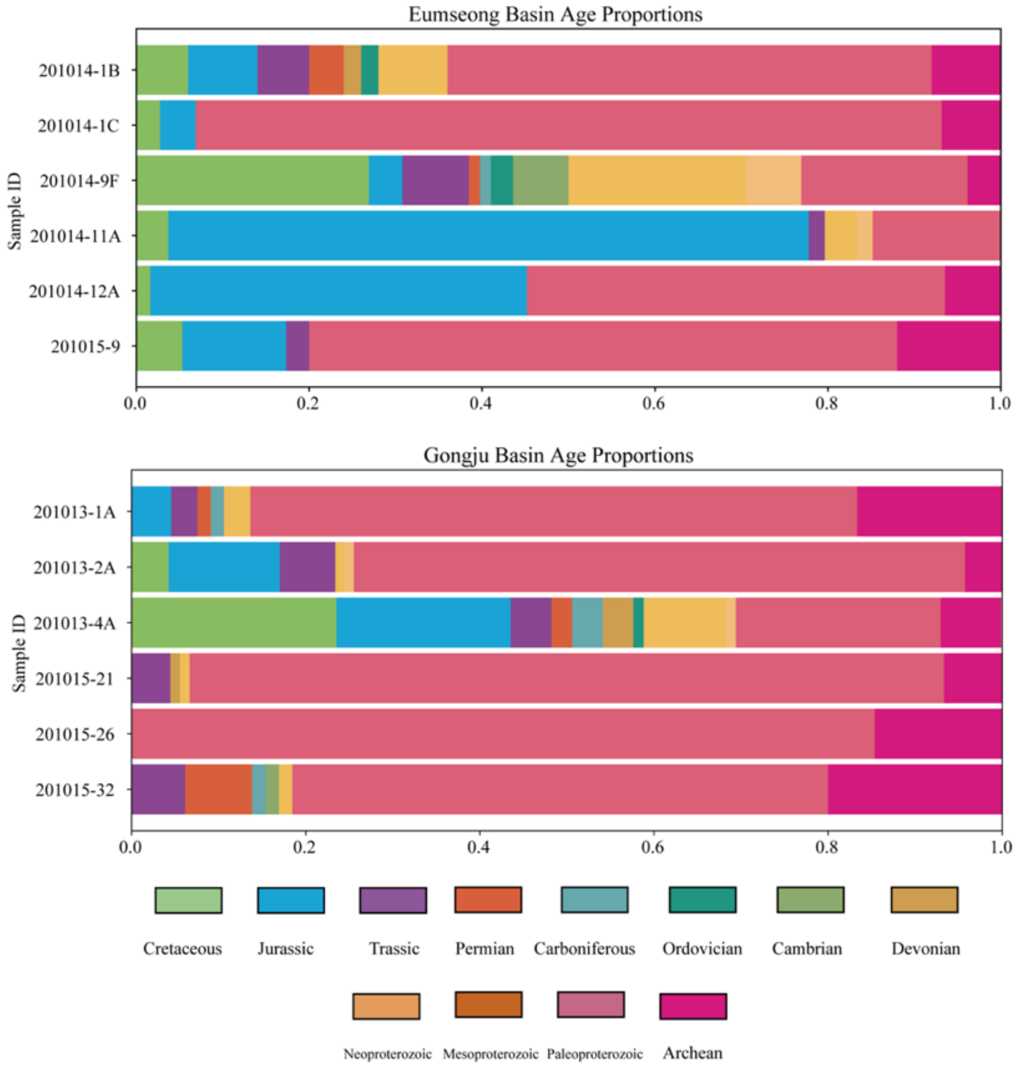

Figure 11 Age proportions for the Eumseong and Gongju basins.

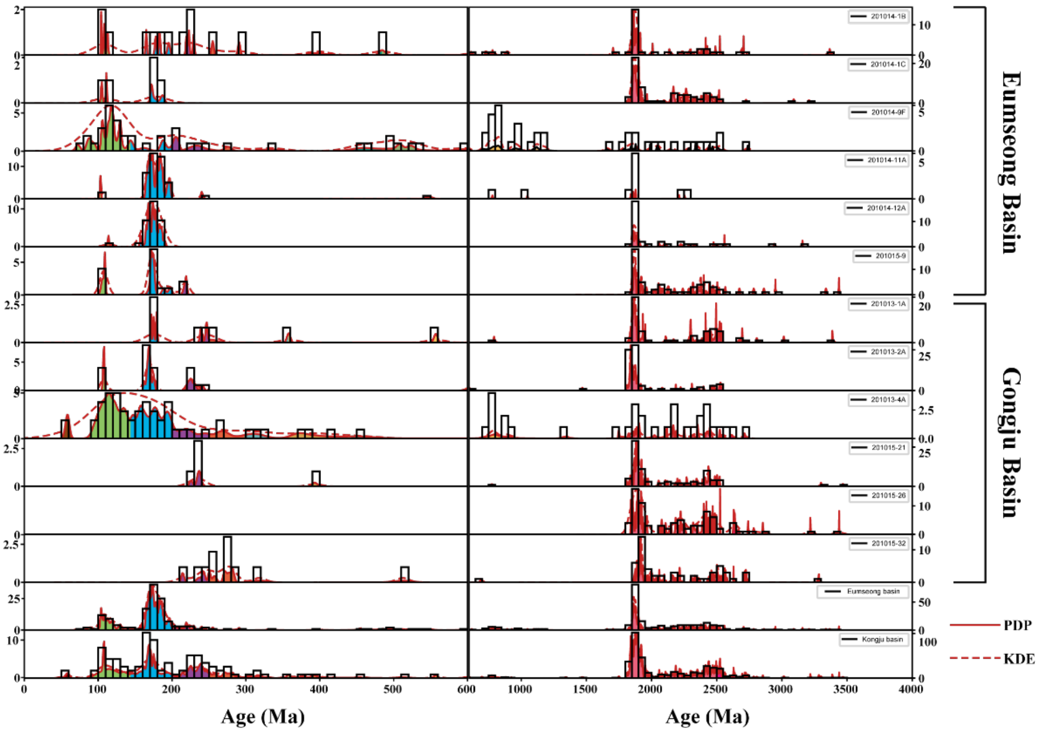

Figure 12 Relative distribution diagram of zircon ages in the Eumseong and Gongju basins. Straight line represents probability density plot, dotted line represents kernel density estimate.

4.3 Haenam Basin

4.3.1 Petrographic analysis

I collected three samples from Haenam Basin and listed their location and lithology information in the table 3.

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Table 3 Sample information sheet of the Haenam Basin

Formation	Name	Latitude (°)	Longitude (°)	Lithology
Uhangri formation	HN-211201-2	34.60958837	126.39120077	Andesitic Lithic-Crystal Tuff
Hwangsan formation	HN-211201-11	34.66755847	126.30905086	Basaltic Andesitic Volcanic Breccia-Lithic-Crystal Tuff

Hwangsan formation	HN-211201-14	34.68130345	126.27868683	Andesitic Crystal Pyroclast-Cuttings Tuff

HN-211201-2 (Andesitic lithic-crystal tuff)

The rock is mainly composed of a large amount of crystal debris and some volcanic debris and cement (Fig. 13). The crystal chips are mainly plagioclase (varying degrees of sericitization, a small number of carbonations, most of the particles remain in tabular form, which is phenocrysts from magmatic origin, and polysynthetic twins can be seen), with some altered dark minerals (complete serpentinization, partial sliding and precipitation of iron along the edge or cleavage), The particle size is less than 1.9mm, accounting for 75% of the total. The cuttings are andesitic cuttings (composed of microcrystalline plagioclase and a small amount of plagioclase phenocryst, with interwoven structure) and felsitic cuttings (composed of felsitic felsic, clay minerals and a small amount of plagioclase phenocryst, with felsitic texture faintly visible), subangular, particle size ≤ 1.8mm, accounting for 10% of the total. It is cemented by cryptocrystalline glassy (most of which have been devitrified and recrystallized as cryptocrystalline clay minerals), accounting for 15%. The sharp edges and corners of crystals and rock fragments show that they have experienced a very short transportation distance.

HN-211201-11 (Basaltic andesitic volcanic breccia-lithic-crystal tuff)

The rock is mainly composed of volcanic debris, crystal debris, volcanic breccia and a small amount of cement (Fig. 13). The cuttings are mainly andesitic cuttings (composed of microcrystalline plagioclase and a small amount of plagioclase phenocryst, with interwoven structure) and part of felsitic cuttings (composed of felsitic felsic and a small amount of plagioclase phenocryst), It is composed of iron oxide, some microcrystalline plagioclase and plagioclase phenocryst, with glass matrix interlacing structure. The grain size is ≤ 1.8mm, accounting for 45% of the total. The crystal chips are mainly plagioclase (varying degrees of sericitization, turbidity on the surface, most of the particles remain plate-shaped, which are phenocrysts from magmatic origin, and polysynthetic twins can be seen), It contains a small part of quartz (visible erosion structure), subangular shape, particle size ≤ 1.8mm, accounting for 23%. The breccia is composed of andesite, felsitic, basaltic, granite, etc., which is subangular, with particle size ≤ 5.0 mm, accounting for 30% of the total. The above pyroclastic rocks are cemented by cryptocrystalline iron argillaceous, accounting for 2%. The sharp edges and corners of crystals and rock fragments show that they have experienced a very short transportation distance.

HN-211201-14 (Andesitic crystal pyroclastic cuttings tuff)

The rock is mainly composed of volcanic cuttings and part of crystal pyroclast and cement (Fig. 13). The cuttings are mainly Andesitic cuttings (composed of microcrystalline plagioclase and some cryptocrystalline iron argillaceous and glassy, visible interweaving-glass-based interweaving structure, and most of the grain boundaries are fuzzy and weakly consolidated), with a small number of felsitic cuttings (composed of felsitic felsic and felsitic texture), and subangular, particle size ≤ 0.8 (a few up to 1.8) mm, accounting for 85%. Crystal pyroclastic is composed of plagioclase (some particles are sericitized to varying degrees, and polysynthetic twins can be seen; most of the particles remain in tabular form, which are phenocrysts from magmatic origin) and quartz (visible melting structure). They are subangular, with particle size ≤ 0.7mm, accounting for 10% of the total. The above pyroclastic rocks are cemented by cryptocrystalline iron argillaceous, accounting for 5%. The sharp edges and corners of crystals and rock fragments show that they have experienced a very short transportation distance.

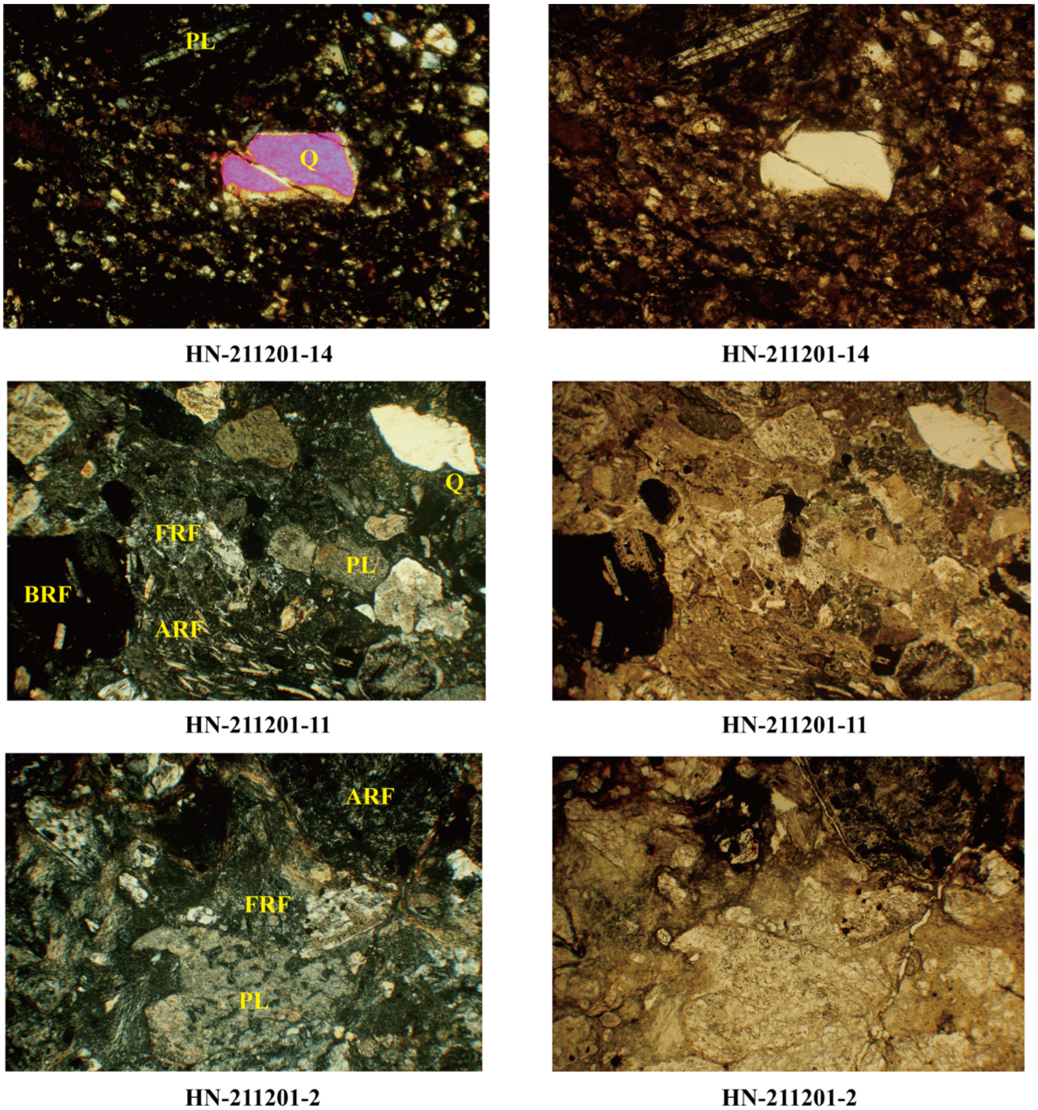


Figure 13 Thin-section microphotographs in plane- and cross-polarized light of sedimentary rock from Haenam Basin (crossed [left] and open [right] nicols). Q, quartz; PL, plagioclase; FRF, felsic rock fragments; BRF, basaltic rock fragments; VRF, volcanic fragments.

4.3.2 Zircon U-Pb age dating

I analyzed 300 zircon grains from three samples and 247 analysis points in concordant age. Age ranging from 79.7 Ma to 2073 Ma (Fig. 13). Zircon grains in detrital materials have a transparent, translucent appearance and can be anhedral or euhedral. Angular and euhedral prismatic crystals have prevailed in Mesozoic zircon grains, while metamorphic overgrowth rim is dominant in Paleoproterozoic zircons (Fig. 12).

HN-211201-2

Figure 14 Typical Cathodoluminescence (CL) images of detrital zircon grains of the Eumseong and Gongju Basins. CL imaging has been used to recognize the zircons' internal textures and target coherent domains within grains for laser spots. Circles show laser analyze.

U-Pb dating of edge of grains belonging Uhangri formation showed range in 79.7 Ma to 87.1 Ma and concordant age in 82.77 ± 0.44 Ma excepted one Jurassic grain (Fig. 17). The particles of Jurassic age show deep color, broken cracks, multiple oscillatory bands and dark inclusions, and are characterized by metamorphic recrystallized zircon. Both Probability density plot and kernel density plot have the same peak point at 81 Ma (Fig. 15).

HN-211201-11

U-Pb dating of edge of grains belonging Hwangsan tuff showed range in 83.6 Ma to 2073 Ma. Grains in Cretaceous age ranged in 83.5 to 106 Ma and concordant age is 90.35 ± 0.17 Ma (n=77), 2 grains are 197 Ma and 211 Ma corresponding in Jurassic and Triassic, Paleoproterozoic grains ranged 1769 Ma to 2073 Ma, concordant age in 1853.77 ± 3.30 Ma (n=14). Both Probability density plot and kernel density plot have the same peak point at 91 Ma (Fig. 145.

HN-211201-14

Zircon grains in Hwangsan tuff formation of HN-211201-14, U-Pb age dating of edge of grains yielded an age range of 87.3 Ma to 1095 Ma (Fig. 16). Cretaceous age ranged 87.3 Ma to 108 Ma, concordant age in 93.01 ± 0.19 Ma (n=69). Two grains in Jurassic, one grain in Triassic and two grains in Proterozoic.

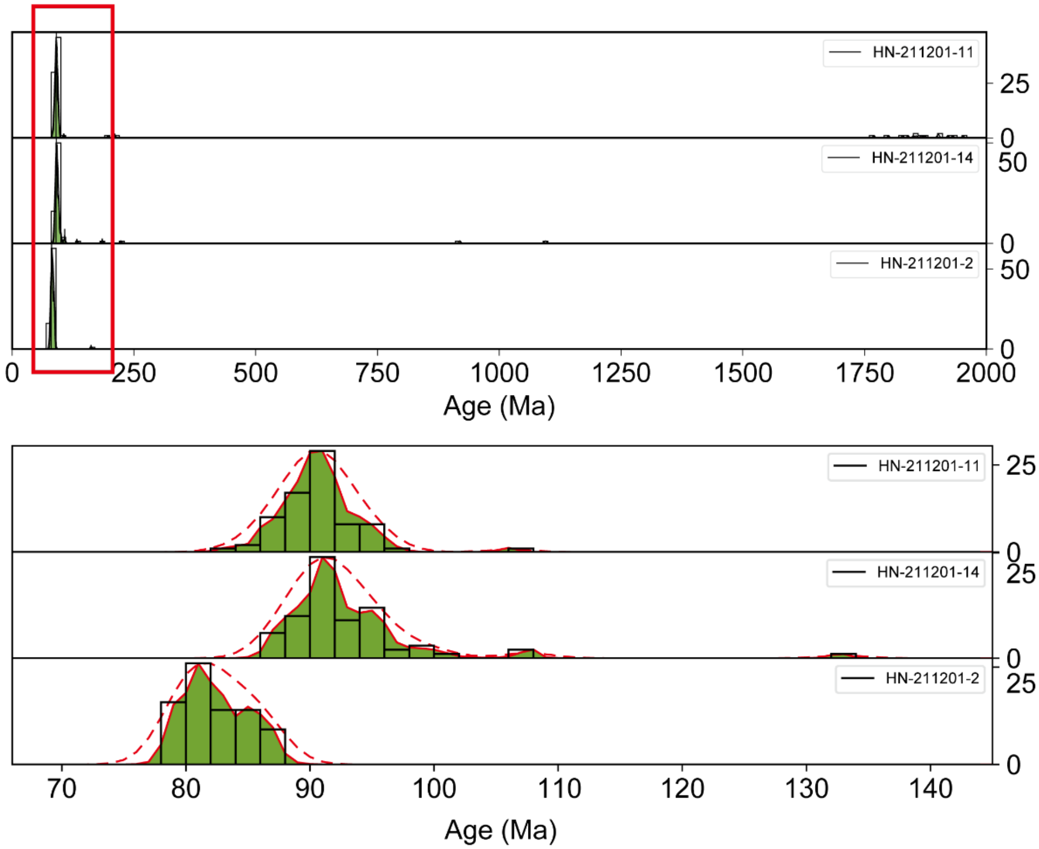


Figure 16 Probability distribution diagram of zircon ages in the Haenam Basin.

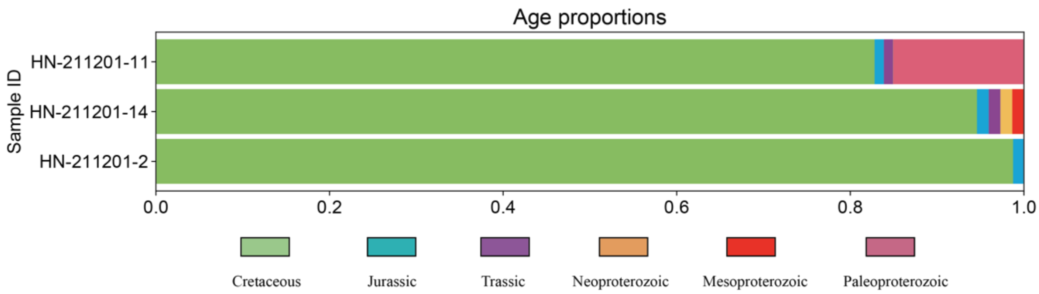


Figure 15 Age proportions for the Haenam Basin.

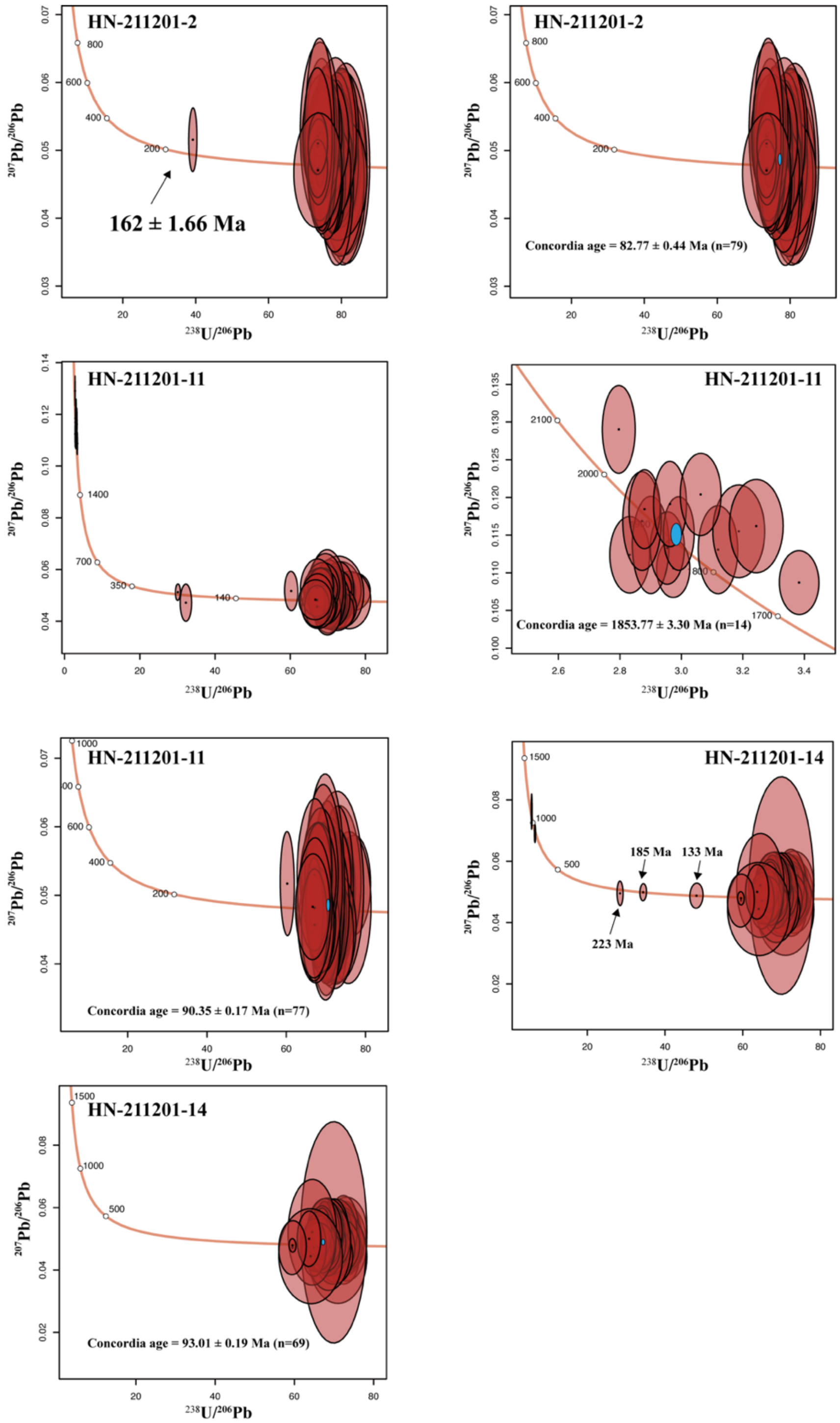


Figure 17 Terra-Wasserburg diagrams of LA-MC-ICPMS U-Pb for detrital zircon ages in the Haenam Basin.

4.4 Yeongdong Basin

4.4.1 Petrographic analysis

Four clastic sedimentary rocks and five igneous rocks from the Yeongdong Basin were collected (Table 4).

Table 4 Sample information sheet of the Yeongdong Basin.

Formation	Name	Latitude (°)	Longitude (°)	Lithology
Dacite	YD-211202-1	36.10262554	127.6776419	Sodium Zoisite Fossilized Spherulitic Dacite
Monzogranite	YD-211202-3	36.12850081	127.7181579	Sericitized Chloritized Fine-Grained Biotite Monzogranite
Porphyry	YD-211202-4	36.12850081	127.7181579	Quartz Monzonite Porphyry
Mangyeri Formation	YD-211202-5	36.12837207	127.73753288	Unequal Grain Lithic Arkose
Saniri Formation	YD-211202-17	36.20505852	127.73983293	Unequal Grain Arkose
Porphyry	YD-211203-1	36.26513266	127.9031973	Slightly Ferruginous Kaolinized Monzonite Porphyry
Baekmasan Formation	YD-211203-2	36.36670012	127.991746	Conglomeratic Unequal Grain Tuffaceous Arkose
Myeongyundong Formation	YD-211203-14	36.34936805	127.984203	Slight Sericite Almond Andesite
Dongjeongri formation	YD-211203-15	36.19542997	127.7955179	Breccia -Crystal Debris-Cuttings Deposition Tuff

Volcanic rock

Sample YD-211202-1 is named in Sodium Zoisite Fossilized Spherulitic Dacite and composed of phenocrysts and the matrix is interlaced spherulite (Fig. 18). The phenocrysts consist of anhedral granular quartz with a grain size less than 1.3mm, subhedral granular plagioclase, and schistose biotite. Quartz phenocrysts exhibit a corrosion structure. A Plagioclase Phenocryst with varying amounts of Sodium Zoisite fossilized appears slightly sericitized, has a turbid surface, and contains polysynthetic twins. Fibrous plagioclase and lath plagioclase are found in the matrix, along with heteromorphic granular quartz and scaly muscovite. Most commonly, plagioclase is found in fibrous aggregates, forming spherulite structures, but it is also found in laths, semi-parallel and disorderly arranged to form an interwoven structure with varying degrees of sodium zoisite fossilization and surface turbidity. Between plagioclase spheres is a mosaic of xenomorphic granular quartz. Muscovite is scattered between microcrystalline plagioclase grains.

Sample YD-211203-14 is named in slight sericite amygdaloid andesite and is composed of porphyritic structure and an interlaced matrix (Fig. 18). The phenocrysts are semi-euhedral granular plagioclase less than 1.0 mm in size with a small amount of augite, and a few of the phenocrysts are spot-like. Various degrees of sericitization are present in platyclase porphyry, and polysynthetic twins are visible. A plurality of plate-shaped microcrystalline plagioclase grains with grain sizes less than 0.3mm are distributed in the matrix; the interlaced structure is made up of heteromorphic granular augite particles with particle sizes less than 0.05mm and aphanitic glass particles. Cryptocrystalline scaly chlorite and a small amount of allomorphic granular calcite form an amygdaloidal structure within the subcircular and irregular pores.

Hypabyssal rock

Sample YD-211202-4 is named in quartz monzonite porphyry and composed of phenocrysts with a monzonitic matrix (Fig. 18). Phenocrysts consist of anhedral granular quartz with a grain size less than 1.5mm and a small amount of subhedral granular plagioclase and potash feldspar. Quartz phenocrysts exhibit a melting corrosion structure. Polysynthetic twins are found in plagioclase porphyry. Xenomorphic granular potash feldspar and fibrous plagioclase form the matrix. Allomorphic granular K-feldspar contains fibrous plagioclase of a grain size less than 0.15mm, there is no apparent monzonitic texture.

Sample YD-211203-1 named in slightly ferruginous kaolinized monzonite porphyry and composed phenocrysts and the matrix is monzonitic (Fig. 18). Phenocrysts consist of allotriomorphic granular K-feldspar and subhedral granular plagioclase with particle sizes less than 3.0 mm, and some of these phenocrysts appear as plaques. Sericitized and argillaceous plagioclase porphyry is evident, as well as polysynthetic twins. K-feldspar phenocrysts are argillaceous in varying degrees, their surface is turbid, and the structure of striate feldspar is clearly visible. The matrix consists of euhedral granular plagioclase and quartz with grain sizes less than 0.7 mm and xenomorphic granular K-feldspar. There is a typical monzonitic structure formed by the authigenic granular plagioclase embedded in the relatively large allomorphic granular K-feldspar.

Plutonic rock

Sample YD-211202-3 is named in sericitized chloritized fine-grained biotite monzogranite and primarily consists of fine-grained plagioclase, K-feldspar, quartz, and biotite, with a small amount of Muscovite, with grain size less than 1.8 (a few up to 2.5) mm, mixed in and inlaid (Fig. 18). They are mainly fine-grained, with a small number of medium grains mixed and forming fine-grained granite structures. Plagioclase is sericitized to varying degrees, and its surface is turbid and shows polysynthetic twins. Some grains of potash feldspar are carbonated to different degrees. A striated structure and grid twin are visible, and there is an uneven distribution of carbonation. Plagioclase is the most common type of metasomatized mineral. Chloritization of biotite varies in degree, and most particles are completely chloritized.

Clastic sedimentary rock

Mangyeri formation (YD-211202-5)

This sample named in unequal-grain lithic arkose and composed mainly of unequal-grained sandy fragments (95%) with a particle size of less than 0.7 mm and matrix (5%). As a result of poor rounding and subangular of the fragments, the results indicate poor separation and a variation in particle size, in which the fine sand chip is the predominant distribution, followed by the medium sand chip, and a small part of coarse sand fragments mixed distribution. The composition consists of feldspar, quartz and rock fragments. Cemented by iron argillaceous and cryptocrystalline clay, it is supported by particles and cemented by contact.

Saniri formation (YD-211202-17)

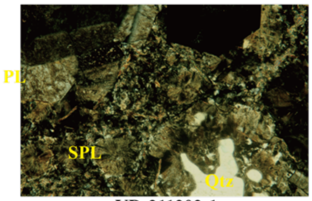
This sample named in unequal-grain lithic arkose and consists primarily of unequal-grained sandy clasts with grain sizes less than 1.9 mm (98%) and matrix (2%). It is evident that there is poor roundness and subangular in the fragments. The results also indicate that the grain size is variable, with silt fragments predominating, followed by medium sandy fragments, and a small percentage of coarse sand fragments mixed throughout the fragments. This composition is primarily composed of feldspar, quartz, and a small amount of rock fragments. It is also supported by grains and cemented through contact, in addition to being cemented by cryptocrystalline clay and argillaceous.

Baekmasan formation (YD-211203-2)

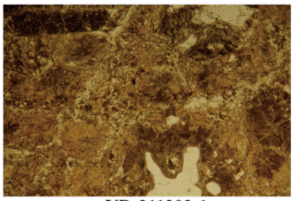
This sample is named in breccia unequal grain tuffaceous arkose and primarily composed of breccia sandy fragments with a size less than 3.0 mm (98%) and matrix (2%). It is poorly rounded and subangular; it has poor sorting and a variety of particle sizes, with coarse sand fragments being the most abundant, followed by medium sand fragments and a small amount of fine sand fragments, and 10% gravel mixed distribution. Sand-like clastic compositions are composed mainly of feldspar, quartz, and volcanic fragments, while gravel is composed primarily of quartz, some argillaceous rock fragments and Andesitic rock fragments. Cementation methods include cryptocrystalline iron clay, contact cementation, and granular support. To form the grain-supporting structure, the particles within the rock are in line contact with each other.

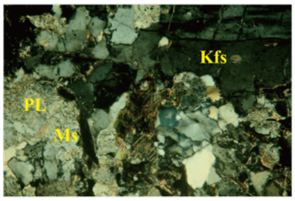
Dongjeongri formation (YD-211203-15)

This sample is named in breccia crystal fragments lithic sedimentary tuff and primarily composed of rock fragments, crystal fragments, breccia, and cement. Crystal fragments consist of quartz (with erosion structure) and feldspar (plagioclase and potash feldspar) with subangular shapes (Fig. 18). Approximately 30% of the particles are rounded with particle sizes less than 2.5mm, and 10% are rounded. The rock fragments consist primarily of volcanic fragments (andesite fragments and a few felsic fragments), with a small proportion of sedimentary fragments (argillaceous fragments), subangular, and the percentage of round abrasives is less than or equal to 30.5 mm. It is primarily composed of volcanic fragments (andesite fragments and felsic fragments), with a few sedimentary fragments (argillaceous fragments), mostly rounded, with a particle size below 4.5mm, accounting for 25%, grinded for 20%. Most of the particles are subangular. Cryptocrystalline clay and argillaceous cement account for 5% of the volcanic fragments above.

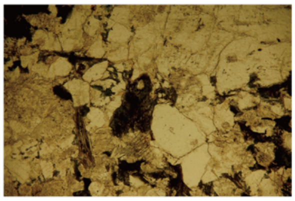


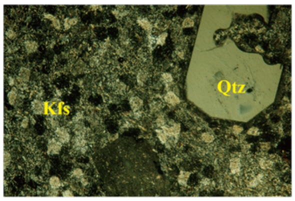
YD-211202-1


YD-211202-1

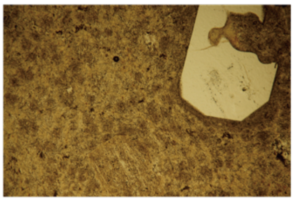


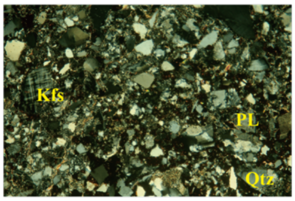
YD-211202-3


YD-211202-3

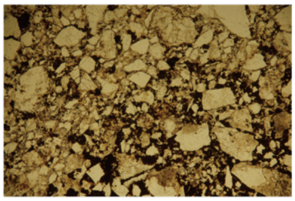


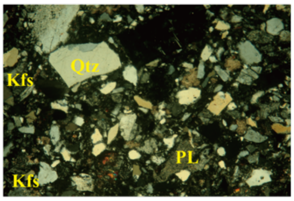
YD-211202-4


YD-211202-4

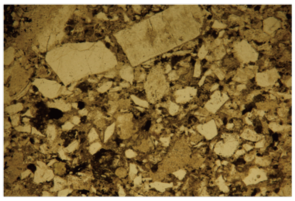


YD-211202-5


YD-211202-5



YD-211202-17


YD-211202-17

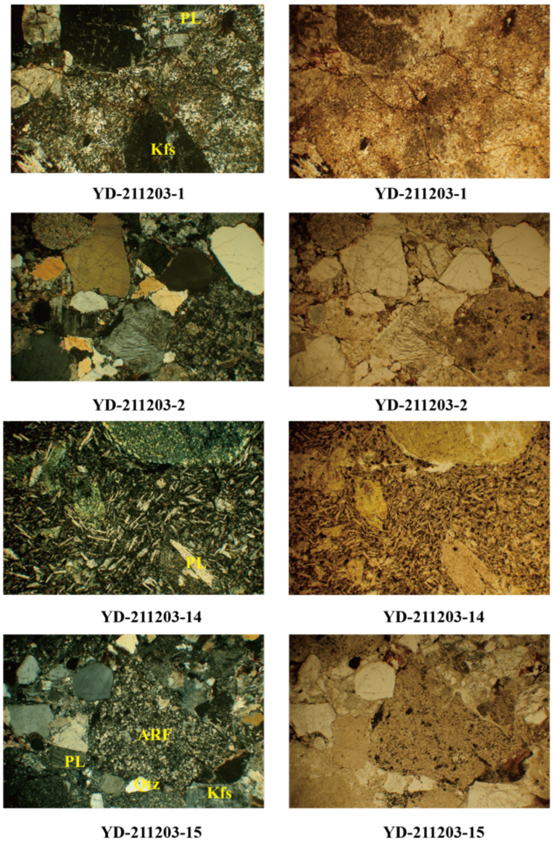


Figure 18 Thin-section microphotographs in plane- and cross-polarized light of sedimentary rock from the Yeongdong Basin (crossed [left] and open [right] nicols). Qtz, quartz; PL, plagioclase; Kfs, Potash feldspar; Ms, Muscovite; ARF, andesite rock fragments.

4.4.2 Zircon U-Pb analysis

For the LA-MC-ICPMS age determination, I analyzed 620 zircon grains from eleven samples and 460 analysis points in concordant age (Fig. 20). Zircon grains in detrital materials are anhedral or euhedral. Angular and euhedral prismatic crystals have prevailed in Cretaceous zircon grains, while metamorphic overgrowth rim is dominant in Precambrian zircons, and angular and euhedral, prismatic, oscillatory patterns are predominant in Triassic and Jurassic zircons (Fig. 19).

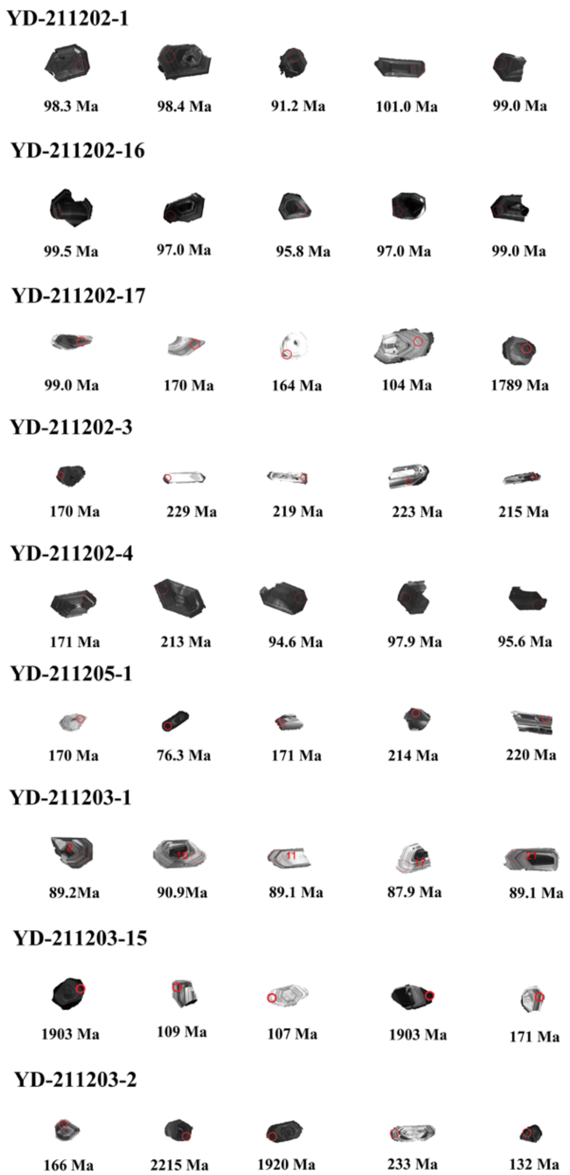


Figure 19 Typical Cathodoluminescence (CL) images of detrital zircon grains of the Yeongdong Basin. CL imaging has been used to recognize the zircons' internal textures and target coherent domains within grains for laser spots. Circles show laser analyze.

The U-Pb age data analyzed by LA-MC-ICPMS for the detrital zircons are in the appendix. Fig. 21 shows age distributions of the detrital zircons for the analyzed samples.

The age ranges from less than 76 Ma to about 2757 Ma for Yeongdong Basin, felsic subvolcanic rock concentrate on Turonian to Cenomanian age (Fig. 22). Plutonic rock concentrate on middle to late Jurassic epoch and late Triassic. Lithic arkoses concentrate on Middle Jurassic, Late Triassic epoch. Tuffaceous arkose concentrates on Middle Jurassic Late Triassic and Paleoproterozoic. Sedimentary tuff concentrates on Early Cretaceous, Middle Jurassic, Late Triassic and Paleoproterozoic.

Volcanic rock

30 zircon grains were analyzed 17 spots were available from sample YD-211202-1. Age peak is in Late Cretaceous (ca. 98 Ma), age proportion is total Cretaceous, the ratio of Th/U for total zircon grains is more than 0.4.

Subvolcanic Rock (Hypabyssal Rock) Adjacent Basin

30 zircon grains were analyzed 20 spots were available from sample YD211202-4. Age peak is in Late Cretaceous (ca. 96 Ma), age proportion is total Cretaceous, the ratio of Th/U for total zircon grains is more than 0.4. 30 zircon grains were analyzed 21 spots were available from sample YD-211203-1. Age peak is in Late Cretaceous (ca. 90 Ma), age proportion is total Cretaceous, the ratio of Th/U for total zircon grains is more than 0.4.

Plutonic rock adjacent basin

84 zircon grains were analyzed 67 spots were available from sample YD2112-2-3. Age peak is in Middle Jurassic (ca. 163 Ma) and Late Triassic (ca. 222 Ma), age proportion is 24% Jurassic and 73% Triassic.

Mangyeri Formation

100 zircon grains were analyzed 82 spots were available from sample YD-211202-5. Age peak is in Late Jurassic (ca. 173 Ma) and late Triassic (ca. 218 Ma), one zircon grain was found age in Campanian, age proportion is 2% Cretaceous, 78% Jurassic, 18% Triassic and 1% Permian.

Saniri Formation

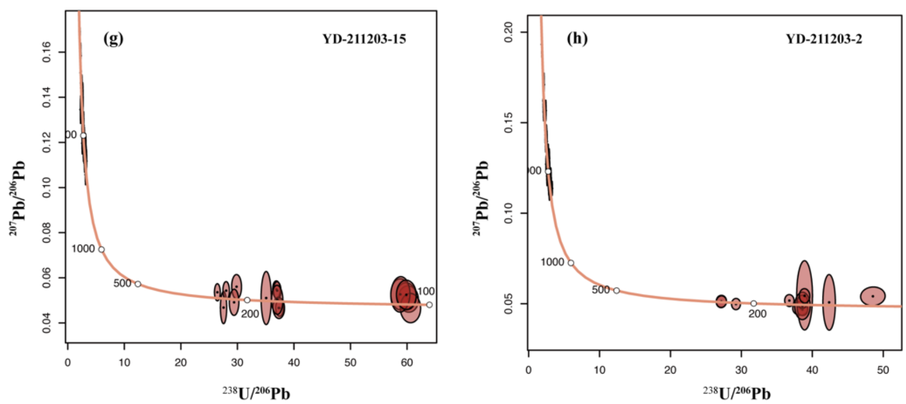
100 zircon grains were analyzed 66 spots were available from sample YD1202-17. Age peak is in Early Cretaceous (ca. 105 Ma) and middle Jurassic (ca. 172 Ma), age proportion is 5% Cretaceous, 56% Jurassic, 5% Triassic, carboniferous, Devonian, Silurian and Cambrian are all 2%, Neoproterozoic is 12%, Mesoproterozoic is 2%, Paleoproterozoic is 12% and Archean is 2%.

Dongjeongri Formation

100 zircon grains were analyzed 71 spots were available from sample YD211203-15. Age peak is in Early Cretaceous (ca. 108 Ma), middle Jurassic (ca. 173 Ma), Late Triassic (ca. 229 Ma) and Paleoproterozoic (ca. 1888 Ma), age proportion is 8% Cretaceous, 8% Jurassic, 7% Triassic, 76% Paleoproterozoic.

Baekmasan Formation

100 zircon grains were analyzed 89 spots were available from sample YD211203-2. Age peak is in Middle Jurassic (ca. 165 Ma), late Triassic (ca. 233 Ma) and Paleoproterozoic (ca. 1868 Ma), three zircon grains concentrate on Berriasian age (ca.154 Ma), age proportion is 1% Cretaceous, 9% Jurassic, 3% Triassic, 84% Paleoproterozoic and 2% Archean.



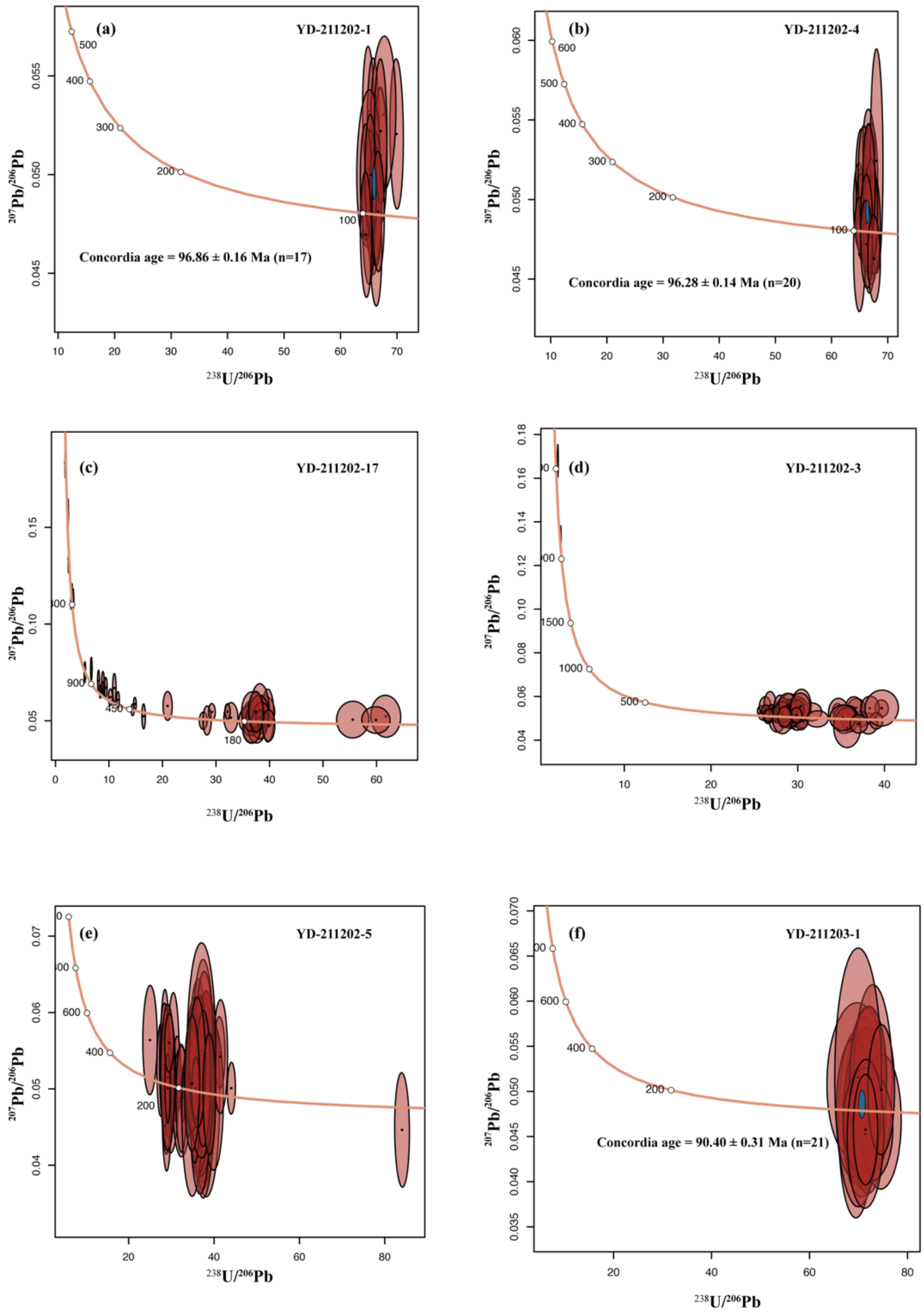


Figure 20 Terra-Wasserburg diagrams of LA-MC-ICPMS U-Pb for detrital zircon ages in the Yeongdong Basin.

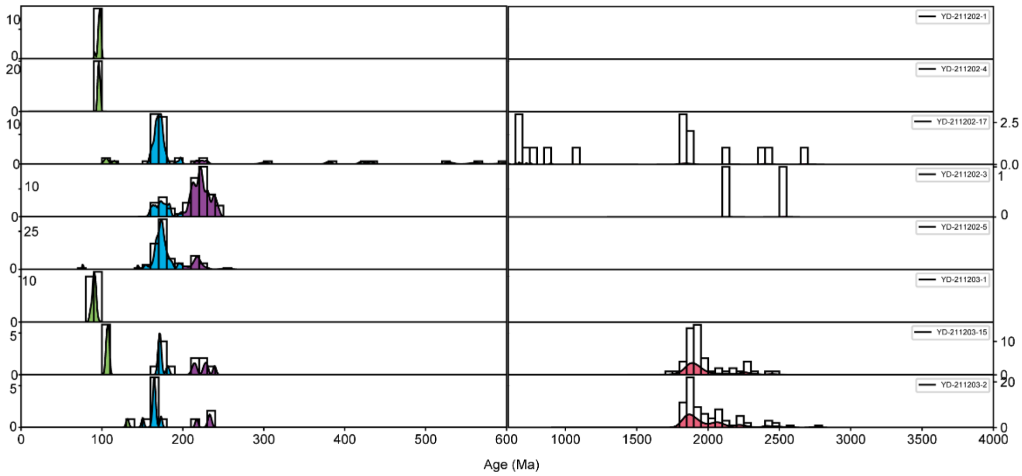


Figure 21 Probability distribution diagram of zircon ages in the Yeongdong Basin.

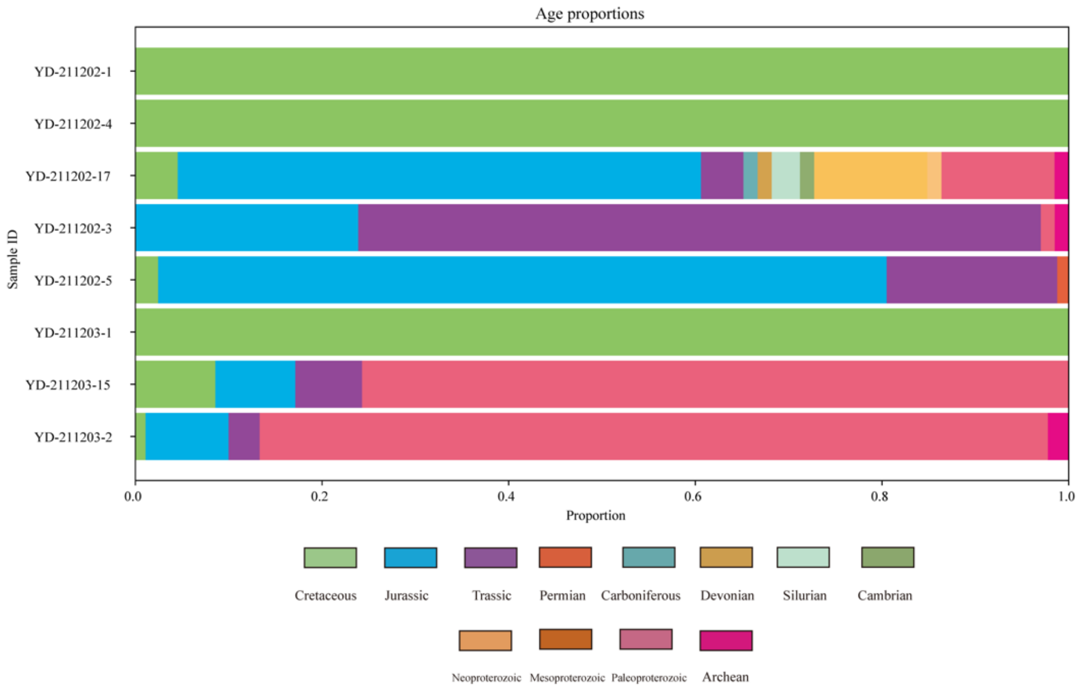


Figure 22 Age proportions for the Yeongdong Basin.

V. Discussion

5.1 Depositional age of the Eumseong, Gongju, Yeongdong, and Haenam basins

Detrital zircons originating from igneous sources can typically determine the maximum depositional age of sedimentary strata. Generally, a zircon is considered as igneous origin if its Th/U ratio is greater than 0.1 (Vavra et al., 1999); this criterion is met by all Cretaceous zircons found in the Eumseong, Gongju, Haenam, and Yeongdong basins. Given the high Th/U ratio and internal structures, I assume that the Cretaceous zircon grains analyzed are derived from igneous rocks. In order to determine the maximum depositional age of the two basins, I used the age of the youngest age group rather than that of the youngest grain (Dickinson and Gehrels, 2009).

5.1.1 Eumseong Basin

The occurrence of the Charophyta fossils in the green mudstone indicates the depositional age as the Hauterivian-Aptian age (Choi, 1995). 201014-1B shows the youngest concordant age in 106.57 ± 0.33 Ma (n=3), 201014-1C has young concordant age of 108.93 ± 0.52 Ma (n=2). 201014-11A young weighted mean age of 103.33 ± 0.45 Ma (n=2), 201014-12A has the grain of 113.8 ± 1.7 Ma, and 201014-9F has a youngest grain of 106.2 ± 5.7 Ma. 201014-9F has four Late Cretaceous zircons ranging 94-72 Ma, but the errors of their ages are not overlapped each other. This suggests that the deposition of the Eumseong Basin might be resumed in the Late Cretaceous shortly, although these data are not considered as the maximum depositional age of the whole Eumseong Basin. The youngest zircon age group (YC2σ(3+); (Dickinson and Gehrels, 2009) of the Eumseong Basin sediments is obtained by combining the zircon age data except for 201014-9F as ca. 103 Ma (Fig. 23).

5.1.2 Gongju Basin

Plant fossils, Frenelopsis species, reported from black shale in the southwestern part of the basin (Song et al., 1990) are correlated with those found in the upper Hayang Group (e.g., Sagok and Chunsan formations) in the Gyeongsang Basin (Chang, 1999), indicating that the Gongju Group was formed during the late Early Cretaceous. Sample 201013-1A, 201015-21, 201015-26, and 201015-21 have no Cretaceous zircons, the youngest age group concentrate on Triassic to Permian. 201013-2A shows the youngest concordant age group in 107.68 ± 0.34 Ma (n=4). 201013-4A has zircon grains with ages of 57.6 and 58.8 Ma corresponding to Cenozoic. Like the case of the Eumseong Basin, these ages are suggestive of additional sedimentation in the Gongju Basin during the Cenozoic. The maximum depositional age was constrained by the average age of the youngest age group of detrital zircons (Dickinson and Gehrels, 2009) of the Gongju Basin samples except for 201013-4A as ca. 108 Ma (Fig. 23).

5.1.3 Haenam Basin

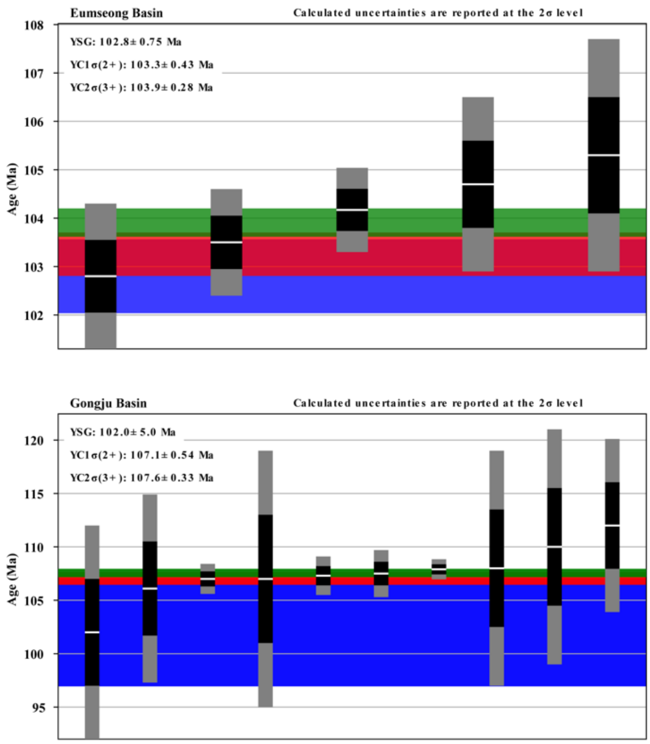


Figure 23 Maximum depositional age (MDA) calculations for the Eumseong and Gongju basins.

The pterosaurs, web-footed birds and dinosaurs, reported from volcanic tuffaceous material in the Uhangri formation indicate the depositional age from Cenomanian to Campanian time. HN–211201-11 of the Hwangsan Formation shows youngest concordant age in 90.35 ± 0.17 Ma (n=77), HN-211201-14 shows the youngest concordant age in 93.01 ± 0.19 Ma (n=69), two zircon grains with age in 106 ± 1.52 Ma and 133 ± 1.60 Ma indicates that small-scale volcanic activity may occurred Valanginian to Albian in the early Cretaceous. HN-211201-2 of the Uhangri Formation has the youngest concordant age in 82.77 ± 0.44 Ma (n=79). The youngest zircon age group (YC2σ(3+); (Dickinson and Gehrels, 2009) of the Haenam Basin sediments is obtained by combining the zircon age data as ca. 80 Ma (Fig. 24).

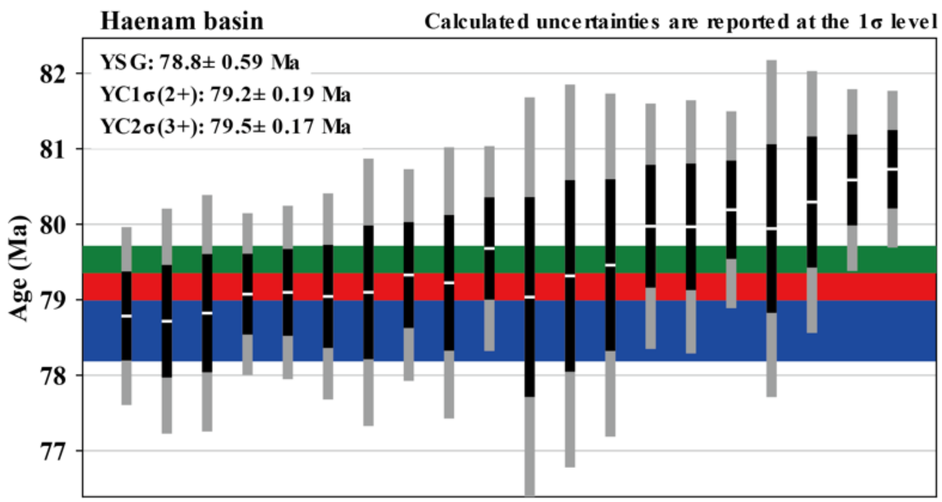


Figure 24 Maximum depositional age (MDA) calculations for the Haenam basin.

5.1.4 Yeongdong Basin

Paleontological analysis divides the sedimentation of Yeongdong group into two stages, Neocomian (covered by the Berriasian, Valanginian and Hauterivian) and Aptian to Albian in the Early Cretaceous. YD-211202-5 of the Mangyeri formation shows young concordant age in 180 ± 1.6 Ma (n=79), and one youngest zircon grain age with 76.3 ± 0.92 Ma suggests that the Haenam Basin might be deposited again in the late Cretaceous soon. YD-211202-17 of the Saniri formation shows youngest concordant age group in 107.29 ± 1.19 Ma (n=3). YD-2112-2-15 of the Dongjeongri formation shows youngest age group in 107 ± 0.52 Ma (n=6). YD-211203-2 of the Baekmasan formation has a youngest grain age with 132 ± 1.7 Ma. The maximum depositional age was constrained by the average age of the youngest age group of detrital zircons (Dickinson and Gehrels, 2009) of the Yeongdong Basin samples except for YD-211202-5 as ca. 107 Ma (Fig. 25).

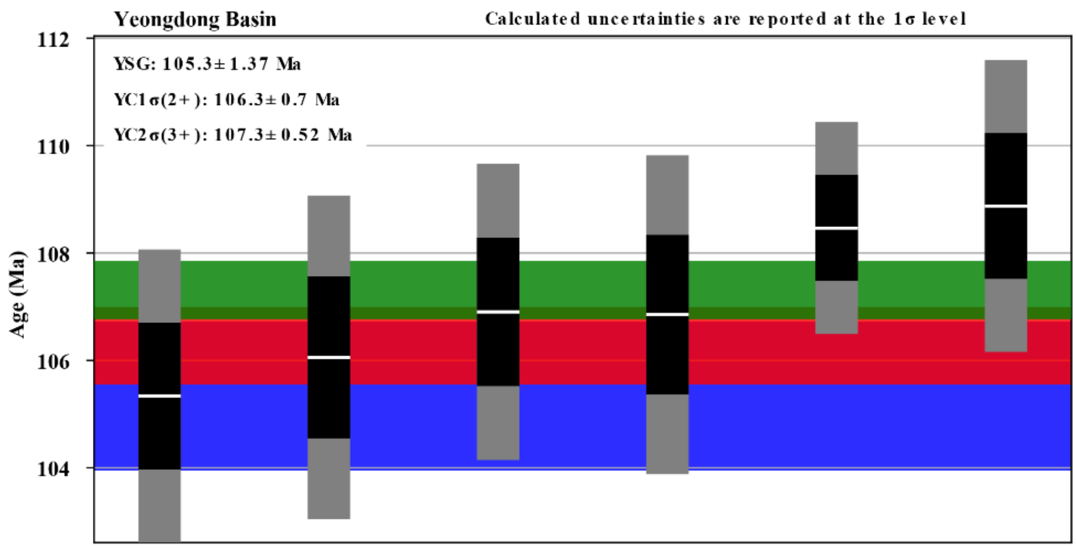


Figure 25 Maximum depositional age (MDA) calculations for the Yeongdong Basin.

5.2 The provenance of the Eumseong, Gongju, Yeongdong and Haenam Basin Sediments

The spatial differences of the zircon age spectra in the Eumseong, Gongju and Yeongdong basins are well explained by sediment supply from their adjacent basement rocks (Figs 2, 3, 4 and 21), except for the Paleozoic to Mesoproterozoic zircon ages. In the Eumseong Basin, northern part of the basinfill (201014-11A, 12A) received sediments mainly from Jurassic granite and Paleoproterozoic gneiss while the other parts (201014-1C, 201015-9) were supplied exclusively from Paleoproterozoic basement rocks. On the other hand, the uppermost sediments (201014-1B, 9F) including various Mesoproterozoic to Paleozoic and Triassic zircons suggest significant sediment supply from the western Gyeonggi Massif. 201014-9F shows the highest proportion of the Cretaceous (26%) and Mesoproterozoic to Paleozoic (37%) zircon ages among the samples. The Cretaceous zircons might be derived from syndepositional volcanism (Fig. 2).

In the Gongju Basin, most parts received sediments mainly from the adjacent Paleoproterozoic basement rocks except for the northernmost area (201013-4A). Jurassic aplite might have provided sediments only to the northern parts of the basin (201013-1A, 2A, 4A). Considerable amounts of the Neoproterozoic to Paleozoic zircon grains are included in the northern part (201013-1A, 4A) and southern part (201015-32). The uppermost sample (201013-4A) shows the highest proportion of the Cretaceous (24%) and Mesoproterozoic to Paleozoic (21%) zircons among the samples. The andesitic rock at the boundary of the basin is the only candidate for the source of the Cretaceous zircons in this sample, considering the lithology around the basin.

In the Yeongdong basin, the uppermost part (YD-211203-15, YD-211203-2) received sediments primarily from adjacent Paleoproterozoic basement rocks, as well as significant amounts of zircon grains from the Jurassic and Triassic periods. Otherwise, Jurassic and Triassic granite might have provided mainly sediments for the lower parts (YD-211202-5, YD-211202-17). Only the Saniri Formation includes Paleozoic and Neoproterozoic zircon grains, Carboniferous to Permian age might be from adjacent Paleozoic sandstones, and Devonian, Silurian, Cambrian and Neoproterozoic zircons suggest supplies from the southwestern Okcheon metamorphic Belt. The proportion of Cretaceous age gradually increased from the lowest Mangyeri formation, but suddenly declined in the Baekmasan formation, indicating changes in synsedimentary volcanism.

In the Haenam basin, the majority of the Cretaceous zircon grains are associated with syndepositional volcanic activity. Approximately one percent of each sample is composed of Jurassic zircon grains. The uppermost sample is composed of Triassic zircon grains, suggesting a minor contribution from adjacent granite. An apparent Paleoproterozoic to Neoproterozoic zircon grain age indicates further sediment supply from the Okcheon metamorphic belt.

The source of the sediment input of the Mesoproterozoic to Paleozoic zircons in the uppermost samples in the Eumseong and Gongju basins and lower sample in the Yeongdong Basin should be Paleozoic metasedimentary rocks in the central Okcheon Metamorphic Belt and the western Gyeonggi Massif, located not far from each basin. The Okcheon Metamorphic Belt has been subdivided into the northeastern Taebaeksan Basin and southwestern Okcheon Basin. Metavolcanic and metasedimentary rocks are found of the Mesozoic, Neoproterozoic, and Paleozoic ages, along with granitic intrusions (Kim et al., 2006; Lee et al., 1998; Park, 2011). The northeastern part of the Okcheon Basin (central Okcheon Metamorphic Belt) includes Upper Paleozoic metasedimentary rocks which include detrital zircon grains showing similar age spectra to those of the Taean Formation (Cho et al., 2013; Kim et al., 2014). Metasedimentary rocks of the Okcheon Metamorphic Belt and sedimentary rocks of the Pyeongan Supergroup contain a few Paleozoic detrital zircons of the Cambrian, Carboniferous, and Permian periods (Kim et al., 2017a; Lee et al., 2010c).

The Gyeonggi Massif consists mainly of Paleo- to Neoproterozoic rocks, including banded paragneiss, migmatite, orthogneiss, and quartzofeldspathic gneiss with minor amphibolite, schist, and quartzite with vestiges of the Neoarchean basement blocks (Kim et al., 2014). The western Gyeonggi Massif has Neoproterozoic rocks, including Paleozoic metasedimentary rocks and late Permian to early Triassic metamorphic and plutonic rocks (Kim et al., 2021 amongst others; Kim et al., 2014; Oh et al., 2009). The Upper Paleozoic metasedimentary rocks (Taean Formation) widely distributed in the western Gyeonggi Massif include detrital zircon grains showing wide age ranges from Archean to Devonian (Cho, 2007; Cho et al., 2010; Han et al., 2017; Kim et al., 2014 amongst others.). Recently discovered igneous activity within the Gyeonggi Massif from the Late Ordovician to the Early Devonian (Park et al., 2017).

5.3 The evolution of Eumseong, Gongju, Haenam and Yeongdong basin.

In the Late Cretaceous, the Cretaceous nonmarine strike-slip basins in the Korean Peninsula were closed by subduction direction changes of the oceanic plate beneath the Eurasian Plate (Choi and Lee, 2011; Lee and Paik, 1990; Lee, 1992b). The Izanagi Plate (Paleo-Pacific Plate) changed the subducting direction from north to northwest (Lithgow-Bertelloni and Richards, 1998), resulting in the compressional stress to the continental margin. The Gongju (Lee, 1990) and Jinan basins (7 in Fig. 1; Choi and Lee, 2011; Lee, 1992b) are supposed to have experienced basin inversion and uplift of the basinfill due to the compression. The Neungju Basin was partly covered by volcanic and volcaniclastic rocks erupted at adjacent area during 87-85 Ma (Ahn et al., 2014), and then alluvial fan deposition occurred shortly after the eruption (Lee et al., 2019; Lee and Park, 2020). On the contrary, the Pungam Basin (2 in Fig. 1) was formed in the Late Cretaceous (ca. 84 Ma) as a transpressional basin, and continued deposition until ca. 70 Ma (Cheong and Kim, 1999; Kim, 1998).

Samples in the Eumseong and Gongju basins with high proportion of Cretaceous ages (201014-9F, 201013-4A, YD-211203-15) show common characteristics. They are conglomerate with pebbles comprising volcanic rocks and include Late Cretaceous (94-72 Ma; 201014-9F) and Paleogene (59-58 Ma; 201013-4A) zircon grains. Furthermore, the three samples commonly include Mesoproterozoic to Paleozoic zircon grains with various ages suggestive of changes in provenance of each basin. These characteristics suggest that sudden deposition of coarse sediments occurred at the latest stage of the basin evolution after the deposition of the rest of the basinfill of the basins, probably at Late Cretaceous (Eumseong Basin) and Paleogene (Gongju Basin) or later. A similar case is found in the Neungju Basin as the deposition of the alluvial fan deposit on the volcanic and volcaniclastic rocks in the basin after 85 Ma (Lee et al., 2019; Lee and Park, 2020). Although the zircon age spectrum of the Saniri Formation sample in the Yeongdong Basin shows similar aspects with these samples, this sample was deposited in the early stage of the basin evolution. Thus, the Yeongdong Basin does not fit this explanation.

Conglomerate deposition at the uppermost strata of the Cretaceous subbasins in Korea might be a response to the changes in the tectonic environment caused by reactivation of the boundary faults of the Okcheon Metamorphic Belt in the Late Cretaceous to Early Cenozoic time. During this period, the Korean Peninsula experienced the orogeny called 'Bulguksa Orogeny' caused by the oceanic plate subduction with associated magmatism occurred in 110-50 Ma (Jin, 1988), generally correlated to Sichuanian Tectonism in China (Kim, 1996b; Wan and Sun, 1993). The orogeny is interpreted to have produced E-W trending folds and thrusts and resulted in the inversion of the subbasins (Kim, 1996b). The timing of the conglomerate deposition varies from basins to basins, indicating that the reactivation of the boundary faults did not occur contemporaneously, and the compressional tectonic environment continued until after 58 Ma.

Samples collected in the Yeongdong Group were mainly deposited in Albian of the late Cretaceous, with an abrupt appearance of igneous rock corresponding to the Campanian through the Cenomanian in the late Cretaceous between 76 Ma and 99 Ma. A similar phenomenon was also observed in the Haenam Basin in the late Cretaceous. Three tuff samples were found with zircons dated to the late Cretaceous, indicating that the basin experienced transient volcanic activity in the early Cretaceous, followed by a sudden eruption in the late Cretaceous between 78.7 Ma and 100 Ma, which were all roughly in the same age range as the Yeongdong Basin, suggesting a sudden increase in volcanic activity due to the change in the subduction direction of the Paleo Pacific plate.

VI. Conclusions

The depositional ages and provenance of the Cretaceous Eumseong, Gongju, Haenam, and Yeongdong basins in Korea were investigated by detrital zircon U-Pb geochronology, to understand the response of the basins to the changes in the tectonic environment of the East Asian continental margin in the Late Cretaceous. Twenty-two clastic samples were collected in the four basins, and 1357 ages ranging from 3400 to 58 Ma were obtained from 1901 zircon grains. The maximum depositional age for the Eumseong, Gongju, Haenam and Yeongdong basins are 103 $\pm$ 0.28 Ma, 107.6 $\pm$ 0.33 Ma, 79.5 $\pm$ 0.17 Ma and 107.3 $\pm$ 0.52 Ma, respectively, consistent with previous paleontological studies.

The main provenance of the Eumseong, Gongju, and Yeongdong basins is their adjacent basement rocks, Paleoproterozoic metamorphic rock and Triassic, Jurassic granite. Additional sediment input of three basins were derived from Paleozoic metasedimentary rocks and Triassic and Cretaceous igneous rocks in the western Gyeonggi Massif and Okcheon Metamorphic Belt, respectively, in the late stage of the deposition, the Haenam Basin is syn-sedimentary porphyritic rock and the adjacent basement rock comprising Paleoproterozoic metamorphic rocks and Jurassic, Triassic granitoids. Conglomerates in the uppermost part of the Eumseong and Gongju basins are supposed to have been deposited in the Late Cretaceous to Paleogene time, suggesting the reactivation of the northwestern boundary fault of the Okcheon Metamorphic Belt. The Yeongdong and Haenam basins show sudden intensification of volcanism in the Late Cretaceous, caused by the changes in the subduction of the Paleo-Pacific Plate.

Reference

Ahn, K.-S., Huh, M., and Son, J.-M., 2014, Geological history and landscape of Mudeungsan National Park: Journal of the Geological Society of Korea, v. 50, no. 1, p. 91-105.

Andersen, T., 2002, Correction of common lead in U–Pb analyses that do not report 204Pb: Chemical geology, v. 192, no. 1-2, p. 59-79.

Baag, C., 1994, Geophysical studies on major faults in the Ogcheon Fold Belt: Aeromagnetic data interpretation on the Jinan sedimentary basin, Korea: Korean Journal of Petroleum Geology, v. 2, p. 33-38.

Bowden, C. D., 2007, Epithermal systems of the Seongsan district, South Korea an investigation on the geological setting and spatial and temporal relationships between high and low sulfidation systems: James Cook University.

Bruguier, O., Lancelot, J., and Malavieille, J., 1997, U–Pb dating on single detrital zircon grains from the Triassic Songpan–Ganze flysch (Central China): provenance and tectonic correlations: Earth and Planetary Science Letters, v. 152, no. 1-4, p. 217-231.

Chang, H., 1982, A study on the Sedimentary Facies and Paleoenvironment of the Cretaceous Kongju Basin: Masters Thesis, Korea University.

Chang, H., 1999, Upper Mesozoic Stratifraphic synthesis of Korean Peninsula: Economic and Environmental Geology, v. 32, no. 4, p. 353-363.

Chang, K., 1977, Late Mesozoic stratigraphy, sedimentation and tectonics of southeastern Korea: J. Geol. Soc. Korea, v. 13, p. 76-90.

Chang, K. H., 1975, Cretaceous stratigraphy of southeast Korea: Journal of the Geological Society of Korea, v. 11, no. 1, p. 1-23.

Chang, R.-I., Park, S.-G., Meen, W.-S., and Lee, S.-Y., Tectonics, 2003, sedimentation, and magmatism of the Cretaceous Gyeongsang (Kyongsang) Basin, Korea: integrated approach to defining basin history and event mineralization, *in* Proceedings Proceedings of the KSEEG Conference, The Korean Society of Economic and Environmental Geology, p. 27-31.

Cheong, D., and Kim, K., 1999, Basin evolution and provenance of sediments of the Cretaceous Poongam sedimentary Basin: Korean journal of petroleum geology, v. 7, p. 28-34.

Cheong, D.-K., and Kim, Y.-I., 1996, Sedimentological study of the Nakdong Formation to analyse the forming and evolving tectonics of the Cretaceous Gyeongsang Basin, I: depositional setting, source, and paleocurrent analyses of the Nakdong Formation in the southwestern Gyeongsang Basin: Economic and Environmental Geology, v. 29, no. 5, p. 639-660.

Cho, D., 2007, SHRIMP zircon dating of a low-grade meta-sandstone from the Taean Formation: Provenance and its tectonic implications: KIGAM Bulletin, v. 11, no. 8, p. 3-14.

Cho, M., Cheong, W., Ernst, W. G., Yi, K., and Kim, J., 2013, 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: Journal of Asian Earth Sciences, v. 63, p. 234-249.

Cho, M., and Kim, H., 2005, Metamorphic evolution of the Ogcheon belt, Korea: a review and new age constraints: International Geology Review, v. 47, no. 1, p. 41-57.

Cho, M., Na, J., and Yi, K., 2010, SHRIMP U-Pb ages of detrital zircons in metasandstones of the Taean Formation, western Gyeonggi massif, Korea: Tectonic implications: Geosciences Journal, v. 14, no. 2, p. 99-109.

Choi, D. K., and Park, J. B., 1987, Palynology of the Jinju Formation (Lower Cretaceous), Waegwan-Daegu and Jinju areas, Korea: Journal of the Paleontological Society of Korea, v. 3, no. 1, p. 28-43.

Choi, H.-I., 1986b, Sandstone petrology of the Sindong Group, southwestern part of the Gyeongsang Basin: Journal of the Geological Society of Korea, v. 22, no. 3, p. 212-223.

Choi, S., 1989, Fossil charophytes from the Nagdong formation in Seonsangun, Gyeongsangbukdo, Korea: Journal of the Paleontological Society of Korea, v. 5, p. 28-38.

Choi, S., 1995, Charophytes from the Chopyeong Formation (Cretaceous) of the Eumsung Basin, Korea: Journal of the Geological Society of Korea, v. 31, p. 523-528.

Choi, S.-G., Ryu, I.-C., Pak, S. J., Wee, S.-M., Kim, C. S., and Park, M.-E., 2005, Cretaceous epithermal gold–silver mineralization and geodynamic environment, Korea: Ore Geology Reviews, v. 26, no. 1-2, p. 115-135.

Choi, T., and Lee, Y. I., 2011, Thermal histories of Cretaceous basins in Korea: Implications for response of the East Asian continental margin to subduction of the Paleo-Pacific Plate: Island Arc, v. 20, no. 3, p. 371-385.

Choi, Y., 1996, Structural evolution of the Cretaceous Eumseong Basin, Korea [unpublished Ph. D. thesis]: Seoul National University, Seoul, Korea, 159 p, *in* Proceedings Korean with English abstract.

Chough, S., 2000, Tectonic and sedimentary evolution of the Korean peninsula: a review and new view: Earth-Science Reviews, v. 52, no. 1-3, p. 175-235.

Chough, S., and Sohn, Y., 2010, Tectonic and sedimentary evolution of a Cretaceous continental arc–backarc system in the Korean peninsula: new view: Earth-Science Reviews, v. 101, no. 3-4, p. 225-249.

Chun, H., 1994, Fossil Floral and Faunal Assemblages and Paleoenvironmental Modelling Study on the Cretaceous Sedimentary Basins Scattered in/near the Ogcheon Belt: Annual Rep., v. 94.

Chun, S., 1992, Tectonic history of Crataceous sedimentary basins in the southwestern Korean Peninsula and Yellow Sea: The Sedimentary Basins in the Korean Peninsula and Adjacent Seas, p. 60-76.

Chun, S. S., and Chough, S. K., 1995, The Cretaceous Uhangri Formation, SW Korea: lacustrine margin facies: Sedimentology, v. 42, no. 2, p. 293-322.

Cluzel, D., 1992, Late Palaeozoic to early Mesozoic geodynamic evolution of the Circum-Pacific orogenic belt in South Korea and Southwest Japan: Earth and Planetary Science Letters, v. 108, no. 4, p. 289-305.

Dickinson, W. R., and Gehrels, G. E., 2009, Use of U–Pb ages of detrital zircons to infer maximum depositional ages of strata: A test against a Colorado Plateau Mesozoic database: Earth and Planetary Science Letters, v. 288, no. 1-2, p. 115-125.

Doh, S.-J., Cho, Y.-Y., and Suk, D., 1996, Remagnetization of the Cretaceous sedimentary rocks in the Yeongdong Basin: Economic and environmental geology, v. 29, no. 2, p. 193-209.

Han, S., de Jong, K., and Yi, K., 2017, Detrital zircon ages in Korean mid-Paleozoic meta-sandstones (Imjingang Belt and Taean Formation): Constraints on tectonic and depositional setting, source regions and possible affinity with Chinese terranes: Journal of Asian Earth Sciences, v. 143, p. 191-217.

Hu, Z., Liu, Y., Gao, S., Xiao, S., Zhao, L., Günther, D., Li, M., Zhang, W., and Zong, K., 2012, A “wire” signal smoothing device for laser ablation inductively coupled plasma mass spectrometry analysis: Spectrochimica Acta Part B: Atomic Spectroscopy, v. 78, p. 50-57.

Huh, M., Paik, I., Chung, C., Hwang, K., and Kim, B., 2003, Theropod tracks from Seoyuri in Hwasun, Jeollanam-do, Korea: Occurrence and petrological significance: Journal of the Geological Society of Korea, v. 39, p. 461-478.

Huh, M., Paik, I. S., Lockley, M. G., Hwang, K. G., Kim, B. S., and Kwak, S. K., 2006, Well-preserved theropod tracks from the Upper Cretaceous of Hwasun County, southwestern South Korea, and their paleobiological implications: Cretaceous Research, v. 27, no. 1, p. 123-138.

Hwang, K.-G., Huh, M., Lockley, M. G., Unwin, D. M., and Wright, J. L., 2002, New pterosaur tracks (Pteraichnidae) from the Late Cretaceous Uhangri formation, southwestern Korea: Geological Magazine, v. 139, no. 4, p. 421-435.

Jin, M.-S., 1988, Geochemistry of the Cretaceous to Early Tertiary Granitic Rocks in Southern Korea Pt. II. Trace Elements Geochemistry: Journal of the Geological Society of Korea, v. 24, no.10, p. 168-188.

Jonghyuk, L., and Junghwan, K., 1971, Geological map of Jeungpyong sheet (1:50000).

Jung, W., Kil, Y., and Huh, M., 2014, A petrological study of the Mudeungsan Tuff focused on Cheonwangbong and Anyangsan: The Journal of the Petrological Society of Korea, v. 23, no. 4, p. 325-336.

Kang, P. C. a. L., J.H., 1974, Geological map of Gwangjeong sheet (1:50000).

Kim, B., 1996a, Sequential development of depositional systems in a strike-slip basin: southern part of the Cretaceous Youngdong Basin, Korea: Unpublished Ph. D. thesis, Yonsei University, Seoul.

Kim, B., and Park, B., 1966, Geological report of the Dongbok sheet (1: 50,000): Geological Survey of Korea, 33p.

Kim, B.-C., Choi, S.-J., Suzuki, K., Adachi, M., Obayashi, T., and Yu, K.-M., 1997, Provenance of Createaceous sandstones in the southeastern Yongdong Basin, Korea: CHIME geochronology of detrital monazites: Geosciences Journal, v. 1, no. 1, p. 37-49.

Kim, I., 1991, Geochemistry of hydrothermal alteration and clay deposits in the Haenam area, southwest Korea: Ph. D. Thesis, Univ. Tokyo, p. 169-219.

Kim, I. J., and Nagao, K., 1992, K-Ar ages of the hydrothermal clay deposits and the surrounding igneous rocks in southwest Korea: The Journal of the Petrological Society of Korea, v. 1, no. 1, p. 58-70.

Kim, J. H., 1996b, Mesozoic tectonics in Korea: Journal of Southeast Asian Earth Sciences, v. 13, no. 3-5, p. 251-265.

Kim, K., 1998, Sedimentological study of the Cretaceous sedimentary sequence in the Poongam Basin in the Northern Hongcheon Area, Kangwon-do: MS thesis, Kangwon National University, Kangwon-do, 96 p (in Korean).

Kim, K., and Hwang, J., 1986, Geological report of the Yongdong sheet (1: 50,000): Korea Institute of Energy and Resources, Seoul.

Kim, M. G., Lee, Y. I., Choi, T., and Orihashi, Y., 2017a, The tectonic setting of the eastern margin of the Sino-Korean Block inferred from detrital zircon U–Pb age and Nd isotope composition of the Pyeongan Supergroup (upper Palaeozoic – Lower Triassic), Korea: Geological Magazine, v. 156, no. 3, p. 471-484.

Kim, S., Kim, Y.-G., Jo, H., Jeong, K., and Chough, S., 2009, Depositional facies, architecture and environments of the Sihwa Formation (Lower Cretaceous), mid-west Korea with special reference to dinosaur eggs: Cretaceous Research, v. 30, no. 1, p. 100-126.

Kim, S., You, H., and Woo, Y., 1977, Geological Map of the Gongju Sheet (1: 50000): Korea.

Kim, S. J., Ju, Y. J., Song, J. H., Hong, S. G., and Yi, K., 2015, SHRIMP U-Pb detrital zircon ages in Southwest Eumseong Basin.

Kim, S. W., Kwon, S., Ryu, I.-C., Jeong, Y.-J., Choi, S.-J., Kee, W.-S., Yi, K., Lee, Y. S., Kim, B. C., and Park, D. W., 2012, Characteristics of the Early Cretaceous Igneous Activity in the Korean Peninsula and Tectonic Implications: The Journal of Geology, v. 120, no. 6, p. 625-646.

Kim, S. W., Kee, W.-S., Lee, S. R., Santosh, M., and Kwon, S., 2013, Neoproterozoic plutonic rocks from the western Gyeonggi massif, South Korea: implications for the amalgamation and break-up of the Rodinia supercontinent: Precambrian Research, v. 227, p. 349-367.

Kim, S. W., Kwon, S., Jeong, Y.-J., Kee, W. S., Lee, B. C., Byun, U. H., Ko, K., Cho, D.-L., Hong, P. S., Park, S.-I., and Santosh, M., 2021, The Middle Permian to Triassic tectono-magmatic system in the southern Korean Peninsula: Gondwana Research, v. 100, p. 302-322.

Kim, S. W., Kwon, S., Park, S.-I., Yi, K., Santosh, M., and Kim, H. S., 2017b, Early to Middle Paleozoic tectonometamorphic evolution of the Hongseong area, central western Korean Peninsula: Tectonic implications: Gondwana Research, v. 47, p. 308-322.

Kim, S. W., Kwon, S., Santosh, M., Cho, D.-L., Kee, W.-S., Lee, S.-B., and Jeong, Y.-J., 2019, Detrital zircon U-Pb and Hf isotope characteristics of the Early Neoproterozoic successions in the central-western Korean Peninsula: Implication for the Precambrian tectonic history of East Asia: Precambrian Research, v. 322, p. 24-41.

Kim, S. W., Kwon, S., Yi, K., and Santosh, M., 2014, Arc magmatism in the Yeongnam massif, Korean Peninsula: Imprints of Columbia and Rodinia supercontinents: Gondwana Research, v. 26, no. 3-4, p. 1009-1027.

Kim, S. W., Oh, C. W., Ryu, I.-C., Williams, I., Sajeev, K., Santosh, M., and Rajesh, V., 2006, Neoproterozoic bimodal volcanism in the Okcheon Belt, South Korea, and its comparison with the Nanhua Rift, South China: implications for rifting in Rodinia: The journal of Geology, v. 114, no. 6, p. 717-733.

Ko, K., Kim, S., and Gihm, Y., 2021, U-Pb Age Dating and Geochemistry of Soft-Sediment Deformation Structure-Bearing Late Cretaceous Volcano-

Sedimentary Basins in the SW Korean Peninsula and Their Tectonic Implications: Minerals, v. 11, no. 5.

Koh, 1996, Geochemical characteristics of the cretaceous volcanic rocks and Bukok hydrothermal deposits in the Haenam volcanic field, Chollanamdo, Korea: Seoul National University.

Kwon, B.-D., Jung, G.-J., and Baag, C.-E., 1994, Geophysical studies on major faults in the Gyeonggi Massif: Gravity and electrical surveys in the Gongju Basin: The Korean Journal of Petroleum Geology, v. 2, no. 2, p. 43-50.

Lee, D. W., 2002, Strike–slip fault tectonics and basin formation during the Cretaceous in the Korean Peninsula: Island Arc, v. 8, no. 2, p. 218-231.

Lee, D. W., and Paik, K. H., 1990, Evolution of strike-slip fault-controlled Cretaceous Yongdong Basin, South Korea: signs of strike-slip tectonics during infilling: Journal of the Geological Society of Korea, v. 26, no. 3, p. 257-276.

Lee, H., 1986, Structural Analysis of Gong-ju Pull-Apart Basin. Korea, Master Thesis, Seoul Nat. Univ. Seoul.

Lee, H., Sim, M. S., and Choi, T., 2019, Stratigraphic evolution of the northern part of the Cretaceous Neungju Basin, South Korea: Geosciences Journal, v. 23, no. 6, p. 849-865.

Lee, J., 1990, Structural evolution of the Gongju Basin: PhD thesis, Seoul National University.

Lee, K.-S., Chang, H.-W., and Park, K.-H., 1998, Neoproterozoic bimodal volcanism in the central Ogcheon belt, Korea: age and tectonic implication: Precambrian Research, v. 89, no. 1-2, p. 47-57.

Lee, M., 1992a, The cretaceous volcanic activities and petrology in Kyonggi Massif-on the Kapcheon, Eumsung and Kongju Basin: J. Geol. Soc. Korea., v. 28, p. 314-333.

Lee, S. M., Kim, H. S., and Oh, I. S., 1986, Metamorphic petrology of Precambrian gneisses in Samcheok-Jukbyeon area: Journal of the Geological Society of Korea, v. 22, no. 3, p. 257-277.

Lee, T.-H., and Park, K.-H., 2020, Detrital Zircon U-Pb Geochronology and Hf Isotope Geochemistry of the Hayang Group, SE Korea and the Himenoura and Goshoura Groups, SW Japan: Signs of Subduction-Related Magmatism after a Long Resting Period: Minerals, v. 10, no. 11.

Lee, T.-H., Park, K.-H., Chun, J.-H., and Yi, K.-W., 2010a, SHRIMP U-Pb zircon ages of the Jinju Formation and Silla conglomerate, Gyeongsang Basin: The Journal of the Petrological Society of Korea, v. 19, no. 1, p. 89-101.

Lee, Y., Cho, M., Cheong, W., and Yi, K., 2014, 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, v. 26, no. 5, p. 408-416.

Lee, Y.-U., 1992b, Stratigraphy, depositional environments, and evolution of the cretaceous Chinan basin: PhD thesis, Seoul National University.

Lee, Y. I., Choi, T., Lim, H. S., and Orihashi, Y., 2010b, Detrital zircon geochronology of the Cretaceous Sindong Group, Southeast Korea: Implications for depositional age and Early Cretaceous igneous activity: Island Arc, v. 19, no. 4, p. 647-658.

Lee, Y. I., Lim, H. S., Choi, T., and Orihashi, Y., 2010c, Detrital zircon U-Pb ages of the late Paleozoic Sadong Formation in the Pyeongchang coalfield, Gangweon-do Province, Korea: implications for depositional age and provenance: Journal of the Geological Society of Korea, v. 46, no. 1, p. 73-81.

Leier, A. L., Kapp, P., Gehrels, G. E., and DeCelles, P. G., 2007, Detrital zircon geochronology of Carboniferous–Cretaceous strata in the Lhasa terrane, Southern Tibet: Basin Research, v. 19, no. 3, p. 361-378.

Lithgow-Bertelloni, C., and Richards, M. A., 1998, The dynamics of Cenozoic and Mesozoic plate motions: Reviews of Geophysics, v. 36, no. 1, p. 27-78.

Liu, S., Gurnis, M., Ma, P., and Zhang, B., 2017, Reconstruction of northeast Asian deformation integrated with western Pacific plate subduction since 200 Ma: Earth-Science Reviews, v. 175, p. 114-142.

Liu, Y., Gao, S., Hu, Z., Gao, C., Zong, K., and Wang, D., 2010, Continental and oceanic crust recycling-induced melt–peridotite interactions in the Trans-North China Orogen: U–Pb dating, Hf isotopes and trace elements in zircons from mantle xenoliths: Journal of petrology, v. 51, no. 1-2, p. 537-571.

Liu, Y., Hu, Z., Gao, S., Günther, D., Xu, J., Gao, C., and Chen, H., 2008, In situ analysis of major and trace elements of anhydrous minerals by LA-ICP-MS without applying an internal standard: Chemical Geology, v. 257, no. 1-2, p. 34-43.

Meng, Q.-R., Zhou, Z.-H., Zhu, R.-X., Xu, Y.-G., and Guo, Z.-T., 2022, Cretaceous basin evolution in northeast Asia: tectonic responses to the paleo-Pacific plate subduction: National Science Review, v. 9, no. 1, p. nwab088.

Moon, H.-S., Kim, Y. H., Kim, J. H., and You, J. H., 1990, K-Ar ages of alunite and sericite in altered rocks, and volcanic rocks around the Haenam area, southwest Korea: Economic and Environmental Geology, v. 23, no. 2, p. 135-141.

Oh, C., Choi, S.-G., Seo, J., Rajesh, V., Lee, J., Zhai, M., and Peng, P., 2009, Neoproterozoic tectonic evolution of the Hongseong area, southwestern Gyeonggi Massif, South Korea; implication for the tectonic evolution of Northeast Asia: Gondwana Research, v. 16, no. 2, p. 272-284.

Oh, C. W., Imayama, T., Lee, S. Y., Yi, S.-B., Yi, K., and Lee, B. C., 2015, Permo-Triassic and Paleoproterozoic metamorphism related to continental collision in Yangpyeong, South Korea: Lithos, v. 216, p. 264-284.

Okada, H., 2000, Nature and development of Cretaceous sedimentary basins in East Asia: a review: Geosciences Journal, v. 4, no. 4, p. 271-282.

Paik, I. S., Huh, M., So, Y. H., Lee, J. E., and Kim, H. J., 2007, Traces of evaporites in Upper Cretaceous lacustrine deposits of Korea: Origin and paleoenvironmental implications: Journal of Asian Earth Sciences, v. 30, no. 1, p. 93-107.

Park, K.-H., 2011, SHRIMP U-Pb ages of detrital zircons in the Daehyangsan Quartzite of the Okcheon Metamorphic Belt: Journal of the Geological Society of Korea, v. 47, p. 423-431.

Park, S.-G., Ryu, I.-C., So, C.-S., Wee, S.-M., Kim, C.-S., Park, S.-J., and Kim, S.-Y., 2003a, Overview of Epithermal Gold-Silver Mineralization, Korea, *in* Proceedings Proceedings of the KSEEG Conference, The Korean Society of Economic and Environmental Geology, p. 7-14.

Park, S.-I., Kim, S. W., Kwon, S., Santosh, M., Ko, K., and Kee, W.-S., 2017, Nature of Late Mesoproterozoic to Early Neoproterozoic magmatism in the western Gyeonggi massif, Korean Peninsula and its tectonic significance: Gondwana Research, v. 47, p. 291-307.

Park, S.-O., Kozai, T., Ishica, K., and Chang, K.-H., 2003b, Correlation of Early Cretaceous non-marine molluscan faunas of Korea and Japan: Journal of the Paleontological Society of Korea, v. 19, p. 1-20.

Peng, D., Liu, L., and Wang, Y., 2021, A newly discovered Late-Cretaceous East Asian flat slab explains its unique lithospheric structure and tectonics: Journal of Geophysical Research: Solid Earth, v. 126, no. 10, p. e2021JB022103.

Ross, G. M., Parrish, R. R., and Winston, D., 1992, Provenance and U-Pb geochronology of the Mesoproterozoic Belt Supergroup (northwestern United States): Implications for age of deposition and pre-Panthalassa plate reconstructions: Earth and Planetary Science Letters, v. 113, no. 1-2, p. 57-76.

Ryang, W., 1997, Sequential development of alluvial/lacustrine system; southeastern Eumsung Basin (Cretaceous), Korea: Journal of Sedimentary Research, v. 67, no. 2, p. 274-285.

Ryang, W., 2003, Contrasting basin fills in a strike-slip setting, Eumsung Basin (Cretaceous), Korea: Geosciences Journal, v. 7, no. 3, p. 263-275.

Ryang, W.-H., 2013a, Characteristics of strike-slip basin formation and sedimentary fills and the Cretaceous small basins of the Korean Peninsula: Journal of the Geological Society of Korea, v. 49, no. 1, p. 31-45.

Ryang, W.-H., 2013b, Origin of volcaniclastics in the central part of a pull-apart basin, the Cretaceous Eumsung Basin, Korea: Geosciences Journal, v. 17, no. 2, p. 129-137.

Safonova, I. Y., and Santosh, M., 2014, Accretionary complexes in the Asia-Pacific region: tracing archives of ocean plate stratigraphy and tracking mantle plumes: Gondwana Research, v. 25, no. 1, p. 126-158.

Sharman, G. R., Sharman, J. P., and Sylvester, Z., 2018, detritalPy: A Python-based toolset for visualizing and analysing detrital geo-thermochronologic data: The Depositional Record, v. 4, no. 2, p. 202-215.

Shin, S., and Jin, M., 1995, Isotope age map of plutonic rocks in Korea: Korea Institute of Geology, Mining and Materials, Taejon, Korea.

Sláma, J., Košler, J., Condon, D. J., Crowley, J. L., Gerdes, A., Hanchar, J. M., Horstwood, M. S., Morris, G. A., Nasdala, L., and Norberg, N., 2008, Plešovice zircon—a new natural reference material for U–Pb and Hf isotopic microanalysis: Chemical Geology, v. 249, no. 1-2, p. 1-35.

Son, C., and Kim, S., 1966, Geological report of the Changpyeong sheet (1: 50,000): Geological Survey of Korea, 50p.

Song, M.-Y., Lee, C.-J., and Lee, J.-R., 1990, Integrated Geotectonic Study on the Mesozoic Sedimentary Basins in Eumseong-Jeungpyeong and Kongju Area (II. Kongju Basin): Journal of the Korean earth science society, v. 11, no. 1, p. 1-1.

Vavra, G., Schmid, R., and Gebauer, D., 1999, Internal morphology, habit and U-Th-Pb microanalysis of amphibolite-to-granulite facies zircons: geochronology of the Ivrea Zone (Southern Alps): Contributions to Mineralogy and Petrology, v. 134, no. 4, p. 380-404.

Vermeesch, P., 2018, IsoplotR: A free and open toolbox for geochronology: Geoscience Frontiers, v. 9, no. 5, p. 1479-1493.

Wan, T., and Sun, P., On the accretion, intraplate deformation and mineralization for the eastern Eurasian continent since Triassic, *in* Proceedings Abstract of Third International Symposium of IGCP1993, Volume 321, p. 36-37.

Yang, S., 1992, Stratigraphic distribution and taxonomic problems of the Mesozoic non-marine mollusks in Korea: Biostratigraphy, bioprovincialism and bioevents in the Far East. Paleontological Society of Korea, p. 194-196.

Yang, S.-J., Duuring, P., and Kim, Y.-S., 2012, Structural genesis of the Eunsan and Moisan low-sulphidation epithermal Au–Ag deposits, Seongsan district, Southwest Korea: Mineralium Deposita, v. 48, no. 4, p. 467-483.

Yi, S., Yun, H., and Lee, J., 1998, Palynofacies of the sansudong formation (lower cretaceous), Jinan Basin: Korea. Journal of the Paleontological Society of Korea, v. 14, p. 1-13.

Yarmolyuk, V., Nikiforov, A., Kozlovsky, A., and Kudryashova, E., 2019, Late Mesozoic East Asian magmatic province: structure, magmatic signature, formation conditions: Geotectonics, v. 53, no. 4, p. 500-516.

Yu, H.-S., Mun, B.-C., Go, Y.-G., and Kim, H.-G., 1998, A study on the paleodepositional environment of Cretaceous sedimentary rocks-northeastern area of Chonnam: Journal of the Korean earth science society, v. 19, no. 3, p. 318-318.

Appendix

Table 1 U-Pb isotopic data for zircon grains in Eumseong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201014-1B-68	0.048	0.0011	0.1089	0.0028	0.01629	0.00014	104.9	2.5	104.17	0.87	194	24	0.7
201014-1B-6	0.0495	0.0018	0.1154	0.0045	0.0169	0.00021	110.7	4.1	108	1.3	288	40	2.4
201014-1B-9	0.0488	0.0022	0.1195	0.0057	0.01761	0.00025	114.4	5.1	112.6	1.6	300	48	1.6
201014-1B-18	0.04945	0.00083	0.1766	0.0035	0.02594	0.00025	165	3	165.1	1.6	179	20	-0.1
201014-1B-42	0.0487	0.001	0.1878	0.0045	0.02795	0.00033	174.5	3.8	177.7	2.1	169	21	-1.8
201014-1B-48	0.04897	0.00055	0.1955	0.0026	0.02884	0.00027	181.2	2.2	183.3	1.7	156	16	-1.2
201014-1B-69	0.04968	0.00068	0.211	0.004	0.03078	0.00051	194.2	3.4	195.4	3.2	206	21	-0.6
201014-1B-37	0.05125	0.00093	0.2463	0.0041	0.03466	0.0003	223.4	3.3	219.6	1.9	268	24	1.7
201014-1B-24	0.05088	0.00059	0.2483	0.0039	0.03517	0.00026	225	3.2	222.8	1.6	249	14	1.0
201014-1B-45	0.05105	0.0008	0.2543	0.0048	0.03621	0.00031	229.8	3.9	229.3	1.9	245	21	0.2
201014-1B-36	0.05132	0.00045	0.2834	0.0036	0.04035	0.00047	253.6	2.9	255	2.9	254	12	-0.6
201014-1B-12	0.0565	0.0012	0.3603	0.0084	0.04613	0.0005	311.8	6.3	290.7	3.1	449	26	6.8
201014-1B-23	0.0569	0.004	0.501	0.041	0.0636	0.0029	410	28	397	18	520	110	3.2
201014-1B-10	0.0629	0.0011	0.685	0.018	0.078	0.0013	529	11	484.3	8	693	21	8.4
201014-1B-49	0.0648	0.002	0.912	0.037	0.1008	0.0031	662	19	621	18	772	37	6.2
201014-1B-26	0.0647	0.0011	1.084	0.026	0.1198	0.0019	743	12	729	11	762	19	1.9
201014-1B-50	0.06349	0.00068	1.127	0.018	0.1286	0.0014	765.5	8.4	780.5	8.1	726	12	-2.0
201014-1B-47	0.0691	0.001	1.426	0.026	0.1486	0.002	900	11	893	11	908	16	0.8
201014-1B-20	0.10455	0.00049	4.262	0.049	0.2961	0.0032	1685.8	9.3	1671	16	1704.9	5.5	2.1
201014-1B-46	0.114	0.00029	4.745	0.057	0.3004	0.0038	1774	10	1694	19	1863.5	2.5	9.1
201014-1B-35	0.11397	0.00062	4.744	0.058	0.3006	0.0036	1774	10	1696	17	1863.3	5.6	8.9
201014-1B-28	0.11387	0.00056	4.786	0.06	0.3037	0.0035	1782	10	1711	17	1862.2	4.8	8.1
201014-1B-27	0.11494	0.00028	4.866	0.064	0.3059	0.004	1797	11	1720	20	1878.5	3.1	8.2
201014-1B-11	0.11198	0.00063	4.731	0.071	0.3066	0.004	1774	12	1723	20	1832.8	5.7	6.1
201014-1B-4	0.11546	0.00034	4.884	0.036	0.3068	0.002	1799	6.2	1724.5	9.9	1887.7	3.1	8.5
201014-1B-5	0.11529	0.00028	4.911	0.059	0.3086	0.0036	1805	10	1733	17	1884.7	2.6	8.1
201014-1B-14	0.11417	0.00035	4.911	0.039	0.3113	0.0023	1803.5	6.6	1747	11	1865.4	3.2	6.5
201014-1B-51	0.11454	0.00083	4.931	0.095	0.3118	0.0056	1805	17	1750	28	1874.7	7.7	6.7
201014-1B-55	0.11483	0.00065	5.001	0.063	0.316	0.004	1819	11	1769	20	1876.5	6	5.9
201014-1B-70	0.11432	0.0005	4.998	0.043	0.3163	0.0023	1818.3	7.2	1771	11	1866.9	4.7	5.5
201014-1B-41	0.1172	0.0002	5.149	0.035	0.3185	0.002	1844.3	5.7	1782.2	9.7	1914.4	1.6	6.9

Table 1 U-Pb isotopic data for zircon grains in Eumseong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201014-1B-64	0.1138	0.00044	5.027	0.038	0.3184	0.0023	1824	6.4	1783	11	1861.2	4.5	4.1
201014-1B-21	0.11518	0.00048	5.071	0.037	0.3209	0.0021	1830.8	6.2	1794	10	1883.5	4.6	4.6
201014-1B-29	0.11343	0.00075	5.152	0.079	0.3269	0.0047	1842	13	1822	23	1854.7	6.8	1.7
201014-1B-58	0.11565	0.00067	5.194	0.07	0.3263	0.0035	1852	12	1822	17	1890.5	6.4	3.5
201014-1B-53	0.1148	0.00074	5.374	0.089	0.3391	0.0043	1881	14	1882	21	1874.5	6.6	-0.5
201014-1B-63	0.12352	0.00035	5.891	0.061	0.3448	0.0032	1958.8	8.9	1909	15	2008.1	3.5	4.9
201014-1B-31	0.13278	0.00067	6.75	0.11	0.3656	0.0052	2076	14	2007	24	2136.8	6.8	6.0
201014-1B-19	0.1475	0.0011	8.05	0.14	0.3962	0.0051	2236	16	2153	24	2319	13	6.8
201014-1B-2	0.1394	0.0031	7.62	0.35	0.402	0.015	2178	41	2172	71	2237	40	1.1
201014-1B-67	0.14615	0.00078	8.31	0.14	0.411	0.0061	2263	16	2218	28	2296.9	7	3.6
201014-1B-8	0.1562	0.00032	9.05	0.099	0.4183	0.0047	2341.7	9.8	2252	21	2415.6	2.2	6.7
201014-1B-7	0.15776	0.00057	9.41	0.12	0.4317	0.0043	2382	11	2313	19	2428.2	4.5	4.4
201014-1B-38	0.1532	0.00072	9.18	0.12	0.4338	0.005	2355	12	2322	22	2382.2	7.3	2.5
201014-1B-62	0.1514	0.0014	9.52	0.22	0.4517	0.0078	2388	21	2400	35	2364	14	-1.9
201014-1B-34	0.16278	0.00067	10.33	0.17	0.4579	0.0063	2462	15	2429	28	2489.9	4.6	2.5
201014-1B-25	0.16647	0.00032	10.74	0.11	0.4696	0.0048	2499.8	9.2	2483	21	2524.2	2.1	1.6
201014-1B-66	0.18471	0.00099	12.22	0.21	0.4787	0.007	2618	16	2519	31	2697.9	7	6.5
201014-1B-22	0.18592	0.00038	12.58	0.11	0.4932	0.0041	2648.6	8.1	2584	17	2706.3	2.1	4.6
201014-1B-65	0.2812	0.0016	25.55	0.67	0.655	0.016	3323	25	3239	61	3366.7	6.6	3.9
201014-1C-150	0.0483	0.0017	0.1097	0.0042	0.01638	0.00028	105.5	3.8	104.7	1.8	228	36	0.8
201014-1C-182	0.0474	0.0017	0.1142	0.0039	0.01738	0.0002	109.7	3.5	111.1	1.3	237	35	-1.3
201014-1C-137	0.0496	0.0045	0.186	0.016	0.0276	0.0012	172	13	175.2	7.8	483	86	-1.9
201014-1C-194	0.05015	0.00082	0.1878	0.0039	0.02708	0.00041	174.6	3.3	172.2	2.6	202	17	1.4
201014-1C-136	0.04985	0.00079	0.2027	0.0072	0.02944	0.00082	187.1	6.1	187	5.1	191	18	0.1
201014-1C-169	0.11665	0.00085	5.006	0.089	0.3095	0.005	1819	15	1738	24	1903.8	5.8	8.7
201014-1C-193	0.114	0.0013	5.04	0.25	0.326	0.016	1823	41	1819	79	1863	14	2.1
201014-1C-186	0.11742	0.00036	5.08	0.1	0.3142	0.0061	1832	17	1760	30	1918	3.2	8.2
201014-1C-184	0.1139	0.00098	5.132	0.091	0.3296	0.0066	1841	15	1836	32	1871.1	9.9	1.7
201014-1C-163	0.1147	0.0011	5.22	0.13	0.3337	0.0074	1858	21	1859	35	1874.4	9.8	1.1
201014-1C-188	0.1137	0.0012	5.25	0.17	0.3338	0.0096	1858	27	1856	46	1863	11	0.2
201014-1C-173	0.1142	0.0014	5.25	0.16	0.334	0.01	1860	26	1856	49	1866	13	0.5
201014-1C-153	0.11486	0.00095	5.25	0.13	0.3343	0.0073	1861	20	1861	35	1882.9	7.4	0.7

Table 1 U-Pb isotopic data for zircon grains in Eumseong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201014-1C-175	0.1145	0.0011	5.3	0.14	0.3346	0.0082	1868	22	1860	40	1878	11	0.8
201014-1C-177	0.1146	0.0012	5.31	0.13	0.3362	0.0076	1868	21	1867	37	1874.1	7.3	0.3
201014-1C-196	0.11415	0.0008	5.286	0.087	0.3348	0.0053	1868	15	1865	27	1865.3	7.2	-0.3
201014-1C-143	0.1259	0.0025	6.22	0.76	0.362	0.043	1990	100	1980	200	2046	15	3.0
201014-1C-125	0.1294	0.0015	6.39	0.34	0.356	0.017	2025	46	1960	81	2096	14	6.5
201014-1C-149	0.1363	0.0011	6.67	0.2	0.358	0.011	2074	23	1972	51	2175	12	9.4
201014-1C-192	0.1354	0.0014	6.78	0.14	0.3598	0.0068	2082	18	1980	32	2168	17	8.5
201014-1C-183	0.1348	0.0011	7.33	0.49	0.391	0.027	2148	60	2130	130	2166.8	7	2.1
201014-1C-146	0.13863	0.00059	7.69	0.21	0.408	0.01	2201	24	2204	47	2211.4	4.3	0.4
201014-1C-127	0.14312	0.00095	7.96	0.44	0.401	0.023	2223	49	2170	110	2269.2	5.9	4.3
201014-1C-132	0.1476	0.0012	7.89	0.26	0.39	0.012	2224	31	2123	57	2315	10	9.0
201014-1C-156	0.1417	0.0013	7.98	0.26	0.412	0.011	2227	29	2223	50	2246	10	1.0
201014-1C-155	0.1451	0.0024	8.19	0.4	0.416	0.017	2249	45	2239	78	2285	12	1.9
201014-1C-119	0.14845	0.00067	8.4	1.4	0.406	0.067	2260	140	2180	300	2333	11	6.0
201014-1C-154	0.15491	0.00079	8.6	0.21	0.4029	0.008	2299	23	2181	37	2401.8	6.8	9.0
201014-1C-140	0.1512	0.004	9.1	0.93	0.436	0.043	2325	95	2320	190	2385	32	2.4
201014-1C-165	0.1565	0.0012	9.25	0.19	0.4328	0.0075	2364	20	2317	34	2414	8.4	3.6
201014-1C-126	0.1581	0.0011	9.46	0.53	0.432	0.023	2379	53	2310	100	2435.5	6.5	5.1
201014-1C-141	0.16	0.001	9.8	0.44	0.447	0.021	2423	42	2394	89	2457.7	6.5	2.6
201014-1C-122	0.1564	0.00081	9.92	0.16	0.4581	0.0078	2425	15	2429	34	2419.4	5.3	-0.5
201014-1C-145	0.15885	0.00079	9.95	0.23	0.4588	0.0098	2429	21	2432	43	2445.8	5.8	0.6
201014-1C-181	0.1612	0.002	10.46	0.46	0.463	0.018	2479	38	2465	75	2462	13	0.7
201014-1C-138	0.1637	0.0016	10.58	0.38	0.472	0.017	2486	34	2485	73	2491.2	9.5	0.4
201014-1C-162	0.16626	0.00045	10.78	0.17	0.4734	0.0074	2502	14	2497	32	2518.6	3	0.6
201014-1C-130	0.1885	0.0026	13.23	0.6	0.517	0.023	2701	45	2682	98	2725	12	1.7
201014-1C-152	0.2362	0.0017	19.8	0.5	0.613	0.015	3078	24	3078	60	3091	10	0.5
201014-1C-171	0.2532	0.0032	21.05	0.76	0.609	0.019	3144	33	3064	75	3208	14	3.8
201014-11A-45	0.0486	0.002	0.1074	0.0046	0.01607	0.00024	104.2	4.2	102.8	1.5	319	40	1.3
201014-11A-33	0.0487	0.0013	0.1082	0.0029	0.01619	0.00018	104.3	2.7	103.5	1.1	207	28	0.8
201014-11A-17	0.0498	0.0011	0.1765	0.0043	0.02586	0.00027	164.8	3.7	164.5	1.7	214	22	0.2
201014-11A-2	0.0485	0.0011	0.1748	0.0043	0.02601	0.00029	163.4	3.7	165.5	1.9	173	25	-1.3
201014-11A-35	0.0499	0.0012	0.1823	0.0043	0.02627	0.00046	169.9	3.7	167.2	2.9	199	32	1.6

Table 1 U-Pb isotopic data for zircon grains in Eumseong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201014-11A-1	0.04959	0.00087	0.182	0.0038	0.02629	0.00026	169.7	3.2	167.3	1.6	188	19	1.4
201014-11A-30	0.04993	0.00084	0.1809	0.0035	0.02632	0.00041	169.3	3.1	167.5	2.6	183	23	1.1
201014-11A-15	0.0537	0.0028	0.199	0.015	0.0265	0.001	186	12	168.8	6.5	428	80	9.3
201014-11A-51	0.0508	0.0019	0.1853	0.0074	0.02653	0.00045	172.5	6.3	168.8	2.8	252	50	2.1
201014-11A-34	0.0495	0.00081	0.1818	0.0038	0.02663	0.00032	169.5	3.2	169.4	2	185	19	0.1
201014-11A-7	0.0498	0.00079	0.1819	0.0032	0.02673	0.00037	170.3	2.8	170	2.3	193	17	0.2
201014-11A-19	0.0488	0.0017	0.1808	0.0062	0.02673	0.0004	169.6	5.1	170	2.5	289	38	-0.2
201014-11A-63	0.0507	0.0017	0.1899	0.0067	0.02676	0.00036	176.1	5.7	170.2	2.3	303	40	3.4
201014-11A-20	0.04922	0.00098	0.1816	0.0041	0.02701	0.00033	169.3	3.5	171.8	2.1	208	25	-1.5
201014-11A-31	0.04926	0.00065	0.1831	0.0028	0.02702	0.00028	170.6	2.4	171.9	1.7	177	17	-0.8
201014-11A-32	0.0499	0.00097	0.1867	0.0043	0.02718	0.00044	173.8	3.7	172.8	2.8	170	30	0.6
201014-11A-11	0.04919	0.00065	0.184	0.0024	0.02728	0.00024	171.4	2.1	173.5	1.5	163	17	-1.2
201014-11A-50	0.04982	0.00079	0.1877	0.0032	0.02727	0.00022	174.6	2.7	173.5	1.4	202	20	0.6
201014-11A-44	0.04901	0.00086	0.1858	0.004	0.02738	0.00032	172.9	3.4	174.3	2	180	19	-0.8
201014-11A-27	0.04925	0.00083	0.1863	0.0035	0.02747	0.00031	173.6	3	174.9	2	187	21	-0.8
201014-11A-14	0.051	0.0013	0.1946	0.0074	0.02772	0.00072	180.4	6.3	176.2	4.5	220	35	2.3
201014-11A-22	0.04926	0.00076	0.1914	0.0038	0.02811	0.00041	177.7	3.3	178.7	2.6	162	20	-0.6
201014-11A-49	0.04977	0.0006	0.1942	0.0031	0.02811	0.00028	180.1	2.6	178.7	1.7	184	15	0.8
201014-11A-57	0.04974	0.00088	0.1927	0.004	0.02814	0.00033	179.1	3.5	178.9	2.1	208	24	0.1
201014-11A-55	0.05015	0.00075	0.195	0.0039	0.02834	0.00031	180.7	3.3	180.1	1.9	200	19	0.3
201014-11A-8	0.04979	0.00061	0.1953	0.0042	0.0284	0.00044	181	3.6	180.5	2.8	190	17	0.3
201014-11A-38	0.04963	0.00044	0.1948	0.0032	0.02857	0.00043	180.6	2.7	181.6	2.7	181	14	-0.6
201014-11A-36	0.04958	0.00048	0.1956	0.0037	0.02872	0.00048	181.2	3.1	182.5	3	173	14	-0.7
201014-11A-47	0.04986	0.00089	0.1989	0.0037	0.02888	0.00029	184.1	3.2	183.5	1.8	197	23	0.3
201014-11A-41	0.05141	0.00083	0.2043	0.0048	0.02893	0.00039	188.6	4	183.8	2.4	267	27	2.6
201014-11A-25	0.05006	0.0008	0.2011	0.0033	0.02896	0.00038	185.9	2.8	184	2.4	233	21	1.0
201014-11A-13	0.04944	0.00055	0.1981	0.0036	0.02898	0.00042	183.4	3	184.2	2.7	173	14	-0.4
201014-11A-58	0.04964	0.00065	0.2011	0.0051	0.02923	0.00055	186.3	4.4	185.7	3.5	185	18	0.3
201014-11A-5	0.0504	0.0018	0.207	0.01	0.02915	0.00076	190.2	8.4	185.8	4.7	274	34	2.3
201014-11A-60	0.0504	0.0016	0.2039	0.007	0.02932	0.00044	188.8	5.7	186.3	2.7	253	33	1.3
201014-11A-54	0.0501	0.001	0.2024	0.0053	0.02939	0.0004	186.9	4.5	186.7	2.5	228	27	0.1
201014-11A-43	0.04997	0.00072	0.2003	0.0042	0.02947	0.0005	185.2	3.6	187.2	3.1	207	18	-1.1
201014-11A-39	0.04977	0.00058	0.2081	0.0035	0.03045	0.00047	191.4	2.9	193.3	3	187	15	-1.0

Table 1 U-Pb isotopic data for zircon grains in Eumseong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201014-11A-61	0.0536	0.001	0.222	0.006	0.03061	0.00051	203.3	5	194.3	3.2	341	27	4.4
201014-11A-62	0.04972	0.00054	0.2121	0.0043	0.0308	0.00056	195.5	3.6	195.5	3.5	188	13	0.0
201014-11A-29	0.04961	0.00062	0.2133	0.0037	0.03102	0.00036	196.2	3.1	196.9	2.2	179	16	-0.4
201014-11A-56	0.05064	0.00099	0.2161	0.0046	0.03104	0.00043	198.5	3.8	197	2.7	232	23	0.8
201014-11A-12	0.05046	0.00063	0.266	0.0042	0.03795	0.00042	239.4	3.4	240.1	2.6	215	14	-0.3
201014-11A-42	0.0599	0.0013	0.733	0.02	0.0884	0.0019	558	12	548	10	599	26	1.8
201014-11A-53	0.0648	0.001	1.144	0.035	0.1285	0.0027	775	16	779	16	773	13	-0.5
201014-11A-65	0.07432	0.00086	1.842	0.034	0.1794	0.0026	1060	12	1063	14	1048	13	-0.6
201014-11A-4	0.1125	0.0004	4.593	0.081	0.2938	0.0049	1745	15	1659	24	1841.4	3.7	9.7
201014-11A-37	0.11467	0.00038	4.741	0.07	0.3	0.0044	1777	12	1690	22	1878.3	3.4	4.9
201014-11A-28	0.11394	0.00042	4.798	0.055	0.3055	0.0035	1784.7	9.8	1718	17	1867.6	4.3	7.7
201014-11A-46	0.11364	0.00045	5.249	0.084	0.3344	0.0051	1859	14	1859	24	1860.2	4.1	-0.1
201014-11A-18	0.11362	0.00048	5.211	0.077	0.3348	0.0049	1856	13	1860	24	1857.4	4.2	-0.3
201014-11A-52	0.11457	0.00049	5.286	0.066	0.3342	0.0042	1865	11	1862	20	1876.8	3.9	1.0
201014-11A-64	0.13868	0.00049	7.46	0.12	0.3881	0.0064	2168	14	2116	30	2210.9	4.8	4.3
201014-11A-6	0.14198	0.00062	8.08	0.15	0.415	0.0077	2240	17	2240	35	2253.3	5.9	-0.1
201014-12A-63	0.0499	0.0019	0.122	0.0047	0.01781	0.00027	117.3	4.3	113.8	1.7	223	36	3.0
201014-12A-12	0.0497	0.0011	0.1675	0.0042	0.02472	0.00025	157.1	3.6	157.4	1.6	178	24	-0.2
201014-12A-9	0.0534	0.0081	0.185	0.031	0.0257	0.0018	169	26	164	11	560	120	3.0
201014-12A-18	0.04926	0.00046	0.1753	0.0017	0.02587	0.00015	164.2	1.5	164.65	0.96	155	14	-0.3
201014-12A-30	0.0528	0.0045	0.182	0.014	0.02614	0.0007	169	12	166.4	4.4	468	85	1.5
201014-12A-25	0.04965	0.0007	0.1782	0.0025	0.02619	0.00024	166.5	2.2	166.7	1.5	188	19	-0.1
201014-12A-90	0.04961	0.00076	0.18	0.003	0.02631	0.00022	168	2.6	167.4	1.4	188	17	0.4
201014-12A-36	0.04991	0.00053	0.1802	0.0028	0.0264	0.00028	168.2	2.4	168	1.7	185	14	0.1
201014-12A-41	0.04922	0.00042	0.1789	0.0019	0.02647	0.00018	167.1	1.7	168.4	1.2	157	12	-0.8
201014-12A-4	0.04964	0.00071	0.185	0.0033	0.02676	0.00026	172.2	2.8	170.2	1.7	178	19	1.2
201014-12A-48	0.0487	0.001	0.1797	0.0048	0.02682	0.00051	168.5	4	170.6	3.2	140	23	-1.2
201014-12A-14	0.04969	0.00045	0.1861	0.0021	0.02721	0.00022	173.3	1.8	173.1	1.4	178	12	0.1
201014-12A-82	0.04936	0.00066	0.1883	0.0033	0.02735	0.00031	175.1	2.8	173.9	1.9	175	15	0.7
201014-12A-97	0.0499	0.0013	0.1882	0.005	0.02739	0.00029	175	4.3	174.2	1.8	242	22	0.5
201014-12A-77	0.0517	0.0029	0.19	0.012	0.02741	0.00072	179	11	174.3	4.5	307	59	2.6
201014-12A-59	0.04922	0.00083	0.1886	0.0042	0.02745	0.00031	175.3	3.6	174.5	2	186	20	0.5

Table 1 U-Pb isotopic data for zircon grains in Eumseong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201014-12A-71	0.04966	0.0006	0.1886	0.0029	0.02754	0.00026	175.3	2.5	175.1	1.7	183	14	0.1
201014-12A-32	0.04978	0.00048	0.1896	0.0026	0.02786	0.00026	176.2	2.2	177.1	1.6	183	13	-0.5
201014-12A-61	0.04933	0.00075	0.1886	0.0032	0.02786	0.00029	175.4	2.8	177.1	1.8	169	21	-1.0
201014-12A-70	0.04944	0.00072	0.192	0.0035	0.02795	0.00028	178.3	3	177.7	1.8	176	17	0.3
201014-12A-74	0.04945	0.00083	0.192	0.0038	0.02809	0.00032	178.2	3.3	178.6	2	199	23	-0.2
201014-12A-37	0.0497	0.001	0.193	0.0045	0.02839	0.0004	179.1	3.8	180.5	2.5	199	28	-0.8
201014-12A-40	0.04966	0.00037	0.1937	0.0033	0.02868	0.00038	179.7	2.8	182.3	2.4	170	10	-1.4
201014-12A-73	0.05003	0.0009	0.2006	0.0041	0.02875	0.00029	185.8	3.4	182.7	1.8	244	22	1.7
201014-12A-57	0.049	0.0011	0.195	0.0048	0.0291	0.00052	180.8	4.1	184.9	3.3	180	25	-2.3
201014-12A-42	0.0498	0.00059	0.1997	0.0038	0.02912	0.00035	184.8	3.2	185	2.2	185	13	-0.1
201014-12A-60	0.05	0.00053	0.2029	0.0028	0.02932	0.00031	187.5	2.3	186.3	2	188	13	0.6
201014-12A-47	0.04982	0.00049	0.2046	0.0037	0.02989	0.00048	188.9	3.1	189.9	3	182	14	-0.5
201014-12A-79	0.11249	0.00078	4.68	0.18	0.297	0.011	1758	33	1675	53	1844.4	9.3	9.3
201014-12A-1	0.11342	0.00031	4.66	0.037	0.2979	0.0021	1761.1	6.6	1682	11	1852.2	3.5	9.1
201014-12A-29	0.11446	0.00043	4.691	0.083	0.2997	0.0049	1765	15	1689	24	1871.1	3.4	9.6
201014-12A-81	0.11481	0.00041	4.95	0.077	0.3106	0.0049	1810	13	1743	24	1876.1	4.3	7.1
201014-12A-22	0.11526	0.00074	4.982	0.044	0.3125	0.0023	1816	7.5	1753	11	1886.8	6.2	7.0
201014-12A-51	0.11337	0.00067	4.932	0.076	0.3139	0.0045	1807	13	1760	22	1853.7	4.2	5.3
201014-12A-39	0.11417	0.00055	5.077	0.051	0.3234	0.0027	1831.6	8.5	1806	13	1871.6	5.2	3.2
201014-12A-68	0.11664	0.00077	5.21	0.12	0.325	0.0059	1858	18	1813	29	1902	8.7	4.8
201014-12A-17	0.1141	0.0014	5.154	0.088	0.3267	0.0048	1845	15	1822	24	1866	15	2.8
201014-12A-5	0.1166	0.00029	5.301	0.088	0.3303	0.005	1870	14	1839	24	1902.5	3.6	3.3
201014-12A-66	0.1138	0.0014	5.16	0.14	0.329	0.01	1844	23	1839	48	1857	12	1.7
201014-12A-13	0.114	0.00045	5.258	0.052	0.3341	0.0029	1861.5	8.5	1858	14	1861.8	4.3	0.5
201014-12A-45	0.11402	0.00042	5.25	0.063	0.3344	0.0038	1860	10	1859	18	1862.1	4.2	0.5
201014-12A-92	0.11464	0.00074	5.273	0.067	0.3357	0.004	1864	11	1865	19	1869.6	6.2	0.1
201014-12A-27	0.1151	0.00095	5.298	0.085	0.3357	0.0047	1867	14	1866	23	1886.7	8.4	0.7
201014-12A-43	0.11547	0.00049	5.34	0.14	0.3363	0.0086	1872	23	1867	41	1885	5	1.0
201014-12A-56	0.11363	0.00077	5.3	0.12	0.3365	0.0052	1867	19	1869	25	1857.5	5.2	-0.5
201014-12A-69	0.11393	0.00056	5.3	0.13	0.3359	0.0086	1865	21	1871	41	1860.5	4.9	0.0
201014-12A-54	0.1158	0.001	5.46	0.33	0.34	0.019	1877	48	1880	88	1888	10	0.6
201014-12A-52	0.11486	0.00066	5.447	0.081	0.3425	0.0046	1892	13	1899	22	1878.7	6.3	-0.8
201014-12A-33	0.12977	0.00096	6.16	0.16	0.347	0.0085	1996	23	1919	41	2096.1	7.4	8.4

Table 1 U-Pb isotopic data for zircon grains in Eumseong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201014-12A-62	0.1151	0.0014	5.533	0.086	0.3494	0.0059	1905	13	1932	28	1877.3	8.9	-2.9
201014-12A-53	0.12007	0.00091	5.86	0.21	0.353	0.012	1952	31	1948	58	1954	11	0.3
201014-12A-72	0.12726	0.0007	6.37	0.14	0.3622	0.0064	2027	19	1992	30	2058.9	5.8	3.1
201014-12A-49	0.1406	0.0013	7.29	0.26	0.372	0.011	2149	33	2036	49	2237	12	9.2
201014-12A-76	0.1307	0.0013	6.79	0.18	0.372	0.01	2083	24	2039	49	2105.8	9.5	3.2
201014-12A-85	0.13983	0.00082	7.17	0.11	0.3733	0.0044	2132	13	2044	21	2225	8.6	7.9
201014-12A-65	0.1456	0.0014	7.74	0.23	0.3859	0.0099	2202	26	2102	46	2292	12	9.0
201014-12A-55	0.1491	0.0017	8.23	0.26	0.4	0.01	2253	29	2165	48	2330	13	7.3
201014-12A-26	0.16168	0.0006	9.348	0.084	0.4225	0.0033	2374.2	8.7	2272	15	2475.8	4.1	8.3
201014-12A-99	0.1642	0.0022	9.96	0.28	0.442	0.011	2433	27	2357	48	2501	17	5.4
201014-12A-28	0.17023	0.00026	11.18	0.11	0.4791	0.0046	2538.8	9.2	2523	20	2559.2	1.6	1.4
201014-12A-83	0.2147	0.0013	16.55	0.29	0.5575	0.0099	2911	18	2855	41	2941.9	6.2	3.0
201014-12A-34	0.24587	0.00056	21.27	0.19	0.6301	0.0058	3150.1	8.6	3151	23	3158.3	3.1	0.3
201014-9F-13	0.039	0.012	0.066	0.019	0.01118	0.00095	71	18	72.4	6.2	720	140	-2.0
201014-9F-16	0.049	0.016	0.088	0.028	0.01338	0.00075	86	28	85.7	4.8	920	210	0.3
201014-9F-20	0.0466	0.0073	0.092	0.016	0.01394	0.00073	89	15	89.2	4.6	650	120	-0.2
201014-9F-53	0.0476	0.0049	0.1	0.01	0.01475	0.00083	95.1	9.6	94.4	5.3	535	90	0.7
201014-9F-58	0.0477	0.0039	0.1092	0.0089	0.01646	0.00037	104.7	8.2	105.3	2.4	378	82	-0.6
201014-9F-49	0.0483	0.0041	0.1104	0.0092	0.01658	0.00056	105.7	8.3	106	3.5	328	61	-0.3
201014-9F-8	0.0482	0.0035	0.1161	0.0095	0.0169	0.00088	110.4	8.6	107.9	5.6	431	73	2.3
201014-9F-54	0.0468	0.0055	0.121	0.013	0.01752	0.00082	115	12	111.9	5.2	597	96	2.7
201014-9F-77	0.046	0.0062	0.117	0.016	0.0188	0.0011	115	14	120.1	7	620	130	-4.4
201014-9F-68	0.046	0.014	0.125	0.031	0.0195	0.0017	118	26	124	11	890	180	-5.1
201014-9F-61	0.0488	0.0031	0.124	0.0076	0.01818	0.00038	118.1	6.9	116.1	2.4	335	52	1.7
201014-9F-93	0.0511	0.0026	0.1244	0.0064	0.01776	0.00038	118.8	5.8	113.5	2.4	352	54	4.5
201014-9F-92	0.0497	0.0016	0.126	0.0046	0.01842	0.00033	120.8	4.1	117.7	2.1	212	31	2.6
201014-9F-75	0.0485	0.0012	0.1264	0.0044	0.01884	0.00041	120.8	3.9	120.3	2.6	160	25	0.4
201014-9F-21	0.0505	0.0036	0.13	0.011	0.0185	0.001	123.6	9.6	117.8	6.5	453	83	4.7
201014-9F-27	0.0512	0.0051	0.132	0.013	0.01872	0.00071	124	11	119.5	4.5	660	100	3.6
201014-9F-73	0.0484	0.0033	0.138	0.01	0.02012	0.00063	130.5	9.1	128.4	4	377	72	1.6
201014-9F-91	0.0492	0.0016	0.1383	0.0056	0.02038	0.0004	131.2	5	130	2.5	287	43	0.9
201014-9F-69	0.0501	0.0037	0.143	0.011	0.0205	0.001	134	10	130.5	6.3	469	95	2.6

Table 1 U-Pb isotopic data for zircon grains in Eumseong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201014-9F-39	0.0496	0.0029	0.148	0.011	0.0225	0.001	140	10	143.5	6.5	255	46	-2.5
201014-9F-10	0.0502	0.0038	0.157	0.013	0.0226	0.0014	147	11	144.1	8.5	306	82	2.0
201014-9F-34	0.0544	0.0074	0.19	0.031	0.0255	0.0021	174	26	162	13	650	110	6.9
201014-9F-22	0.0492	0.0014	0.2012	0.0075	0.02951	0.00095	186.4	6.5	187.4	6	218	34	-0.5
201014-9F-24	0.049	0.0038	0.206	0.017	0.0298	0.0014	192	15	189	8.7	397	72	1.6
201014-9F-63	0.0499	0.0018	0.2195	0.0086	0.03211	0.00075	201.1	7.2	203.7	4.7	213	36	-1.3
201014-9F-89	0.05013	0.0009	0.2232	0.006	0.03279	0.0007	204.3	5	208	4.4	208	24	-1.8
201014-9F-81	0.0513	0.0025	0.226	0.014	0.0318	0.0014	205	11	201.6	8.8	375	47	1.7
201014-9F-51	0.0504	0.0024	0.253	0.019	0.0356	0.0023	229	15	225	14	323	47	1.7
201014-9F-48	0.0523	0.0073	0.26	0.034	0.0371	0.002	234	27	235	12	700	150	-0.4
201014-9F-7	0.0507	0.0032	0.275	0.03	0.0388	0.0035	249	24	245	21	429	77	1.6
201014-9F-52	0.0521	0.0016	0.312	0.016	0.0437	0.0015	279	13	275.6	9.3	307	33	1.2
201014-9F-50	0.0511	0.0055	0.383	0.036	0.0531	0.0038	334	29	333	23	618	93	0.3
201014-9F-19	0.0565	0.0019	0.573	0.036	0.0728	0.0042	455	23	454	26	504	39	0.2
201014-9F-41	0.0551	0.0041	0.564	0.051	0.0735	0.0051	460	31	460	30	574	65	0.0
201014-9F-4	0.0553	0.0042	0.628	0.064	0.0799	0.0064	489	40	493	38	600	100	-0.8
201014-9F-3	0.0567	0.0032	0.628	0.059	0.0795	0.0066	493	36	496	39	552	74	-0.6
201014-9F-28	0.057	0.0014	0.641	0.02	0.0821	0.0013	501	12	508.3	8	490	32	-1.5
201014-9F-25	0.0576	0.00079	0.671	0.017	0.0846	0.0017	524	10	523.4	9.9	509	18	0.1
201014-9F-40	0.0576	0.0013	0.712	0.062	0.0868	0.0076	533	38	534	45	515	24	-0.2
201014-9F-29	0.0695	0.004	0.906	0.048	0.0968	0.0037	657	27	595	22	935	64	9.4
201014-9F-76	0.0633	0.0038	1.008	0.075	0.116	0.0046	702	37	707	26	704	45	-0.7
201014-9F-23	0.0644	0.0018	1.089	0.069	0.1233	0.0068	740	34	746	39	741	34	-0.8
201014-9F-33	0.0663	0.0055	1.24	0.21	0.143	0.029	755	68	758	83	880	100	-0.4
201014-9F-17	0.0666	0.0021	1.17	0.11	0.126	0.012	773	53	768	68	833	41	0.6
201014-9F-66	0.06455	0.00093	1.159	0.039	0.128	0.0042	778	19	777	24	764	17	0.1
201014-9F-67	0.0661	0.0014	1.187	0.044	0.1303	0.0036	790	20	791	20	826	22	-0.1
201014-9F-26	0.0661	0.0013	1.242	0.048	0.1346	0.0047	815	22	815	27	818	23	0.0
201014-9F-31	0.0661	0.0014	1.24	0.065	0.136	0.0059	818	29	820	33	800	25	-0.2
201014-9F-47	0.0658	0.0016	1.28	0.05	0.1375	0.0059	829	23	828	34	810	30	0.1
201014-9F-64	0.0669	0.0024	1.292	0.09	0.1412	0.008	829	33	835	39	817	48	-0.7
201014-9F-45	0.0656	0.002	1.28	0.084	0.1382	0.0086	830	38	836	48	814	32	-0.7
201014-9F-18	0.0724	0.0016	1.52	0.11	0.157	0.011	925	47	928	61	985	26	-0.3

Table 1 U-Pb isotopic data for zircon grains in Eumseong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201014-9F-59	0.07062	0.00099	1.578	0.062	0.1595	0.0053	955	25	952	29	952	19	0.3
201014-9F-84	0.07	0.0017	1.574	0.081	0.161	0.0077	960	31	962	43	946	26	-0.2
201014-9F-79	0.07229	0.00099	1.651	0.049	0.1664	0.0048	991	19	991	27	986	19	0.0
201014-9F-35	0.0805	0.0074	2.06	0.52	0.176	0.04	1070	120	1080	180	1160	130	6.9
201014-9F-11	0.0755	0.0012	1.97	0.11	0.185	0.01	1094	39	1094	57	1095	20	0.1
201014-9F-5	0.0771	0.0012	1.99	0.13	0.187	0.011	1099	41	1098	59	1132	20	3.0
201014-9F-85	0.07666	0.00077	1.962	0.068	0.1881	0.0064	1107	23	1108	34	1117	13	0.8
201014-9F-80	0.1024	0.0016	4.1	0.26	0.291	0.016	1639	51	1642	78	1658	24	-1.9
201014-9F-56	0.1105	0.0025	5	0.45	0.313	0.024	1794	72	1740	110	1824	24	1.0
201014-9F-44	0.11288	0.0009	5.05	0.26	0.326	0.016	1824	45	1812	76	1843.4	9.3	4.6
201014-9F-55	0.1139	0.0019	5.26	0.2	0.333	0.011	1854	32	1861	53	1862	17	1.7
201014-9F-82	0.1094	0.0021	5.29	0.51	0.354	0.033	1856	87	1920	160	1791	18	0.1
201014-9F-90	0.11484	0.00062	5.344	0.093	0.3381	0.0059	1876	16	1877	29	1878.1	6	-7.2
201014-9F-30	0.1143	0.0039	5.5	1.8	0.43	0.18	1930	130	2150	310	1845	33	0.1
201014-9F-78	0.12255	0.00061	6.07	0.11	0.3611	0.0062	1985	15	1986	29	1990.6	5.5	0.2
201014-9F-65	0.1258	0.0021	6.32	0.3	0.368	0.019	2015	42	2007	87	2051	17	2.1
201014-9F-87	0.1262	0.001	6.46	0.25	0.375	0.013	2044	35	2047	59	2044	11	-0.1
201014-9F-38	0.1391	0.0068	6.7	2.7	0.37	0.15	2100	150	2100	390	2158	48	2.7
201014-9F-86	0.1454	0.0014	8.5	0.43	0.425	0.019	2278	48	2275	87	2288	13	0.6
201014-9F-43	0.1493	0.0047	10.1	1.4	0.486	0.067	2340	140	2450	290	2352	30	-4.2
201014-9F-83	0.14944	0.00073	9.49	0.49	0.461	0.023	2374	48	2440	100	2338.2	5.8	-4.4
201014-9F-72	0.158	0.0012	10.21	0.18	0.4639	0.0081	2453	16	2456	36	2441.5	6.7	-0.6
201014-9F-74	0.1616	0.0014	10.48	0.31	0.47	0.013	2477	27	2479	58	2468.4	8.6	-0.4
201014-9F-14	0.1628	0.0054	11	1.5	0.481	0.067	2480	140	2470	290	2532	33	2.4
201014-9F-70	0.1642	0.0025	11.53	0.94	0.509	0.041	2528	73	2640	180	2509	15	-5.2
201014-9F-60	0.1898	0.0012	13.98	0.39	0.539	0.016	2747	27	2782	64	2739.4	7	-1.6
201015-9-99	0.0491	0.0018	0.1118	0.0056	0.01653	0.0005	108	5.2	105.6	3.2	234	34	2.2
201015-9-28	0.0518	0.0026	0.1137	0.0063	0.01661	0.0009	109.3	5.7	106.2	5.7	274	45	2.8
201015-9-88	0.0484	0.0017	0.1135	0.0043	0.01697	0.00027	109.5	3.8	108.5	1.7	245	37	0.9
201015-9-4	0.0482	0.00084	0.113	0.0023	0.01712	0.00019	109.2	2.2	109.4	1.2	149	20	-0.2
201015-9-82	0.0509	0.0013	0.1872	0.0082	0.0269	0.001	174.1	7	171.1	6.3	239	30	1.7
201015-9-7	0.04942	0.00035	0.1837	0.0022	0.027	0.00026	171.4	1.8	171.7	1.6	170.9	9.9	-0.2

Table 1 U-Pb isotopic data for zircon grains in Eumseong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201015-9-27	0.04984	0.00058	0.1858	0.0086	0.0271	0.0011	174.6	6.7	172.5	7.2	194	13	1.2
201015-9-50	0.05367	0.00071	0.2011	0.0055	0.02715	0.00062	185.9	4.6	172.7	3.9	357	22	7.1
201015-9-44	0.0508	0.00089	0.1908	0.0056	0.0272	0.00062	177.2	4.8	173	3.9	247	27	2.4
201015-9-70	0.05012	0.00047	0.1887	0.0031	0.02752	0.00037	175.4	2.7	175	2.3	197	13	0.2
201015-9-49	0.04997	0.00075	0.1912	0.0046	0.02757	0.00056	177.5	3.9	175.3	3.5	220	17	1.2
201015-9-56	0.04957	0.00072	0.203	0.0061	0.02973	0.00078	188	5	188.8	4.9	180	18	-0.4
201015-9-94	0.0504	0.0014	0.2149	0.0083	0.03114	0.00078	197	6.9	197.6	4.9	254	33	-0.3
201015-9-46	0.05548	0.00037	0.2638	0.0058	0.03423	0.00061	237.4	4.6	216.9	3.8	429	11	8.6
201015-9-22	0.05277	0.00017	0.2523	0.0029	0.03459	0.00037	228.4	2.4	219.2	2.3	321.1	4.7	4.0
201015-9-71	0.11268	0.00082	4.84	0.14	0.3118	0.0081	1798	22	1748	40	1844.4	8.5	5.2
201015-9-61	0.11788	0.00046	5.08	0.11	0.3127	0.0062	1832	18	1758	30	1923.9	4.1	8.6
201015-9-3	0.11601	0.00038	5.153	0.08	0.3226	0.0051	1846	13	1802	25	1896.1	3.2	5.0
201015-9-2	0.11464	0.00036	5.123	0.045	0.3238	0.0027	1839.6	7.5	1808	13	1875.9	4.4	3.6
201015-9-87	0.11463	0.00062	5.12	0.13	0.3253	0.0079	1842	20	1815	38	1873.8	5	3.1
201015-9-16	0.11566	0.00059	5.4	0.12	0.3392	0.0075	1884	19	1881	36	1894.1	4.9	0.7
201015-9-93	0.13221	0.00093	6.28	0.13	0.3472	0.0072	2013	18	1920	34	2124	10	9.6
201015-9-31	0.11816	0.00043	5.73	0.11	0.3494	0.0064	1933	17	1931	31	1930	3.8	-0.1
201015-9-5	0.1362	0.0018	6.7	0.2	0.3577	0.0074	2069	26	1970	35	2176	16	9.5
201015-9-72	0.1295	0.001	6.64	0.19	0.364	0.012	2063	25	2012	52	2093	12	3.9
201015-9-34	0.12688	0.00034	6.6	0.12	0.3762	0.0069	2059	17	2061	33	2054.3	3.1	-0.3
201015-9-63	0.1326	0.0012	7.27	0.29	0.391	0.014	2140	35	2142	70	2133	16	-0.4
201015-9-45	0.14768	0.00049	8.06	0.27	0.397	0.013	2236	29	2159	56	2319.2	3.6	6.9
201015-9-12	0.15496	0.00044	8.674	0.096	0.4075	0.0042	2306	10	2203	19	2401.1	2.6	8.3
201015-9-55	0.15886	0.00063	9.07	0.15	0.4106	0.0066	2344	15	2216	30	2443.6	3.9	9.3
201015-9-37	0.1504	0.0011	8.49	0.29	0.412	0.012	2284	30	2220	56	2349	10	5.5
201015-9-11	0.1507	0.0015	8.62	0.28	0.413	0.013	2297	29	2226	59	2363	10	5.8
201015-9-66	0.15931	0.00071	9.18	0.2	0.418	0.0083	2354	20	2250	38	2447.5	5.5	8.1
201015-9-62	0.1477	0.0012	8.68	0.3	0.425	0.014	2302	32	2280	64	2317	10	1.6
201015-9-38	0.15503	0.00067	9.24	0.21	0.4306	0.0098	2362	21	2313	43	2400.6	4.9	3.6
201015-9-83	0.17068	0.00065	10.34	0.45	0.441	0.019	2473	40	2348	86	2565.8	4.2	8.5
201015-9-65	0.1549	0.0021	9.65	0.45	0.442	0.018	2391	43	2366	84	2413	12	1.9
201015-9-30	0.152	0.0014	9.33	0.32	0.445	0.012	2368	32	2370	55	2377	12	0.3
201015-9-59	0.1519	0.003	9.37	0.77	0.446	0.038	2369	76	2370	170	2373	29	0.1

Table 1 U-Pb isotopic data for zircon grains in Eumseong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201015-9-17	0.1637	0.0014	10.42	0.28	0.457	0.01	2474	24	2423	44	2495	12	2.9
201015-9-25	0.16458	0.00051	10.48	0.14	0.4587	0.0058	2477	12	2437	27	2504.8	2.7	2.7
201015-9-15	0.16042	0.00077	10.33	0.25	0.465	0.01	2464	22	2462	46	2466.8	7.1	0.2
201015-9-33	0.1947	0.0014	13.49	0.32	0.5013	0.0089	2715	22	2618	38	2784	11	6.0
201015-9-97	0.1824	0.0016	12.8	0.3	0.5112	0.0099	2663	22	2661	42	2674	10	0.5
201015-9-21	0.2758	0.0013	24.77	0.43	0.649	0.011	3297	17	3222	43	3337.6	5.5	3.5
201015-9-36	0.29369	0.00063	28.73	0.68	0.706	0.017	3442	23	3442	63	3437.8	1.9	-0.1

Table 2 U-Pb isotopic data for zircon grains in Gongju basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201013-1A-4	0.05111	0.00058	0.2644	0.0047	0.03782	0.00047	238	3.8	239.3	2.9	253	16	-0.5
201013-1A-21	0.0536	0.0046	0.269	0.03	0.0401	0.0024	243	22	253	15	571	83	-4.1
201013-1A-14	0.1145	0.0012	4.443	0.095	0.3093	0.0049	1724	16	1737	24	1870	14	7.6
201013-1A-35	0.11504	0.00031	4.956	0.065	0.3093	0.004	1813	11	1739	19	1880.4	3.1	7.8
201013-1A-39	0.1155	0.0013	5.3	0.21	0.307	0.013	1866	35	1744	60	1896.8	7.2	8.9
201013-1A-43	0.11429	0.0009	4.54	0.17	0.317	0.011	1735	31	1772	51	1863.9	6.8	5.9
201013-1A-11	0.1132	0.0017	4.47	0.22	0.318	0.015	1735	36	1781	72	1847	12	3.6
201013-1A-48	0.11346	0.0007	4.68	0.32	0.325	0.022	1758	56	1810	110	1853.2	5.9	2.3
201013-1A-7	0.1155	0.00042	4.76	0.22	0.327	0.013	1772	39	1835	65	1885.8	4.4	2.7
201013-1A-12	0.1143	0.0018	4.703	0.093	0.3297	0.0057	1767	17	1837	28	1871	16	1.8
201013-1A-19	0.11475	0.00053	5.056	0.09	0.334	0.0067	1827	15	1861	32	1874.3	4.3	0.9
201013-1A-58	0.11411	0.0009	5.02	0.1	0.3357	0.0055	1820	17	1865	26	1867	9	0.3
201013-1A-51	0.11411	0.00065	5.011	0.096	0.3349	0.0057	1820	16	1868	30	1857.7	4.9	-0.7
201013-1A-37	0.11468	0.00084	5.05	0.16	0.3367	0.0094	1826	26	1868	45	1874.7	7	0.5
201013-1A-25	0.11435	0.00033	5.069	0.083	0.3386	0.0068	1829	14	1878	33	1866.5	3.7	-0.6
201013-1A-24	0.1153	0.00044	5.383	0.068	0.3394	0.0033	1881	11	1885	15	1883.7	3.8	0.0
201013-1A-57	0.11795	0.00085	5.06	0.18	0.342	0.0096	1828	30	1896	46	1920	11	2.1
201013-1A-60	0.11859	0.00089	5.35	0.15	0.3499	0.0089	1881	25	1933	42	1933.8	7.6	0.1
201013-1A-55	0.1353	0.0015	6.76	0.34	0.396	0.018	2078	43	2150	81	2169	13	0.8

Table 2 U-Pb isotopic data for zircon grains in Gongju basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201013-1A-40	0.14597	0.0005	8.98	0.14	0.4282	0.007	2335	14	2301	32	2298.4	2.6	0.0
201013-1A-53	0.15723	0.00068	8.62	0.13	0.4307	0.007	2301	13	2308	32	2425.7	4.4	4.8
201013-1A-16	0.1502	0.0012	8.36	0.18	0.437	0.0094	2269	20	2336	42	2348	12	1.0
201013-1A-46	0.1536	0.002	10.01	0.23	0.4413	0.0079	2435	21	2356	35	2387	10	1.3
201013-1A-17	0.1557	0.0011	8.99	0.26	0.445	0.013	2340	26	2370	59	2414.4	6.5	1.8
201013-1A-8	0.1662	0.0011	9.47	0.2	0.448	0.0068	2383	19	2386	30	2524.7	6.8	5.5
201013-1A-5	0.1614	0.0021	9.08	0.7	0.451	0.035	2335	68	2390	150	2470	12	3.3
201013-1A-41	0.15869	0.00079	9.25	0.19	0.455	0.0097	2366	20	2425	45	2442.1	5.1	0.7
201013-1A-10	0.15996	0.00096	9.54	0.21	0.462	0.011	2389	21	2454	47	2456.5	4	0.8
201013-1A-36	0.1636	0.0006	9.67	0.32	0.464	0.015	2401	30	2454	67	2495	2.9	1.7
201013-1A-18	0.16388	0.00084	9.94	0.19	0.47	0.0096	2427	17	2482	42	2493.2	4.9	0.4
201013-1A-56	0.1631	0.0014	10.16	0.17	0.4709	0.0084	2448	16	2486	37	2485.1	8.5	-0.3
201013-1A-29	0.16593	0.00064	9.94	0.13	0.4765	0.006	2429	12	2512	26	2513.6	3.9	0.1
201013-1A-49	0.16623	0.00074	10.73	0.17	0.4777	0.0073	2505	14	2515	32	2518.8	4.7	0.2
201013-1A-50	0.1666	0.0006	10.93	0.11	0.4777	0.0072	2515.8	9.7	2515	31	2523.2	3.3	0.4
201013-1A-34	0.1848	0.00044	12.03	0.29	0.503	0.012	2605	23	2624	50	2695.8	3.2	2.6
201013-1A-47	0.1829	0.0032	13.74	0.76	0.507	0.029	2728	54	2640	120	2680	14	1.4
201013-1A-52	0.1984	0.002	13.63	0.27	0.544	0.013	2724	19	2801	55	2807.5	9.7	0.2
201013-1A-32	0.28433	0.00087	22.3	0.29	0.6069	0.0081	3196	13	3057	32	3387.2	3.7	9.6
201013-2A-41	0.0483	0.0017	0.1132	0.0042	0.01674	0.00023	109.1	3.9	107	1.4	215	30	1.9
201013-2A-98	0.0487	0.0019	0.113	0.0041	0.01678	0.00029	108.6	3.7	107.3	1.8	216	45	1.2
201013-2A-22	0.0472	0.0018	0.1125	0.0046	0.01682	0.00034	108.1	4.2	107.5	2.2	183	35	0.6
201013-2A-90	0.04838	0.00095	0.1131	0.0021	0.01688	0.00015	108.7	1.9	107.9	0.94	151	23	0.7
201013-2A-59	0.049	0.0018	0.1723	0.0063	0.02548	0.00034	161.2	5.5	162.2	2.2	247	37	-0.6
201013-2A-86	0.04937	0.00053	0.1788	0.0033	0.02607	0.00037	166.9	2.9	165.9	2.3	163	14	0.6
201013-2A-47	0.0488	0.0017	0.1816	0.0063	0.02618	0.00042	169.2	5.4	167	2.6	214	46	1.3
201013-2A-13	0.04941	0.00065	0.1824	0.0032	0.02639	0.00033	170	2.7	167.9	2.1	170	16	1.2
201013-2A-8	0.0473	0.0033	0.174	0.013	0.02642	0.00078	166	12	168.1	4.9	324	76	-1.3
201013-2A-76	0.0486	0.0012	0.1787	0.0054	0.02652	0.00033	166.7	4.6	168.7	2.1	218	28	-1.2
201013-2A-17	0.0491	0.0014	0.181	0.0046	0.02657	0.00042	169.3	4	169	2.6	244	33	0.2
201013-2A-43	0.04863	0.00098	0.1813	0.0045	0.02664	0.0004	169	3.9	169.5	2.5	149	22	-0.3
201013-2A-80	0.0493	0.00047	0.1822	0.0026	0.0268	0.00032	169.9	2.2	170.5	2	151	13	-0.4

Table 2 U-Pb isotopic data for zircon grains in Gongju basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201013-2A-2	0.04939	0.00064	0.1823	0.0051	0.02681	0.00058	169.9	4.4	170.6	3.6	179	16	-0.4
201013-2A-94	0.04905	0.00062	0.1867	0.0035	0.02753	0.00035	173.8	3	175	2.2	158	17	-0.7
201013-2A-21	0.05	0.0024	0.1937	0.0095	0.02754	0.00057	179.5	8.1	175.1	3.6	288	55	2.5
201013-2A-67	0.0504	0.0011	0.2417	0.0092	0.03504	0.00084	219.5	7.5	222	5.2	245	23	-1.1
201013-2A-23	0.0506	0.002	0.249	0.011	0.03503	0.00074	224.8	9.2	222.5	4.5	285	51	1.0
201013-2A-7	0.0506	0.0013	0.252	0.0074	0.03564	0.00049	228.4	6.1	225.8	3	263	26	1.1
201013-2A-85	0.0487	0.0046	0.256	0.026	0.0363	0.0014	229	21	229.7	8.5	392	82	-0.3
201013-2A-28	0.05186	0.00088	0.2591	0.0061	0.03636	0.00067	233.8	4.9	230.2	4.2	267	20	1.5
201013-2A-69	0.0545	0.0018	0.287	0.012	0.03809	0.00071	255.9	9.1	241	4.4	393	38	5.8
201013-2A-19	0.0642	0.0013	0.875	0.023	0.0978	0.0018	637	12	602	11	738	28	5.5
201013-2A-81	0.1122	0.001	4.66	0.11	0.2962	0.0067	1758	20	1671	33	1839	12	9.1
201013-2A-42	0.1128	0.001	4.685	0.085	0.2964	0.0042	1764	15	1673	21	1837	7.9	8.9
201013-2A-40	0.11246	0.0009	4.678	0.073	0.2975	0.0046	1761	13	1678	23	1843.5	7.6	9.0
201013-2A-62	0.11318	0.00066	4.677	0.058	0.2981	0.0031	1762	10	1681	15	1855.7	6.2	9.4
201013-2A-63	0.11351	0.00066	4.684	0.064	0.2988	0.004	1764	12	1685	20	1851.2	5.7	9.0
201013-2A-1	0.11287	0.00063	4.65	0.12	0.2995	0.0071	1757	21	1688	35	1847.4	6	8.6
201013-2A-56	0.115	0.0013	4.79	0.11	0.3	0.0069	1781	19	1690	34	1874	10	9.8
201013-2A-10	0.1124	0.001	4.7	0.11	0.3016	0.0065	1764	20	1698	32	1837.2	8.4	7.6
201013-2A-60	0.11446	0.00098	4.753	0.093	0.3018	0.0057	1775	16	1700	28	1869.1	7.8	9.0
201013-2A-87	0.1125	0.0012	4.702	0.091	0.3024	0.0053	1766	16	1703	26	1837.4	8.6	7.3
201013-2A-11	0.11164	0.00084	4.72	0.1	0.3026	0.0057	1768	18	1704	28	1832.1	9	7.0
201013-2A-54	0.11344	0.00094	4.827	0.077	0.306	0.0051	1791	14	1725	24	1860.4	7.6	7.3
201013-2A-49	0.1136	0.0014	4.83	0.14	0.3073	0.0075	1786	24	1732	36	1852	15	6.5
201013-2A-83	0.11258	0.00076	4.849	0.082	0.3109	0.0053	1792	14	1745	26	1842.8	7.1	5.3
201013-2A-93	0.11379	0.00067	4.938	0.081	0.3126	0.005	1808	14	1753	25	1862.6	6	5.9
201013-2A-66	0.11329	0.00099	4.906	0.09	0.3142	0.0044	1804	16	1761	21	1855	10	5.1
201013-2A-51	0.11341	0.00087	4.91	0.12	0.3147	0.007	1805	19	1763	34	1856.8	6.7	5.1
201013-2A-44	0.1131	0.001	5.06	0.094	0.3174	0.0053	1831	15	1777	26	1844	11	3.6
201013-2A-36	0.11421	0.00081	5.094	0.089	0.323	0.0049	1837	15	1804	24	1867.9	7.1	3.4
201013-2A-50	0.1125	0.0014	4.96	0.29	0.323	0.017	1821	46	1805	81	1841.9	6.9	2.0
201013-2A-37	0.11443	0.00095	5.199	0.097	0.3265	0.0058	1851	16	1821	28	1879.6	9.7	3.1
201013-2A-15	0.11	0.0012	5.04	0.15	0.327	0.01	1825	26	1826	49	1813.8	9.5	-0.7
201013-2A-18	0.1115	0.0035	5.06	0.41	0.328	0.018	1822	69	1829	88	1834	19	0.3

Table 2 U-Pb isotopic data for zircon grains in Gongju basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201013-2A-92	0.11371	0.00075	5.263	0.082	0.3358	0.0041	1862	13	1866	20	1857.8	6.9	-0.4
201013-2A-46	0.11385	0.00086	5.342	0.093	0.3371	0.0062	1875	15	1872	30	1856.2	4.8	-0.9
201013-2A-96	0.11571	0.00062	5.5	0.17	0.343	0.0096	1898	27	1909	44	1892.9	5.9	-0.9
201013-2A-91	0.11733	0.00046	5.673	0.068	0.3477	0.0035	1926	10	1925	17	1917.4	5	-0.4
201013-2A-58	0.12213	0.0007	6.08	0.17	0.3609	0.0088	1997	26	1994	42	1990.5	9.2	-0.2
201013-2A-72	0.1397	0.00096	7.31	0.15	0.3833	0.0067	2149	19	2091	31	2223.3	6.1	6.0
201013-2A-78	0.13668	0.00041	7.642	0.085	0.4044	0.0041	2189	10	2191	19	2186.5	3.3	-0.2
201013-2A-75	0.15471	0.00069	9.48	0.2	0.4484	0.0087	2383	20	2387	39	2398.7	4.9	0.5
201013-2A-9	0.16584	0.00084	10.37	0.29	0.449	0.012	2465	26	2389	51	2520.3	4.1	5.2
201013-2A-34	0.1669	0.0015	10.24	0.29	0.45	0.012	2465	25	2393	52	2529.5	9.9	5.4
201013-2A-95	0.1677	0.0012	10.71	0.18	0.4615	0.0076	2496	16	2445	34	2531.6	7.7	3.4
201013-2A-39	0.1661	0.0014	11.01	0.25	0.4781	0.0096	2526	20	2526	44	2525.5	6.4	0.0
201013-4A-32	0.065	0.027	0.067	0.034	0.00898	0.00096	62	32	57.6	6.1	1510	250	7.1
201013-4A-22	0.0432	0.0068	0.06	0.01	0.00917	0.00075	59.3	9.4	58.8	4.8	513	97	0.8
201013-4A-26	0.053	0.016	0.103	0.028	0.015	0.0017	102	22	96	11	880	160	5.9
201013-4A-25	0.041	0.015	0.109	0.025	0.0153	0.0015	99	24	97.4	9.4	950	190	1.6
201013-4A-29	0.0394	0.0083	0.102	0.017	0.016	0.0016	99	16	102	10	700	130	-3.0
201013-4A-72	0.0466	0.0097	0.117	0.018	0.0166	0.0014	111	17	106.1	8.8	710	130	4.4
201013-4A-88	0.038	0.015	0.106	0.024	0.0168	0.0019	101	22	107	12	740	270	-5.9
201013-4A-14	0.0459	0.0094	0.108	0.02	0.0169	0.0018	102	18	108	11	740	160	-5.9
201013-4A-70	0.046	0.011	0.115	0.021	0.0172	0.0017	108	19	110	11	810	170	-1.9
201013-4A-60	0.0487	0.006	0.126	0.018	0.0176	0.0013	116	16	112	8.1	680	110	3.4
201013-4A-28	0.0453	0.0081	0.121	0.017	0.0177	0.0015	115	16	112.7	9.3	680	130	2.0
201013-4A-89	0.0502	0.0033	0.1211	0.0092	0.01808	0.00088	116.1	8.5	115.4	5.5	455	63	0.6
201013-4A-76	0.0461	0.009	0.127	0.023	0.0188	0.0015	119	21	119.9	9.2	680	110	-0.8
201013-4A-13	0.047	0.012	0.138	0.031	0.0192	0.0024	125	26	122	15	930	170	2.4
201013-4A-86	0.0516	0.0075	0.134	0.021	0.0192	0.0011	128	18	122.3	7.1	640	110	4.5
201013-4A-52	0.0463	0.0065	0.128	0.019	0.02	0.0014	127	16	127.3	9.1	680	120	-0.2
201013-4A-75	0.058	0.011	0.149	0.028	0.0204	0.0015	135	25	129.8	9.4	940	140	3.9
201013-4A-59	0.0459	0.0049	0.14	0.016	0.0211	0.0014	133	15	134.6	9.1	447	78	-1.2
201013-4A-80	0.0492	0.0048	0.143	0.016	0.0213	0.0012	137	14	135.7	7.8	431	77	0.9
201013-4A-63	0.0486	0.0041	0.144	0.018	0.0215	0.0016	135	16	137	9.8	374	62	-1.5

Table 2 U-Pb isotopic data for zircon grains in Gongju basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 2σ	^{207}Pb/^{235}U	Er. 2σ	^{206}Pb/^{238}U	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201013-4A-15	0.0477	0.0095	0.145	0.03	0.0224	0.0015	139	27	142.8	9.2	690	180	-2.7
201013-4A-19	0.0514	0.0024	0.16	0.011	0.02308	0.00092	150.1	9.8	147.1	5.8	353	42	2.0
201013-4A-55	0.051	0.0031	0.174	0.013	0.0238	0.0014	162	11	151.6	9.1	382	78	6.4
201013-4A-20	0.0524	0.0041	0.168	0.016	0.02459	0.00092	156	14	156.6	5.8	389	69	-0.4
201013-4A-4	0.0547	0.0061	0.18	0.02	0.0248	0.0017	166	18	158	11	690	130	4.8
201013-4A-47	0.0536	0.0043	0.182	0.017	0.0253	0.0014	169	14	161.3	8.5	395	81	4.6
201013-4A-73	0.0481	0.0085	0.174	0.028	0.0258	0.0021	168	25	164	13	642	89	2.4
201013-4A-44	0.0497	0.0028	0.178	0.021	0.0262	0.003	162	18	166	19	297	59	-2.5
201013-4A-7	0.0509	0.0093	0.181	0.036	0.0264	0.0021	165	31	168	13	620	170	-1.8
201013-4A-35	0.0501	0.0051	0.189	0.022	0.0277	0.0014	174	19	175.9	9	418	89	-1.1
201013-4A-2	0.0499	0.0013	0.19	0.0096	0.0279	0.0015	176.7	8.3	177.5	9.3	238	33	-0.5
201013-4A-84	0.0492	0.0023	0.197	0.016	0.0281	0.0018	182	14	178	11	334	50	2.2
201013-4A-9	0.057	0.02	0.201	0.07	0.0286	0.006	182	60	181	38	840	360	0.5
201013-4A-67	0.0526	0.008	0.193	0.028	0.0287	0.002	177	24	182	13	640	190	-2.8
201013-4A-79	0.055	0.013	0.219	0.068	0.03	0.0023	196	58	190	14	440	220	3.1
201013-4A-91	0.0498	0.00056	0.2068	0.0097	0.0305	0.0015	191.7	8.3	193.3	9.1	199	14	-0.8
201013-4A-41	0.0496	0.0011	0.208	0.015	0.0305	0.0021	191	13	194	13	198	26	-1.6
201013-4A-92	0.05003	0.00081	0.2136	0.0096	0.0308	0.0016	195.8	8.1	195.3	9.7	185	18	0.3
201013-4A-24	0.05021	0.00092	0.222	0.016	0.0326	0.0025	203	13	206	16	210	25	-1.5
201013-4A-43	0.0498	0.00092	0.237	0.017	0.0346	0.0022	216	14	219	14	186	23	-1.4
201013-4A-1	0.0506	0.0029	0.242	0.021	0.0355	0.0025	222	17	224	16	307	57	-0.9
201013-4A-62	0.0508	0.0014	0.271	0.019	0.0386	0.0025	242	15	244	15	286	28	-0.8
201013-4A-23	0.0502	0.0058	0.312	0.031	0.0425	0.0037	270	25	267	23	433	99	1.1
201013-4A-78	0.059	0.0029	0.318	0.028	0.0422	0.0024	280	22	268	15	567	73	4.3
201013-4A-27	0.0529	0.0021	0.348	0.032	0.0482	0.0045	302	24	303	28	368	47	-0.3
201013-4A-61	0.0567	0.0055	0.393	0.051	0.0501	0.0039	322	32	315	24	595	87	2.2
201013-4A-45	0.068	0.026	0.5	1.1	0.032	0.095	320	190	320	350	1300	290	0.0
201013-4A-58	0.0571	0.0035	0.466	0.037	0.0592	0.0031	388	26	371	19	549	63	4.4
201013-4A-30	0.055	0.002	0.469	0.044	0.0622	0.0056	381	30	386	33	456	41	-1.3
201013-4A-49	0.057	0.013	0.52	0.11	0.0668	0.0094	409	69	411	56	730	110	-0.5
201013-4A-65	0.0571	0.0037	0.58	0.061	0.0734	0.0067	459	39	454	41	545	60	1.1
201013-4A-85	0.0662	0.0028	1.079	0.092	0.1197	0.0081	728	45	725	46	805	52	0.4
201013-4A-38	0.0647	0.0022	1.164	0.098	0.13	0.01	771	48	781	59	796	45	-1.3

Table 2 U-Pb isotopic data for zircon grains in Gongju basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201013-4A-33	0.0663	0.0027	1.21	0.11	0.133	0.012	796	53	795	67	831	49	0.1
201013-4A-50	0.067	0.0017	1.205	0.083	0.1316	0.0084	799	38	795	48	841	29	0.5
201013-4A-64	0.0696	0.0021	1.37	0.15	0.146	0.016	861	64	867	87	929	43	-0.7
201013-4A-10	0.0701	0.0032	1.39	0.14	0.147	0.015	885	65	882	86	932	52	0.3
201013-4A-68	0.069	0.0076	1.72	0.49	0.158	0.061	920	120	930	280	860	100	-1.1
201013-4A-81	0.0868	0.0053	2.27	0.49	0.195	0.042	1240	120	1240	220	1343	69	7.7
201013-4A-31	0.1115	0.0012	4.57	0.25	0.296	0.015	1753	41	1679	74	1825	13	8.0
201013-4A-12	0.10693	0.00067	4.42	0.27	0.304	0.018	1698	51	1696	91	1749.1	7.7	3.0
201013-4A-87	0.1134	0.0014	5.07	0.35	0.326	0.023	1809	59	1800	110	1860	10	3.2
201013-4A-71	0.11649	0.00084	5.3	0.17	0.335	0.01	1865	28	1862	50	1903.7	7.3	2.2
201013-4A-93	0.11472	0.00064	5.26	0.26	0.338	0.017	1867	42	1880	80	1875.8	7	-0.2
201013-4A-77	0.1167	0.001	5.55	0.24	0.345	0.015	1895	39	1900	73	1905	10	0.3
201013-4A-3	0.11556	0.0006	5.4	0.25	0.345	0.017	1878	40	1911	79	1887.2	5.8	-1.3
201013-4A-48	0.1313	0.00073	6.91	0.33	0.384	0.019	2088	42	2084	88	2117.4	5.9	1.6
201013-4A-17	0.13495	0.00095	7.3	0.48	0.394	0.024	2144	59	2150	120	2168.6	7.9	0.9
201013-4A-39	0.1368	0.0012	7.26	0.75	0.391	0.038	2151	84	2160	180	2189.4	8.7	1.3
201013-4A-66	0.1476	0.0023	8.24	0.53	0.416	0.026	2250	59	2230	120	2320	17	3.9
201013-4A-69	0.14204	0.00081	7.89	0.42	0.414	0.02	2225	46	2241	90	2251.1	6.8	0.4
201013-4A-36	0.1511	0.0015	8.94	0.31	0.434	0.013	2328	32	2323	61	2358	12	1.5
201013-4A-11	0.1611	0.0016	9.99	0.98	0.453	0.045	2322	98	2330	200	2457	14	5.2
201013-4A-37	0.15066	0.00082	9.13	0.47	0.441	0.022	2333	46	2340	100	2352.2	6.3	0.5
201013-4A-74	0.1697	0.0025	10.25	0.43	0.449	0.019	2458	40	2388	82	2551	18	6.4
201013-4A-16	0.1574	0.0014	9.74	0.67	0.455	0.029	2389	66	2420	130	2422	13	0.1
201013-4A-18	0.1589	0.0011	10.33	0.95	0.478	0.042	2412	94	2480	190	2433	12	-1.9
201013-4A-6	0.1662	0.0014	10.69	0.65	0.475	0.029	2507	58	2510	120	2523.7	7.6	0.5
201013-4A-42	0.1752	0.0022	12.48	0.9	0.514	0.034	2619	69	2670	150	2615	18	-2.1
201015-21-93	0.0503	0.0011	0.2482	0.0077	0.03564	0.00077	225.5	6.4	225.7	4.8	237	24	-0.1
201015-21-40	0.05119	0.00024	0.2626	0.0044	0.0371	0.00059	236.7	3.5	234.8	3.7	251.3	7.4	0.8
201015-21-88	0.05101	0.00042	0.2617	0.0047	0.0375	0.00058	236	3.8	237.3	3.6	240	14	-0.6
201015-21-85	0.05145	0.00064	0.2663	0.0082	0.03767	0.00095	239.3	6.6	238.3	5.9	258	19	0.4
201015-21-66	0.0544	0.00031	0.4704	0.0098	0.0629	0.0012	390.9	6.8	393	7.3	390.2	9	-0.5
201015-21-26	0.06549	0.00057	1.139	0.036	0.1279	0.0041	776	17	775	23	784	11	0.1

Table 2 U-Pb isotopic data for zircon grains in Gongju basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	$^{207}U-^{235}Pb$ age (Ma)	Er. 2σ	$^{206}U-^{238}Pb$ age (Ma)	Er. 2σ	$^{207}U-^{206}Pb$ age (Ma)	Er. 2σ	Discordance (%)
201015-21-61	0.11492	0.00038	4.775	0.092	0.3013	0.0054	1779	16	1697	27	1881.1	2.9	9.8
201015-21-95	0.1146	0.00047	4.8	0.11	0.3014	0.0052	1783	19	1698	26	1872.3	5.1	9.3
201015-21-25	0.1145	0.00056	4.72	0.15	0.3002	0.0093	1768	27	1699	48	1874.3	5.9	9.4
201015-21-87	0.11319	0.00048	4.74	0.13	0.3051	0.0083	1772	22	1715	41	1850.7	5	7.3
201015-21-57	0.11682	0.00041	4.96	0.17	0.307	0.01	1814	28	1734	47	1908.3	4	9.1
201015-21-34	0.1153	0.00072	5.06	0.29	0.315	0.017	1846	48	1763	85	1886.8	7	6.6
201015-21-90	0.11513	0.00044	5.001	0.073	0.316	0.0046	1819	12	1770	23	1880.2	3.6	5.9
201015-21-12	0.1159	0.00067	5.12	0.22	0.318	0.014	1839	36	1778	67	1894.9	5.1	6.2
201015-21-13	0.11684	0.00034	5.13	0.15	0.3189	0.0096	1838	25	1783	47	1908.5	3.9	6.6
201015-21-1	0.11762	0.00048	5.24	0.17	0.3197	0.0099	1854	27	1786	48	1921.6	4.2	7.1
201015-21-46	0.11639	0.00046	5.17	0.17	0.322	0.01	1844	28	1795	50	1899.4	3.8	5.5
201015-21-3	0.11055	0.00052	4.959	0.087	0.325	0.0055	1814	14	1813	27	1808.2	4.8	-0.3
201015-21-32	0.11945	0.00075	5.3	0.17	0.3241	0.0092	1865	28	1817	43	1948.6	8.4	6.8
201015-21-84	0.11552	0.00087	5.19	0.26	0.327	0.015	1849	42	1822	75	1884.9	3.1	3.3
201015-21-79	0.11399	0.00061	5.14	0.18	0.327	0.011	1838	30	1823	53	1867.4	6.5	2.4
201015-21-72	0.1147	0.00027	5.19	0.091	0.3277	0.0057	1850	15	1826	28	1875.4	1.9	2.6
201015-21-15	0.11418	0.00035	5.161	0.098	0.3276	0.0063	1843	16	1832	29	1867.3	4	1.9
201015-21-69	0.11524	0.00039	5.244	0.087	0.3289	0.0055	1862	13	1838	25	1883.9	3.2	2.4
201015-21-19	0.11249	0.00073	5.09	0.13	0.3303	0.0079	1841	20	1839	38	1842.7	6.5	0.2
201015-21-70	0.11249	0.00037	5.141	0.099	0.3301	0.0059	1843	16	1845	30	1837.9	3.6	-0.4
201015-21-41	0.1143	0.00048	5.2	0.26	0.333	0.017	1852	44	1848	80	1869.5	4.3	1.2
201015-21-62	0.11399	0.00052	5.29	0.16	0.336	0.01	1860	26	1867	49	1867.8	5.4	0.0
201015-21-58	0.11518	0.00064	5.33	0.15	0.337	0.0098	1873	26	1870	47	1880.6	6.4	0.6
201015-21-96	0.11516	0.00026	5.39	0.12	0.3394	0.0075	1882	19	1881	36	1881.6	2.2	0.0
201015-21-48	0.11518	0.00043	5.42	0.18	0.339	0.012	1885	29	1882	55	1885	4.3	0.2
201015-21-80	0.11511	0.00039	5.4	0.23	0.34	0.014	1875	36	1883	67	1879.6	4.1	-0.2
201015-21-27	0.11583	0.00032	5.407	0.09	0.3397	0.0054	1885	14	1884	26	1894	3.4	0.5
201015-21-38	0.11554	0.00046	5.42	0.11	0.3403	0.0065	1887	16	1890	31	1886.6	3.7	-0.2
201015-21-21	0.11541	0.00049	5.44	0.12	0.3405	0.0068	1888	20	1891	34	1886.2	4.9	-0.3
201015-21-35	0.11559	0.00048	5.43	0.11	0.3405	0.0071	1889	18	1892	33	1888.5	4.1	-0.2
201015-21-10	0.11935	0.00073	5.71	0.35	0.34	0.019	1935	54	1920	100	1949.6	6.7	1.5
201015-21-77	0.11789	0.00031	5.67	0.13	0.3492	0.0078	1922	19	1928	37	1924.6	2.9	-0.2
201015-21-18	0.12134	0.00042	5.86	0.12	0.3497	0.007	1954	18	1932	34	1974	3.5	2.1

Table 2 U-Pb isotopic data for zircon grains in Gongju basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 2σ	^{207}Pb/^{235}U	Er. 2σ	^{206}Pb/^{238}U	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201015-21-89	0.11986	0.00031	5.77	0.096	0.3499	0.0059	1939	14	1933	28	1953.6	3.5	1.1
201015-21-83	0.12652	0.00091	6.34	0.29	0.353	0.021	2017	40	1997	83	2053.6	8.3	2.8
201015-21-49	0.1318	0.0017	6.83	0.36	0.377	0.019	2085	47	2058	90	2113	14	2.6
201015-21-56	0.13691	0.0006	7.4	0.19	0.3944	0.0099	2159	22	2147	44	2186.7	6.7	1.8
201015-21-47	0.159	0.001	8.99	0.33	0.408	0.015	2331	34	2204	66	2444.7	8.2	9.8
201015-21-54	0.15883	0.00088	8.97	0.25	0.407	0.011	2331	26	2208	52	2440.7	4.7	9.5
201015-21-9	0.13896	0.00074	7.76	0.87	0.4	0.044	2200	110	2210	220	2215.2	4.8	0.2
201015-21-4	0.15821	0.00078	9.04	0.25	0.413	0.012	2340	25	2227	53	2435.9	6.8	8.6
201015-21-63	0.15829	0.00072	9.17	0.81	0.419	0.037	2372	83	2240	170	2437.7	4.2	8.1
201015-21-98	0.14307	0.00057	8.26	0.13	0.4169	0.0065	2258	14	2249	29	2268.3	6.5	0.9
201015-21-30	0.15583	0.00075	9.01	0.27	0.42	0.012	2334	28	2256	56	2412.8	5.9	6.5
201015-21-42	0.15593	0.00076	9.18	0.26	0.424	0.012	2353	26	2278	54	2409.6	4.9	5.5
201015-21-53	0.14358	0.00073	8.49	0.21	0.426	0.011	2284	24	2283	51	2269.3	5.4	-0.6
201015-21-67	0.14996	0.00073	9.07	0.2	0.4355	0.0086	2343	20	2329	38	2344	6.4	0.6
201015-21-50	0.1509	0.002	9.24	0.39	0.446	0.016	2362	38	2381	69	2354	19	-1.1
201015-21-92	0.1573	0.0011	9.81	0.23	0.451	0.01	2412	21	2398	45	2427.3	8	1.2
201015-21-37	0.16314	0.00089	10.13	0.5	0.455	0.023	2464	43	2410	100	2488.4	5.7	3.2
201015-21-5	0.1588	0.0023	10.1	1.3	0.458	0.059	2420	110	2420	260	2442	13	0.9
201015-21-82	0.1601	0.0011	10.09	0.49	0.458	0.021	2437	43	2420	92	2459.3	6.7	1.6
201015-21-86	0.16276	0.00074	10.19	0.23	0.4561	0.0095	2451	21	2422	42	2485.7	4	2.6
201015-21-94	0.1639	0.0019	10.35	0.36	0.46	0.015	2464	32	2438	65	2503	10	2.6
201015-21-97	0.16435	0.00062	10.57	0.17	0.4656	0.0074	2484	15	2463	32	2501.6	4.4	1.5
201015-21-91	0.16648	0.00045	10.78	0.16	0.4686	0.0064	2503	14	2477	28	2522.7	2.7	1.8
201015-21-6	0.16473	0.00058	10.82	0.3	0.473	0.012	2509	26	2510	53	2505.4	4.7	-0.2
201015-21-76	0.2993	0.0023	27.31	0.78	0.662	0.019	3391	28	3270	71	3468	11	5.7
201015-26-80	0.1133	0.00048	4.82	0.15	0.299	0.0091	1785	27	1685	45	1854.1	4.6	9.1
201015-26-68	0.1177	0.0004	5.14	0.15	0.3081	0.0086	1841	26	1730	43	1920.9	4.2	9.9
201015-26-47	0.117	0.00059	5.25	0.2	0.317	0.012	1857	32	1774	57	1911.7	6.5	7.2
201015-26-46	0.12011	0.00055	5.53	0.44	0.327	0.026	1889	69	1810	120	1956.2	4.5	7.5
201015-26-18	0.11831	0.00034	5.45	0.17	0.3229	0.0096	1891	26	1813	50	1931.3	3.2	6.1
201015-26-96	0.11348	0.00073	5.28	0.4	0.327	0.025	1866	67	1840	130	1853.2	5.6	0.7
201015-26-36	0.11663	0.00044	5.71	0.15	0.3477	0.0093	1935	22	1922	45	1907	5.9	-0.8

Table 2 U-Pb isotopic data for zircon grains in Gongju basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 2σ	^{207}Pb/^{235}U	Er. 2σ	^{206}Pb/^{238}U	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201015-26-67	0.1333	0.0011	6.63	0.34	0.351	0.016	2052	46	1932	77	2138	13	9.6
201015-26-84	0.13367	0.00076	7.24	0.36	0.38	0.019	2143	42	2072	87	2150.2	6.3	3.6
201015-26-11	0.14213	0.00083	7.79	0.47	0.379	0.022	2191	55	2080	110	2257.1	7.8	7.8
201015-26-91	0.13869	0.00069	7.27	0.38	0.387	0.021	2149	48	2103	98	2209.2	6.4	4.8
201015-26-33	0.15485	0.00061	8.78	0.52	0.401	0.023	2303	56	2170	110	2400.7	4.1	9.6
201015-26-9	0.15547	0.00075	8.93	0.2	0.4019	0.0085	2332	21	2183	41	2404	4.6	9.2
201015-26-31	0.1378	0.0012	7.88	0.74	0.404	0.04	2197	82	2210	170	2196.9	7.8	-0.6
201015-26-59	0.15472	0.0007	8.94	0.27	0.41	0.013	2334	27	2212	61	2400.6	4.9	7.9
201015-26-10	0.16404	0.00051	9.95	0.31	0.424	0.013	2426	28	2278	60	2496.7	3.4	8.8
201015-26-50	0.1508	0.001	9.21	0.46	0.428	0.02	2354	45	2316	94	2352.8	5.8	1.6
201015-26-40	0.1505	0.0021	9.21	0.31	0.436	0.013	2356	31	2329	60	2341	11	0.5
201015-26-93	0.16295	0.00049	10.18	0.27	0.437	0.011	2448	25	2337	50	2485.7	3	6.0
201015-26-62	0.1537	0.0026	9.62	0.92	0.441	0.042	2382	89	2350	190	2385	23	1.5
201015-26-88	0.17848	0.00056	11.39	0.72	0.452	0.028	2584	59	2390	120	2638.7	3.3	9.4
201015-26-56	0.16104	0.0007	10.45	0.3	0.457	0.013	2474	27	2423	59	2468.3	4.3	1.8
201015-26-92	0.15701	0.00087	10.16	0.29	0.459	0.012	2455	27	2433	53	2421.7	6	-0.5
201015-26-14	0.1773	0.0013	11.58	0.43	0.458	0.016	2571	33	2440	69	2630.4	9	7.2
201015-26-23	0.1632	0.0014	10.5	0.94	0.452	0.041	2481	94	2440	200	2492	11	2.1
201015-26-20	0.15841	0.00061	10.36	0.32	0.463	0.014	2472	28	2458	66	2437.9	4.3	-0.8
201015-26-100	0.1571	0.00081	10.41	0.67	0.465	0.03	2483	67	2460	130	2422.7	5.1	-1.5
201015-26-95	0.16098	0.00056	10.59	0.23	0.466	0.01	2484	20	2469	44	2465.1	3.4	-0.2
201015-26-52	0.1789	0.0011	12.09	0.4	0.48	0.015	2608	31	2524	64	2634.4	5.9	4.2
201015-26-94	0.17762	0.00059	12.38	0.53	0.509	0.02	2631	41	2667	88	2630.8	4.1	-1.4
201015-26-16	0.1815	0.0018	13.3	0.93	0.514	0.034	2714	67	2690	160	2667	12	-0.9
201015-26-37	0.25519	0.00087	20.84	0.77	0.58	0.021	3126	35	2945	86	3218.5	3.2	8.5
201015-26-98	0.29417	0.00073	26.2	1	0.627	0.024	3347	39	3130	96	3439.3	2.3	9.0
201015-32-80	0.0508	0.0014	0.2369	0.0083	0.0338	0.0006	215.6	6.8	214.3	3.7	249	33	0.6
201015-32-67	0.0508	0.0036	0.267	0.022	0.0374	0.0012	239	17	236.9	7.4	409	67	0.9
201015-32-98	0.05108	0.00056	0.2714	0.0051	0.03842	0.00059	243.5	4.1	243	3.7	249	12	0.2
201015-32-68	0.05075	0.00097	0.2768	0.0059	0.03961	0.00052	247.9	4.7	250.4	3.2	230	26	-1.0
201015-32-25	0.0503	0.0018	0.28	0.015	0.04075	0.00088	250	12	257.4	5.5	220	40	-3.0
201015-32-19	0.05188	0.00051	0.3099	0.0056	0.0429	0.00062	273.9	4.3	270.8	3.8	281	12	1.1

Table 2 U-Pb isotopic data for zircon grains in Gongju basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 2σ	^{207}Pb/^{235}U	Er. 2σ	^{206}Pb/^{238}U	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201015-32-81	0.05111	0.00091	0.3046	0.0083	0.0436	0.00088	270.5	6.6	275.1	5.4	246	25	-1.7
201015-32-61	0.0521	0.0016	0.31	0.013	0.0443	0.00095	276.2	9.5	279.4	5.9	302	40	-1.2
201015-32-52	0.05204	0.00063	0.3224	0.0066	0.04478	0.00066	283.6	5	282.4	4.1	288	18	0.4
201015-32-36	0.0546	0.0052	0.384	0.033	0.0505	0.0032	329	24	318	20	353	76	3.3
201015-32-33	0.0549	0.0024	0.616	0.035	0.0828	0.004	486	22	512	23	408	52	-5.3
201015-32-27	0.06637	0.00056	1.064	0.019	0.1143	0.002	735.4	9.3	698	12	817.7	9.7	5.1
201015-32-71	0.11498	0.0006	4.91	0.077	0.309	0.0043	1803	13	1736	21	1883	5.7	7.9
201015-32-29	0.11764	0.00091	5.12	0.11	0.3171	0.0075	1838	18	1775	37	1922.3	9.9	7.9
201015-32-83	0.11993	0.0006	5.19	0.14	0.3191	0.0079	1859	21	1784	39	1956.8	5	8.3
201015-32-26	0.11837	0.00055	5.305	0.083	0.3221	0.0047	1869	13	1799	23	1932.9	5.1	6.9
201015-32-9	0.12247	0.00054	5.576	0.096	0.3279	0.0056	1911	15	1827	27	1991.4	6	8.3
201015-32-32	0.11429	0.00058	5.208	0.099	0.3305	0.0062	1855	15	1840	30	1867.5	5.2	1.3
201015-32-24	0.11525	0.00081	5.33	0.16	0.3313	0.0091	1872	24	1843	44	1888.7	7.4	2.2
201015-32-49	0.12712	0.0003	5.861	0.073	0.3341	0.0046	1958	11	1860	22	2059.7	2.7	9.7
201015-32-45	0.11581	0.00037	5.366	0.075	0.3365	0.0048	1880	12	1869	23	1891.6	3.6	1.3
201015-32-44	0.11759	0.00036	5.526	0.058	0.3402	0.004	1903.7	9	1890	19	1919.3	4.2	1.7
201015-32-42	0.11749	0.00039	5.545	0.068	0.3418	0.0045	1906	11	1895	22	1920	4	0.8
201015-32-35	0.11691	0.00041	5.59	0.11	0.3433	0.0066	1913	17	1902	32	1912.1	3	0.6
201015-32-73	0.11732	0.00025	5.563	0.071	0.3438	0.0049	1911	11	1904	23	1916.8	2	0.7
201015-32-72	0.11679	0.00087	5.52	0.11	0.3445	0.0057	1906	17	1907	27	1909	8.7	0.6
201015-32-39	0.11716	0.00033	5.612	0.084	0.3442	0.0056	1918	13	1909	26	1915.1	3.4	0.3
201015-32-85	0.11498	0.00057	5.5	0.12	0.345	0.006	1904	18	1914	28	1882.5	6.1	-0.8
201015-32-62	0.11725	0.00026	5.586	0.067	0.3464	0.0045	1914	10	1916	21	1914.8	2.9	-0.3
201015-32-59	0.11783	0.00053	5.61	0.08	0.3475	0.0048	1917	12	1922	23	1922.5	5.4	0.1
201015-32-15	0.1163	0.0011	5.56	0.32	0.35	0.021	1906	49	1929	97	1903.4	6.9	-3.0
201015-32-84	0.1168	0.00038	5.615	0.09	0.3501	0.0064	1921	14	1934	30	1910.6	3.3	-1.6
201015-32-78	0.12102	0.00047	5.88	0.1	0.3535	0.0063	1957	15	1950	30	1972.6	4.7	1.2
201015-32-14	0.13506	0.00084	6.76	0.11	0.363	0.0052	2077	14	1995	24	2163.9	8.5	8.3
201015-32-86	0.123	0.0011	6.11	0.16	0.3638	0.0074	1990	22	1999	35	1997	14	0.9
201015-32-48	0.12538	0.00086	6.36	0.13	0.3675	0.0076	2026	19	2020	37	2034.6	9.2	0.9
201015-32-56	0.12967	0.00054	6.82	0.1	0.3836	0.0055	2089	13	2096	24	2097.5	4.4	0.2
201015-32-87	0.1468	0.0011	7.85	0.19	0.3871	0.0076	2213	22	2108	35	2309	11	8.5
201015-32-88	0.1342	0.00085	7.26	0.11	0.3955	0.0074	2143	14	2147	34	2154.2	9	0.2

Table 2 U-Pb isotopic data for zircon grains in Gongju basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 2σ	$^{207}Pb/^{235}U$	Er. 2σ	$^{206}Pb/^{238}U$	Er. 2σ	^{207}U-^{235}Pb age (Ma)	Er. 2σ	^{206}U-^{238}Pb age (Ma)	Er. 2σ	^{207}U-^{206}Pb age (Ma)	Er. 2σ	Discordance (%)
201015-32-50	0.13663	0.00076	7.57	0.16	0.4018	0.0077	2183	19	2176	35	2185.9	8	0.5
201015-32-60	0.13909	0.00073	7.7	0.19	0.4054	0.0098	2194	21	2193	45	2216.1	5	1.0
201015-32-58	0.15835	0.00096	9.02	0.22	0.4161	0.0088	2342	20	2242	40	2440	6.1	7.6
201015-32-92	0.14898	0.00077	8.66	0.25	0.429	0.011	2313	27	2301	49	2333	5.2	2.0
201015-32-43	0.1512	0.0013	9	0.26	0.432	0.011	2336	27	2309	50	2360.2	9.1	2.3
201015-32-69	0.1615	0.0012	9.49	0.16	0.4313	0.0054	2389	17	2311	24	2471.8	8.3	6.9
201015-32-8	0.162	0.0012	10.02	0.29	0.445	0.013	2437	28	2370	58	2475.3	6	4.3
201015-32-93	0.1645	0.0011	10.07	0.28	0.449	0.011	2443	24	2397	45	2503.3	7.4	4.2
201015-32-2	0.16434	0.00065	10.26	0.18	0.4512	0.0074	2457	16	2399	33	2501.6	3.4	4.1
201015-32-99	0.1653	0.0011	10.39	0.34	0.459	0.015	2466	31	2435	66	2510.5	9.6	3.7
201015-32-1	0.16772	0.0008	11.09	0.19	0.4811	0.0075	2527	15	2529	32	2535.4	5.2	0.3
201015-32-89	0.17116	0.00074	11.51	0.18	0.4864	0.0075	2563	15	2554	33	2568.3	4.3	0.5
201015-32-53	0.17053	0.00091	11.43	0.22	0.487	0.0077	2558	18	2557	33	2564.3	7.1	0.7
201015-32-12	0.17022	0.00092	11.61	0.25	0.498	0.011	2573	21	2605	49	2561.8	3.5	-1.7
201015-32-51	0.17737	0.00043	12.26	0.15	0.5031	0.006	2624	11	2626	26	2628.9	2.2	0.0
201015-32-31	0.18811	0.00079	13.51	0.21	0.5132	0.0088	2715	15	2676	35	2724	3.1	1.8
201015-32-90	0.18706	0.00056	13.38	0.16	0.5222	0.0066	2708	11	2707	28	2715.6	3	0.4

Table 3 U-Pb isotopic data for zircon grains in the Haenam basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 1σ	$^{207}Pb/^{235}U$	Er. 1σ	$^{206}Pb/^{238}U$	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
HN-211201-11-99	0.0531	0.0039	0.0922	0.0057	0.0130	0.0003	89.6	5.28244	83.6	1.77528	332	166.645	1.5	6.7%
HN-211201-11-23	0.0520	0.0072	0.0877	0.0086	0.0132	0.0004	85.4	8.0674	84.7	2.37864	283	288.86	2.3	0.9%
HN-211201-11-72	0.0518	0.0035	0.0944	0.0057	0.0134	0.0002	91.6	5.31245	85.8	1.24672	276	155.535	0.7	6.3%
HN-211201-11-37	0.0491	0.0019	0.0907	0.0034	0.0135	0.0001	88.1	3.12403	86.2	0.91546	154	90.7275	1.5	2.1%
HN-211201-11-95	0.0483	0.0035	0.0876	0.0055	0.0135	0.0002	85.3	5.15989	86.4	1.37731	122	157.38	0.9	-1.4%
HN-211201-11-84	0.0567	0.0077	0.0978	0.0089	0.0136	0.0004	94.7	8.22063	86.8	2.69013	480	303.665	0.6	8.4%
HN-211201-11-46	0.0485	0.0036	0.0901	0.0060	0.0136	0.0002	87.6	5.54524	87.2	1.48062	124	175.9	0.5	0.5%
HN-211201-11-45	0.0480	0.0038	0.0898	0.0069	0.0136	0.0002	87.3	6.43118	87.3	1.58582	102	177.75	0.9	0.0%
HN-211201-11-81	0.0463	0.0043	0.0863	0.0068	0.0137	0.0002	84.0	6.38922	87.4	1.57591	13.1	220.34	0.7	-4.0%

Table 3 U-Pb isotopic data for zircon grains in the Haenam basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 1σ	$^{207}Pb/^{235}U$	Er. 1σ	$^{206}Pb/^{238}U$	Er. 1σ	$^{207}U-^{235}Pb$ age (Ma)	Er. 1σ	$^{206}U-^{238}Pb$ age (Ma)	Er. 1σ	$^{207}U-^{206}Pb$ age (Ma)	Er. 1σ	Th/U	Discordance (%)
HN-211201-11-98	0.0549	0.0094	0.0968	0.0114	0.0137	0.0005	93.8	10.5444	87.5	3.43096	409	344.4	1.2	6.7%
HN-211201-11-38	0.0536	0.0059	0.0940	0.0079	0.0137	0.0003	91.2	7.33651	87.5	1.87272	367	251.82	0.9	4.0%
HN-211201-11-66	0.0528	0.0054	0.0987	0.0086	0.0137	0.0003	95.5	7.96824	87.9	2.02454	320	263.855	0.6	8.0%
HN-211201-11-42	0.0468	0.0028	0.0872	0.0049	0.0137	0.0002	84.9	4.60737	88.0	1.26301	39	137.025	1.3	-3.6%
HN-211201-11-40	0.0485	0.0021	0.0921	0.0039	0.0138	0.0002	89.5	3.65992	88.2	1.00565	124	106.465	1.3	1.4%
HN-211201-11-50	0.0467	0.0027	0.0883	0.0048	0.0138	0.0002	85.9	4.52168	88.4	1.32104	31.6	133.32	0.9	-2.9%
HN-211201-11-49	0.0538	0.0044	0.0990	0.0064	0.0138	0.0003	95.9	5.87644	88.5	1.82744	365	185.163	0.8	7.7%
HN-211201-11-31	0.0465	0.0044	0.0860	0.0068	0.0138	0.0004	83.8	6.31293	88.5	2.4322	20.5	214.78	0.4	-5.6%
HN-211201-11-33	0.0470	0.0032	0.0893	0.0060	0.0138	0.0002	86.8	5.55744	88.5	1.38438	50.1	155.535	1.0	-1.9%
HN-211201-11-88	0.0507	0.0038	0.0948	0.0063	0.0139	0.0002	92.0	5.82338	88.8	1.55726	228	167.57	1.1	3.5%
HN-211201-11-26	0.0464	0.0058	0.0852	0.0069	0.0139	0.0004	83.0	6.46808	88.9	2.84235	16.8	277.74	0.6	-7.1%
HN-211201-11-63	0.0468	0.0020	0.0893	0.0036	0.0139	0.0002	86.9	3.3835	89.0	1.15797	39.0	99.99	1.1	-2.5%
HN-211201-11-77	0.0536	0.0033	0.1006	0.0057	0.0139	0.0002	97.4	5.25936	89.0	1.3669	354	140.725	0.9	8.5%
HN-211201-11-01	0.0468	0.0035	0.0875	0.0053	0.0140	0.0002	85.1	4.96178	89.4	1.37221	35.3	170.35	0.5	-5.0%
HN-211201-11-29	0.0509	0.0029	0.0976	0.0054	0.0140	0.0002	94.6	5.00385	89.4	1.09846	235	133.315	0.7	5.4%
HN-211201-11-48	0.0488	0.0033	0.0928	0.0058	0.0140	0.0002	90.1	5.3586	89.6	1.43003	200	99.985	0.9	0.6%
HN-211201-11-21	0.0489	0.0052	0.0912	0.0078	0.0140	0.0003	88.6	7.27321	89.6	1.77975	143	229.595	0.7	-1.1%
HN-211201-11-91	0.0486	0.0020	0.0932	0.0035	0.0140	0.0002	90.5	3.27234	89.8	0.96804	128	96.2825	1.3	0.7%
HN-211201-11-53	0.0509	0.0025	0.0976	0.0047	0.0140	0.0002	94.6	4.31606	89.9	1.24708	239	116.65	0.8	5.0%
HN-211201-11-100	0.0477	0.0045	0.0895	0.0075	0.0141	0.0003	87.1	7.01262	89.9	1.67522	83.4	211.08	0.6	-3.3%
HN-211201-11-64	0.0491	0.0031	0.0953	0.0060	0.0141	0.0002	92.4	5.57495	90.0	1.46944	154	140.715	0.5	2.7%
HN-211201-11-58	0.0466	0.0030	0.0907	0.0055	0.0141	0.0002	88.2	5.14663	90.1	1.15004	27.9	148.135	0.8	-2.2%
HN-211201-11-17	0.0504	0.0049	0.0955	0.0079	0.0141	0.0003	92.6	7.32198	90.1	2.03097	217	211.085	0.9	2.7%
HN-211201-11-87	0.0498	0.0027	0.0959	0.0049	0.0141	0.0002	93.0	4.50172	90.1	1.21419	187	125.908	0.8	3.1%
HN-211201-11-54	0.0542	0.0044	0.1030	0.0070	0.0141	0.0003	99.5	6.41327	90.2	1.90722	389	181.458	0.7	9.4%
HN-211201-11-08	0.0492	0.0032	0.0938	0.0053	0.0141	0.0002	91.0	4.90465	90.2	1.34	167	135.16	0.7	0.9%
HN-211201-11-18	0.0527	0.0068	0.0937	0.0090	0.0141	0.0004	90.9	8.34019	90.3	2.47783	322	261.08	1.5	0.7%
HN-211201-11-86	0.0525	0.0036	0.1011	0.0062	0.0141	0.0002	97.8	5.72652	90.4	1.54324	309	155.535	1.0	7.6%
HN-211201-11-12	0.0483	0.0038	0.0912	0.0057	0.0141	0.0003	88.6	5.26095	90.5	1.69211	122	177.75	0.9	-2.1%
HN-211201-11-70	0.0479	0.0039	0.0909	0.0068	0.0142	0.0003	88.3	6.35645	90.6	1.72472	100	179.6	1.0	-2.6%
HN-211201-11-28	0.0471	0.0024	0.0912	0.0043	0.0142	0.0002	88.7	3.96163	90.6	1.14426	57.5	118.51	1.1	-2.2%
HN-211201-11-82	0.0463	0.0025	0.0899	0.0047	0.0142	0.0002	87.4	4.33994	90.8	1.30128	13.1	125.915	0.6	-3.9%

Table 3 U-Pb isotopic data for zircon grains in the Haenam basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
HN-211201-11-55	0.0506	0.0035	0.0968	0.0061	0.0142	0.0003	93.8	5.64276	90.9	1.60096	220	162.943	0.5	3.1%
HN-211201-11-61	0.0524	0.0032	0.1038	0.0062	0.0142	0.0002	100	5.74901	91.0	1.49145	302	136.093	0.9	9.3%
HN-211201-11-24	0.0525	0.0053	0.1026	0.0094	0.0142	0.0003	99.2	8.68433	91.0	2.11245	306	229.603	0.7	8.3%
HN-211201-11-52	0.0488	0.0033	0.0946	0.0055	0.0142	0.0002	91.8	5.0851	91.0	1.33281	200	99.985	1.0	0.9%
HN-211201-11-74	0.0499	0.0029	0.0978	0.0054	0.0142	0.0002	94.7	5.02749	91.2	1.23216	191	135.168	0.7	3.8%
HN-211201-11-59	0.0515	0.0055	0.0974	0.0091	0.0142	0.0003	94.4	8.39788	91.2	1.72436	265	49.995	0.7	3.4%
HN-211201-11-07	0.0537	0.0039	0.1027	0.0061	0.0143	0.0002	99.2	5.61321	91.3	1.47611	367	167.57	0.4	8.0%
HN-211201-11-90	0.0475	0.0044	0.0901	0.0069	0.0143	0.0003	87.6	6.40323	91.4	1.75603	76.0	207.375	0.6	-4.2%
HN-211201-11-44	0.0496	0.0034	0.0948	0.0055	0.0143	0.0003	91.9	5.09959	91.5	1.74785	189	157.388	0.9	0.5%
HN-211201-11-36	0.0496	0.0049	0.0905	0.0074	0.0143	0.0003	88.0	6.89965	91.6	2.13123	172	218.485	0.6	-4.1%
HN-211201-11-71	0.0499	0.0028	0.0984	0.0054	0.0143	0.0002	95.3	4.99645	91.6	1.30546	191	131.463	0.9	3.9%
HN-211201-11-19	0.0525	0.0042	0.1011	0.0074	0.0143	0.0003	97.8	6.86111	91.6	1.80937	306	176.83	0.9	6.3%
HN-211201-11-22	0.0528	0.0083	0.1016	0.0134	0.0143	0.0004	98.2	12.3194	91.6	2.84726	320	322.18	2.0	6.7%
HN-211201-11-20	0.0466	0.0033	0.0900	0.0056	0.0143	0.0002	87.5	5.2113	91.6	1.36562	33.4	153.69	0.9	-4.7%
HN-211201-11-96	0.0466	0.0047	0.0865	0.0076	0.0143	0.0003	84.2	7.09658	91.7	1.8596	27.9	229.595	0.7	-8.9%
HN-211201-11-10	0.0474	0.0030	0.0920	0.0051	0.0143	0.0002	89.4	4.77356	91.8	1.56362	77.9	131.46	0.6	-2.7%
HN-211201-11-93	0.0545	0.0076	0.1043	0.0115	0.0144	0.0004	101	10.583	91.9	2.77324	391	318.475	0.7	8.8%
HN-211201-11-09	0.0462	0.0027	0.0902	0.0047	0.0144	0.0002	87.7	4.39232	91.9	1.3183	9.4	137.02	0.8	-4.8%
HN-211201-11-89	0.0531	0.0034	0.1047	0.0065	0.0144	0.0002	101	5.94646	92.1	1.37616	345	141.648	1.2	8.9%
HN-211201-11-51	0.0534	0.0040	0.1041	0.0068	0.0144	0.0002	101	6.2874	92.1	1.46321	346	170.35	0.5	8.5%
HN-211201-11-14	0.0537	0.0038	0.1038	0.0065	0.0144	0.0002	100	5.95672	92.2	1.52591	367	157.388	0.8	8.1%
HN-211201-11-65	0.0465	0.0035	0.0917	0.0061	0.0145	0.0003	89.1	5.67501	93.0	1.66203	33.4	161.095	0.9	-4.3%
HN-211201-11-35	0.0526	0.0045	0.1006	0.0073	0.0146	0.0003	97.4	6.70782	93.3	1.75805	322	196.273	0.8	4.2%
HN-211201-11-25	0.0534	0.0041	0.1052	0.0071	0.0146	0.0003	102	6.51173	93.4	1.93403	343	171.275	0.8	8.0%
HN-211201-11-83	0.0545	0.0056	0.1059	0.0087	0.0146	0.0004	102	7.98166	93.6	2.26562	391	233.3	1.1	8.4%
HN-211201-11-03	0.0466	0.0030	0.0944	0.0057	0.0147	0.0002	91.6	5.29223	93.8	1.39587	27.9	148.135	0.6	-2.5%
HN-211201-11-47	0.0469	0.0030	0.0927	0.0054	0.0147	0.0002	90.0	5.01864	94.0	1.2892	42.7	144.43	0.7	-4.5%
HN-211201-11-15	0.0563	0.0053	0.1061	0.0074	0.0147	0.0004	102	6.79683	94.0	2.46716	465	211.085	1.0	8.2%
HN-211201-11-04	0.0543	0.0039	0.1068	0.0068	0.0147	0.0003	103	6.21816	94.3	1.8652	383	164.798	0.9	8.5%
HN-211201-11-34	0.0472	0.0044	0.0932	0.0074	0.0148	0.0004	90.5	6.90342	94.8	2.27414	57.5	207.38	0.9	-4.8%
HN-211201-11-69	0.0484	0.0031	0.0990	0.0063	0.0149	0.0002	95.9	5.83341	95.1	1.50534	120	144.42	1.3	0.8%
HN-211201-11-30	0.0543	0.0057	0.1088	0.0097	0.0149	0.0004	105	8.9078	95.2	2.34265	383	241.633	1.2	9.2%

Table 3 U-Pb isotopic data for zircon grains in the Haenam basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
HN-211201-11-05	0.0470	0.0041	0.0938	0.0071	0.0149	0.0003	91.0	6.56529	95.3	1.86677	55.7	199.97	1.0	-4.7%
HN-211201-11-41	0.0503	0.0054	0.0989	0.0089	0.0149	0.0004	95.8	8.18294	95.6	2.24925	209	229.605	1.7	0.2%
HN-211201-11-57	0.0505	0.0041	0.0999	0.0070	0.0150	0.0004	96.7	6.50161	96.1	2.43497	217	190.718	0.6	0.6%
HN-211201-11-76	0.0521	0.0034	0.1183	0.0073	0.0166	0.0002	114	6.66562	106	1.52325	300	117.578	1.0	6.6%
HN-211201-11-62	0.0481	0.0036	0.2016	0.0132	0.0310	0.0006	186	11.1347	197	3.77254	102	170.345	1.0	-5.5%
HN-211201-11-60	0.0508	0.0014	0.2345	0.0062	0.0332	0.0003	214	5.09792	211	1.57326	232	65.73	0.3	1.4%
HN-211201-11-94	0.1082	0.0019	4.4285	0.0789	0.2956	0.0023	1718	14.8082	1669	11.673	1769	37.195	0.1	5.6%
HN-211201-11-97	0.1100	0.0018	5.1251	0.0823	0.3363	0.0025	1840	13.6977	1869	12.0357	1799	29.3225	0.1	-3.9%
HN-211201-11-06	0.1116	0.0022	5.4693	0.1133	0.3531	0.0033	1896	17.8263	1949	15.749	1828	35.3425	0.2	-6.6%
HN-211201-11-27	0.1124	0.0028	5.4026	0.1337	0.3448	0.0029	1885	21.2476	1910	14.1585	1839	44.445	0.2	-3.8%
HN-211201-11-43	0.1130	0.0020	5.2850	0.1002	0.3385	0.0026	1866	16.2458	1879	12.4929	1850	32.2525	0.1	-1.6%
HN-211201-11-39	0.1128	0.0025	4.9956	0.1139	0.3206	0.0027	1819	19.3362	1793	13.4279	1856	40.745	0.1	3.4%
HN-211201-11-16	0.1142	0.0038	4.9952	0.1216	0.3138	0.0034	1819	20.6401	1759	16.7038	1866	59.875	0.3	5.7%
HN-211201-11-56	0.1146	0.0022	5.3082	0.0991	0.3343	0.0023	1870	15.9993	1859	11.2146	1874	35.03	0.1	0.8%
HN-211201-11-85	0.1156	0.0026	4.9371	0.1204	0.3083	0.0034	1809	20.6305	1732	16.6513	1900	40.7425	0.4	8.8%
HN-211201-11-75	0.1164	0.0027	5.6082	0.1382	0.3482	0.0031	1917	21.2811	1926	15.0463	1902	40.8975	0.3	-1.2%
HN-211201-11-79	0.1177	0.0022	5.6672	0.1102	0.3472	0.0025	1926	16.8275	1921	11.8356	1921	33.6425	0.1	0.0%
HN-211201-11-67	0.1183	0.0025	5.5409	0.1156	0.3375	0.0025	1907	17.9849	1875	12.3076	1931	37.0375	0.3	2.9%
HN-211201-11-78	0.1197	0.0023	5.4174	0.1111	0.3265	0.0029	1888	17.6332	1821	13.9198	1952	34.725	0.0	6.7%
HN-211201-11-13	0.1281	0.0026	6.3591	0.1274	0.3576	0.0028	2027	17.6292	1971	13.2398	2073	35.19	0.1	4.9%
HN-211201-14-72	0.0467	0.0016	0.0879	0.0029	0.0136	0.0001	85.5	2.75346	87.3	0.82577	31.6	90.73	2.5	-2.1%
HN-211201-14-75	0.0512	0.0053	0.0963	0.0084	0.0137	0.0003	93.4	7.81289	87.4	2.18117	250	225.905	1.3	6.4%
HN-211201-14-28	0.0566	0.0065	0.0978	0.0082	0.0137	0.0003	94.7	7.57928	87.7	2.10949	476	255.523	0.8	7.5%
HN-211201-14-40	0.0519	0.0079	0.0920	0.0099	0.0137	0.0004	89.4	9.19077	87.7	2.78743	280	314.78	1.1	1.9%
HN-211201-14-15	0.0469	0.0042	0.0870	0.0063	0.0137	0.0003	84.7	5.91275	88.0	1.7464	42.7	199.97	1.1	-3.9%
HN-211201-14-55	0.0573	0.0069	0.0996	0.0086	0.0137	0.0004	96.4	7.97173	88.0	2.3794	502	266.633	1.3	8.7%
HN-211201-14-29	0.0483	0.0047	0.0863	0.0058	0.0138	0.0003	84.0	5.45072	88.0	1.95465	122	201.82	1.2	-4.8%
HN-211201-14-41	0.0512	0.0052	0.0914	0.0077	0.0138	0.0004	88.8	7.16736	88.1	2.39165	250	227.755	2.5	0.8%
HN-211201-14-19	0.0467	0.0043	0.0827	0.0064	0.0138	0.0003	80.7	5.99827	88.3	1.74476	35.3	207.38	2.5	-9.4%
HN-211201-14-26	0.0517	0.0061	0.0990	0.0095	0.0138	0.0003	95.8	8.79086	88.4	2.06531	272	251.825	1.5	7.7%
HN-211201-14-35	0.0488	0.0060	0.0903	0.0068	0.0139	0.0004	87.8	6.3403	89.1	2.73007	139	327.735	2.0	-1.4%

Table 3 U-Pb isotopic data for zircon grains in the Haenam basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
HN-211201-14-33	0.0518	0.0043	0.0977	0.0069	0.0139	0.0003	94.6	6.42816	89.2	1.87267	276	189.79	1.2	5.8%
HN-211201-14-92	0.0494	0.0023	0.0952	0.0035	0.0140	0.0001	92.4	3.26621	89.3	0.85138	169	107.393	2.2	3.3%
HN-211201-14-56	0.0497	0.0040	0.0949	0.0064	0.0140	0.0002	92.1	5.96842	89.8	1.38063	189	177.75	2.5	2.4%
HN-211201-14-25	0.0518	0.0063	0.0971	0.0084	0.0140	0.0004	94.1	7.77407	89.9	2.44786	280	320.335	2.1	4.4%
HN-211201-14-30	0.0511	0.0045	0.0977	0.0070	0.0141	0.0003	94.7	6.47554	90.0	1.69809	256	203.678	2.1	4.9%
HN-211201-14-17	0.0534	0.0045	0.1007	0.0066	0.0141	0.0003	97.4	6.11344	90.1	1.92283	346	190.718	2.6	7.5%
HN-211201-14-12	0.0584	0.0142	0.0863	0.0126	0.0141	0.0006	84.1	11.7406	90.3	3.95899	546	464.78	2.4	-7.4%
HN-211201-14-51	0.0517	0.0042	0.0998	0.0073	0.0141	0.0003	96.6	6.76363	90.4	1.70674	272	189.79	1.1	6.4%
HN-211201-14-62	0.0525	0.0039	0.1014	0.0070	0.0141	0.0003	98.0	6.45408	90.5	1.74357	306	168.498	1.2	7.7%
HN-211201-14-57	0.0553	0.0069	0.1013	0.0090	0.0141	0.0004	98.0	8.32115	90.5	2.82907	433	281.443	1.9	7.6%
HN-211201-14-04	0.0494	0.0048	0.0933	0.0081	0.0142	0.0005	90.6	7.48116	90.8	2.96766	169	220.34	0.8	-0.3%
HN-211201-14-71	0.0493	0.0022	0.0959	0.0040	0.0142	0.0002	93.0	3.72696	90.9	1.05062	161	105.54	2.1	2.3%
HN-211201-14-13	0.0512	0.0044	0.0989	0.0076	0.0142	0.0002	95.8	6.98959	90.9	1.55736	250	199.975	0.6	5.1%
HN-211201-14-79	0.0524	0.0039	0.1010	0.0064	0.0142	0.0002	97.7	5.94586	91.0	1.52108	302	168.498	1.0	6.8%
HN-211201-14-08	0.0509	0.0030	0.0994	0.0055	0.0142	0.0002	96.2	5.07384	91.1	1.1716	235	135.168	1.9	5.3%
HN-211201-14-89	0.0500	0.0052	0.0988	0.0093	0.0142	0.0003	95.6	8.61612	91.2	2.09764	195	225.895	0.9	4.7%
HN-211201-14-99	0.0532	0.0070	0.0924	0.0075	0.0142	0.0004	89.8	6.97222	91.2	2.56801	345	301.813	1.0	-1.6%
HN-211201-14-85	0.0537	0.0043	0.1024	0.0074	0.0143	0.0003	99.0	6.82626	91.3	1.75358	367	181.46	1.4	7.8%
HN-211201-14-18	0.0470	0.0046	0.0894	0.0076	0.0143	0.0003	87.0	7.12789	91.3	1.80728	50.1	222.19	1.1	-5.0%
HN-211201-14-61	0.0528	0.0027	0.1036	0.0048	0.0143	0.0002	100	4.44017	91.4	1.16379	320	110.173	2.0	8.7%
HN-211201-14-83	0.0683	0.0200	0.1026	0.0290	0.0143	0.0007	99.2	26.6849	91.4	4.35681	880	634.215	1.9	7.8%
HN-211201-14-50	0.0519	0.0040	0.1008	0.0069	0.0143	0.0003	97.5	6.40874	91.4	1.75948	280	174.978	1.2	6.3%
HN-211201-14-73	0.0466	0.0029	0.0910	0.0051	0.0143	0.0002	88.4	4.76147	91.5	1.23755	27.9	144.43	0.5	-3.4%
HN-211201-14-59	0.0486	0.0048	0.0929	0.0070	0.0143	0.0003	90.2	6.50935	91.5	1.89521	132	218.485	2.0	-1.4%
HN-211201-14-22	0.0550	0.0047	0.1048	0.0080	0.0143	0.0003	101	7.32475	91.6	1.72083	413	192.57	1.2	9.5%
HN-211201-14-05	0.0487	0.0069	0.0878	0.0077	0.0143	0.0004	85.4	7.16637	91.6	2.48912	132	299.96	1.5	-7.3%
HN-211201-14-53	0.0503	0.0020	0.0993	0.0037	0.0143	0.0002	96.1	3.42476	91.7	0.98512	209	87.95	3.1	4.6%
HN-211201-14-14	0.0489	0.0042	0.0961	0.0075	0.0144	0.0003	93.2	6.95836	91.9	1.66725	143	188.86	0.8	1.4%
HN-211201-14-32	0.0544	0.0050	0.1021	0.0074	0.0144	0.0003	98.8	6.79	92.0	2.06585	387	211.083	1.1	6.9%
HN-211201-14-87	0.0538	0.0046	0.1021	0.0072	0.0144	0.0003	98.7	6.62199	92.0	2.08339	361	194.42	1.6	6.8%
HN-211201-14-34	0.0518	0.0054	0.0995	0.0085	0.0144	0.0004	96.3	7.83421	92.1	2.33328	276	240.713	0.8	4.3%
HN-211201-14-23	0.0498	0.0041	0.0958	0.0065	0.0144	0.0003	92.9	6.03331	92.2	1.69481	187	177.75	0.9	0.8%

Table 3 U-Pb isotopic data for zircon grains in the Haenam basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
HN-211201-14-02	0.0492	0.0030	0.0981	0.0059	0.0145	0.0002	95.1	5.42037	92.5	1.40912	167	144.425	1.5	2.7%
HN-211201-14-09	0.0546	0.0051	0.1031	0.0077	0.0145	0.0003	99.6	7.05816	92.6	1.95794	398	211.083	2.8	7.1%
HN-211201-14-44	0.0536	0.0047	0.1048	0.0078	0.0145	0.0003	101	7.12384	92.9	1.77539	354	198.123	0.8	8.1%
HN-211201-14-20	0.0488	0.0044	0.0931	0.0070	0.0146	0.0003	90.4	6.46991	93.2	1.90024	139	205.525	0.9	-3.0%
HN-211201-14-10	0.0548	0.0096	0.0971	0.0127	0.0146	0.0005	94.1	11.7115	93.6	3.46241	406	361.065	2.3	0.5%
HN-211201-14-07	0.0473	0.0030	0.0945	0.0051	0.0147	0.0002	91.7	4.7538	93.9	1.40224	65	144.42	1.1	-2.4%
HN-211201-14-98	0.0535	0.0046	0.1066	0.0076	0.0147	0.0003	103	6.95312	94.1	2.1975	350	226.823	3.1	8.5%
HN-211201-14-38	0.0545	0.0050	0.1060	0.0082	0.0147	0.0003	102	7.51084	94.3	1.8982	394	207.38	0.8	7.8%
HN-211201-14-37	0.0523	0.0040	0.1072	0.0081	0.0148	0.0002	103	7.38349	94.5	1.38202	298	174.053	2.0	8.6%
HN-211201-14-74	0.0493	0.0040	0.0986	0.0070	0.0148	0.0002	95.4	6.48785	94.5	1.46748	167	172.195	0.8	1.0%
HN-211201-14-06	0.0537	0.0061	0.1054	0.0097	0.0148	0.0004	102	8.88618	94.9	2.29587	367	257.375	0.5	6.8%
HN-211201-14-95	0.0525	0.0056	0.1035	0.0089	0.0149	0.0003	100	8.21807	95.0	2.21663	306	278.668	0.8	5.0%
HN-211201-14-81	0.0530	0.0036	0.1070	0.0067	0.0149	0.0002	103	6.15311	95.2	1.50871	328	153.685	1.1	7.8%
HN-211201-14-48	0.0490	0.0049	0.0959	0.0069	0.0149	0.0004	92.9	6.43883	95.3	2.67087	146	222.19	0.7	-2.5%
HN-211201-14-46	0.0507	0.0042	0.1025	0.0073	0.0149	0.0003	99.1	6.71725	95.4	2.17753	228	187.94	0.8	3.8%
HN-211201-14-16	0.0485	0.0043	0.0981	0.0075	0.0149	0.0003	95.0	6.94394	95.4	1.69475	124	196.27	0.6	-0.4%
HN-211201-14-100	0.0474	0.0029	0.0963	0.0053	0.0149	0.0002	93.4	4.86327	95.5	1.49067	77.9	131.46	0.9	-2.3%
HN-211201-14-65	0.0504	0.0030	0.1042	0.0061	0.0150	0.0002	101	5.61597	95.9	1.24694	213	132.39	1.0	4.7%
HN-211201-14-42	0.0524	0.0039	0.1070	0.0065	0.0151	0.0003	103	5.95942	96.3	1.76771	302	172.2	0.6	6.7%
HN-211201-14-67	0.0511	0.0050	0.0992	0.0071	0.0152	0.0004	96.1	6.59507	97.4	2.26668	256	28.7	0.9	-1.4%
HN-211201-14-77	0.0478	0.0043	0.1001	0.0082	0.0154	0.0003	96.8	7.60887	98	1.84053	100.1	199.97	1.2	-1.7%
HN-211201-14-45	0.0508	0.0082	0.1113	0.0154	0.0155	0.0006	107	14.0856	99.4	3.74112	232	337	2.3	7.2%
HN-211201-14-70	0.0521	0.0143	0.0955	0.0143	0.0156	0.0008	92.6	13.2817	99.9	5.26205	300	520.31	1.9	-7.8%
HN-211201-14-66	0.0507	0.0043	0.1082	0.0081	0.0157	0.0003	104	7.44399	100	1.79723	228	194.42	0.7	4.0%
HN-211201-14-91	0.0471	0.0043	0.1092	0.0085	0.0168	0.0004	105	7.77843	107	2.24996	53.8	207.375	2.5	-2.0%
HN-211201-14-80	0.0478	0.0010	0.1109	0.0022	0.0168	0.0001	107	2.05061	108	0.79681	87.1	80.545	1.2	-0.8%
HN-211201-14-78	0.0488	0.0018	0.1398	0.0051	0.0208	0.0003	133	4.50385	133	1.59549	139	85.1725	0.6	0.1%
HN-211201-14-96	0.0496	0.0012	0.2001	0.0049	0.0291	0.0003	185	4.12657	185	1.59822	176	57.3975	1.5	0.2%
HN-211201-14-31	0.0493	0.0018	0.2403	0.0085	0.0352	0.0004	219	6.9299	223	2.71625	161	91.6525	1.1	-2.1%
HN-211201-14-03	0.0685	0.0012	1.4581	0.0297	0.1533	0.0016	913	12.2982	919	9.23015	883	32.41	0.1	-0.7%
HN-211201-14-11	0.0760	0.0025	1.8560	0.0604	0.1767	0.0019	1066	21.5038	1049	10.2178	1095	66.67	0.4	4.3%

Table 3 U-Pb isotopic data for zircon grains in the Haenam basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
HN-211201-2-36	0.0533	0.0037	0.0884	0.0053	0.0123	0.0002	86.0	4.92344	78.7	1.4899	339	163.868	1.1	8.5%
HN-211201-2-90	0.0473	0.0027	0.0793	0.0043	0.0123	0.0002	77.5	4.07975	78.8	1.17745	64.9	133.32	2.4	-1.7%
HN-211201-2-83	0.0488	0.0035	0.0813	0.0054	0.0123	0.0002	79.3	5.07753	78.8	1.56542	139	159.235	3.0	0.6%
HN-211201-2-05	0.0616	0.0111	0.0815	0.0106	0.0123	0.0004	79.5	9.91891	79.0	2.64532	661	393.02	2.2	0.6%
HN-211201-2-48	0.0492	0.0036	0.0825	0.0050	0.0123	0.0002	80.5	4.65005	79.0	1.3645	167	153.68	1.2	1.8%
HN-211201-2-18	0.0478	0.0030	0.0814	0.0045	0.0123	0.0002	79.5	4.20287	79.1	1.07014	100	131.46	1.3	0.5%
HN-211201-2-16	0.0466	0.0033	0.0773	0.0045	0.0123	0.0002	75.6	4.2369	79.1	1.14801	27.9	159.245	2.8	-4.7%
HN-211201-2-94	0.0494	0.0055	0.0796	0.0066	0.0123	0.0003	77.8	6.20882	79.1	1.77037	165	244.41	1.0	-1.6%
HN-211201-2-47	0.0514	0.0059	0.0842	0.0074	0.0124	0.0003	82.1	6.92099	79.2	1.79593	261	240.715	1.7	3.5%
HN-211201-2-46	0.0486	0.0065	0.0798	0.0089	0.0124	0.0004	78.0	8.36691	79.3	2.53607	128	285.145	1.3	-1.7%
HN-211201-2-32	0.0504	0.0036	0.0839	0.0049	0.0124	0.0002	81.8	4.57493	79.3	1.40213	217	164.793	1.0	3.1%
HN-211201-2-22	0.0507	0.0072	0.0809	0.0102	0.0124	0.0004	79.0	9.54532	79.5	2.27188	228	299.97	2.8	-0.6%
HN-211201-2-63	0.0477	0.0038	0.0812	0.0057	0.0124	0.0002	79.3	5.3116	79.7	1.35593	87.1	177.75	2.2	-0.5%
HN-211201-2-19	0.0468	0.0057	0.0783	0.0081	0.0125	0.0004	76.5	7.63193	79.9	2.23212	39	266.63	1.0	-4.5%
HN-211201-2-30	0.0511	0.0052	0.0829	0.0069	0.0125	0.0003	80.9	6.46553	80.0	1.67645	256	209.24	1.6	1.1%
HN-211201-2-43	0.0539	0.0045	0.0908	0.0067	0.0125	0.0003	88.3	6.28056	80.0	1.62511	365	188.865	2.6	9.4%
HN-211201-2-97	0.0483	0.0033	0.0828	0.0054	0.0125	0.0002	80.8	5.02725	80.2	1.30287	122	211.08	1.2	0.7%
HN-211201-2-26	0.0548	0.0053	0.0908	0.0069	0.0125	0.0003	88.2	6.46365	80.3	1.73425	406	214.783	1.1	9.0%
HN-211201-2-25	0.0488	0.0027	0.0846	0.0047	0.0126	0.0002	82.5	4.39017	80.6	1.2032	139	127.76	1.2	2.3%
HN-211201-2-58	0.0489	0.0036	0.0846	0.0059	0.0126	0.0002	82.5	5.57049	80.7	1.43075	143	166.64	1.0	2.1%
HN-211201-2-06	0.0521	0.0026	0.0904	0.0046	0.0126	0.0002	87.9	4.25133	80.7	1.03777	300	147.203	0.9	8.2%
HN-211201-2-20	0.0468	0.0033	0.0811	0.0052	0.0126	0.0002	79.2	4.92883	80.8	1.08601	42.7	168.495	0.9	-2.0%
HN-211201-2-15	0.0517	0.0035	0.0884	0.0050	0.0126	0.0002	86.0	4.67423	80.8	1.5773	272	155.535	0.8	6.0%
HN-211201-2-11	0.0479	0.0025	0.0828	0.0041	0.0126	0.0001	80.8	3.83468	80.9	0.93038	94.5	122.205	1.1	-0.1%
HN-211201-2-17	0.0508	0.0028	0.0885	0.0046	0.0126	0.0002	86.1	4.30114	81.0	1.09683	232	125.91	1.3	6.0%
HN-211201-2-24	0.0489	0.0072	0.0796	0.0071	0.0126	0.0005	77.8	6.63475	81.0	2.96803	146	311.07	1.6	-4.1%
HN-211201-2-84	0.0522	0.0053	0.0894	0.0065	0.0127	0.0003	86.9	6.09149	81.1	2.1822	295	226.825	2.5	6.7%
HN-211201-2-96	0.0505	0.0055	0.0880	0.0082	0.0127	0.0003	85.7	7.61956	81.1	1.66907	217	233.305	1.2	5.3%
HN-211201-2-08	0.0484	0.0040	0.0835	0.0054	0.0127	0.0003	81.5	5.09949	81.1	1.6624	120	181.45	1.6	0.4%
HN-211201-2-27	0.0486	0.0058	0.0809	0.0055	0.0127	0.0003	79.0	5.16084	81.3	2.05226	128	259.225	1.5	-2.8%
HN-211201-2-80	0.0471	0.0031	0.0810	0.0050	0.0127	0.0002	79.1	4.68402	81.4	1.2979	53.8	151.83	0.9	-2.8%
HN-211201-2-54	0.0510	0.0042	0.0867	0.0063	0.0127	0.0002	84.4	5.87981	81.4	1.47291	239	190.718	1.6	3.6%

Table 3 U-Pb isotopic data for zircon grains in the Haenam basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
HN-211201-2-72	0.0484	0.0063	0.0787	0.0087	0.0127	0.0003	76.9	8.17788	81.4	1.85071	120	346.25	2.0	-5.9%
HN-211201-2-02	0.0531	0.0036	0.0910	0.0055	0.0127	0.0002	88.5	5.11658	81.5	1.41281	332	151.833	1.0	7.9%
HN-211201-2-76	0.0503	0.0030	0.0873	0.0049	0.0127	0.0002	85.0	4.61438	81.5	1.33273	209	132.39	2.5	4.2%
HN-211201-2-91	0.0516	0.0039	0.0902	0.0065	0.0127	0.0002	87.7	6.01903	81.7	1.46496	265	174.053	0.9	6.9%
HN-211201-2-100	0.0485	0.0029	0.0843	0.0047	0.0128	0.0002	82.2	4.43216	81.7	1.17188	124	133.31	0.7	0.6%
HN-211201-2-42	0.0500	0.0030	0.0876	0.0052	0.0128	0.0002	85.3	4.88685	81.7	1.17631	195	137.945	1.3	4.1%
HN-211201-2-89	0.0470	0.0054	0.0777	0.0068	0.0128	0.0003	76.0	6.40743	81.8	2.08098	50.1	255.52	1.6	-7.6%
HN-211201-2-04	0.0588	0.0081	0.0914	0.0089	0.0128	0.0004	88.8	8.30765	81.8	2.24411	561	303.668	2.2	7.9%
HN-211201-2-92	0.0470	0.0041	0.0806	0.0057	0.0128	0.0002	78.7	5.39393	81.8	1.55977	55.7	199.97	1.4	-4.0%
HN-211201-2-95	0.0480	0.0037	0.0824	0.0052	0.0128	0.0003	80.4	4.90247	82.0	1.65396	98.2	235.15	1.1	-2.0%
HN-211201-2-59	0.0465	0.0035	0.0806	0.0057	0.0129	0.0002	78.8	5.3683	82.4	1.39383	33.4	161.095	1.3	-4.7%
HN-211201-2-03	0.0471	0.0042	0.0834	0.0067	0.0129	0.0002	81.3	6.26588	82.4	1.53396	53.8	199.97	1.5	-1.4%
HN-211201-2-67	0.0499	0.0030	0.0886	0.0050	0.0129	0.0002	86.2	4.63474	82.5	1.14954	191	138.87	3.0	4.3%
HN-211201-2-66	0.0498	0.0035	0.0881	0.0057	0.0129	0.0002	85.7	5.31674	82.6	1.24461	187	162.943	0.9	3.6%
HN-211201-2-44	0.0494	0.0032	0.0866	0.0053	0.0129	0.0002	84.4	4.97843	82.7	1.28439	165	149.98	3.9	2.0%
HN-211201-2-01	0.0519	0.0028	0.0919	0.0047	0.0129	0.0002	89.2	4.39046	82.9	1.10443	280	122.205	1.0	7.1%
HN-211201-2-10	0.0512	0.0032	0.0884	0.0044	0.0130	0.0002	86.0	4.05914	83.0	1.39635	256	144.425	1.4	3.5%
HN-211201-2-75	0.0468	0.0027	0.0836	0.0047	0.0130	0.0002	81.5	4.4097	83.2	1.01282	42.7	133.32	1.4	-2.1%
HN-211201-2-39	0.0480	0.0033	0.0859	0.0055	0.0130	0.0002	83.6	5.1049	83.3	1.31771	98.2	151.825	1.1	0.5%
HN-211201-2-51	0.0528	0.0037	0.0919	0.0056	0.0130	0.0002	89.3	5.17695	83.3	1.42013	320	161.09	2.0	6.7%
HN-211201-2-33	0.0506	0.0030	0.0907	0.0052	0.0130	0.0002	88.1	4.87285	83.6	1.15631	220	138.87	0.9	5.2%
HN-211201-2-23	0.0519	0.0043	0.0912	0.0062	0.0131	0.0003	88.6	5.73425	83.6	1.71697	280	188.865	0.9	5.6%
HN-211201-2-77	0.0495	0.0045	0.0884	0.0070	0.0131	0.0003	86.0	6.50305	83.7	2.01808	172	199.97	2.6	2.7%
HN-211201-2-78	0.0537	0.0058	0.0938	0.0070	0.0131	0.0004	91.1	6.51735	83.9	2.49584	367	243.488	2.2	7.8%
HN-211201-2-38	0.0485	0.0055	0.0834	0.0070	0.0132	0.0003	81.3	6.56352	84.4	2.16571	124	248.115	1.4	-3.9%
HN-211201-2-53	0.0505	0.0036	0.0906	0.0058	0.0132	0.0002	88.0	5.44465	84.5	1.35111	217	164.793	1.6	4.0%
HN-211201-2-14	0.0539	0.0049	0.0962	0.0073	0.0132	0.0002	93.3	6.71881	84.6	1.52788	369	205.53	1.2	9.3%
HN-211201-2-50	0.0472	0.0039	0.0815	0.0052	0.0132	0.0003	79.5	4.92593	84.7	1.8013	61.2	194.415	1.3	-6.4%
HN-211201-2-52	0.0476	0.0031	0.0865	0.0055	0.0132	0.0002	84.3	5.15106	84.8	1.49941	83.4	144.42	2.2	-0.6%
HN-211201-2-73	0.0468	0.0024	0.0848	0.0043	0.0133	0.0002	82.6	4.00676	85.0	1.18134	42.7	124.06	1.0	-2.9%
HN-211201-2-87	0.0475	0.0019	0.0871	0.0034	0.0133	0.0001	84.8	3.22127	85.0	0.89027	76.0	92.58	2.7	-0.3%
HN-211201-2-62	0.0523	0.0040	0.0935	0.0065	0.0133	0.0003	90.8	6.03877	85.1	1.76363	298	171.275	3.2	6.3%

Table 3 U-Pb isotopic data for zircon grains in the Haenam basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
HN-211201-2-41	0.0490	0.0040	0.0865	0.0058	0.0133	0.0002	84.2	5.40613	85.2	1.53655	146	181.455	0.8	-1.1%
HN-211201-2-49	0.0494	0.0047	0.0888	0.0076	0.0134	0.0003	86.4	7.12001	85.6	1.69002	169	220.34	2.2	1.0%
HN-211201-2-40	0.0488	0.0050	0.0893	0.0083	0.0134	0.0003	86.9	7.73812	85.6	1.86835	200	161.09	2.6	1.4%
HN-211201-2-99	0.0483	0.0015	0.0896	0.0028	0.0134	0.0001	87.1	2.60845	85.8	0.84942	122	75.92	1.4	1.6%
HN-211201-2-98	0.0561	0.0057	0.0963	0.0073	0.0134	0.0004	93.3	6.79437	85.9	2.22989	457	260.153	2.4	8.0%
HN-211201-2-12	0.0464	0.0034	0.0839	0.0057	0.0134	0.0002	81.8	5.36142	85.9	1.38028	16.8	166.65	1.2	-5.0%
HN-211201-2-81	0.0561	0.0062	0.0981	0.0082	0.0134	0.0003	95.0	7.62184	86.0	2.04662	454	248.113	1.1	9.5%
HN-211201-2-07	0.0557	0.0075	0.0982	0.0104	0.0135	0.0004	95.1	9.5766	86.3	2.44151	439	306.44	1.4	9.2%
HN-211201-2-65	0.0490	0.0019	0.0913	0.0035	0.0135	0.0001	88.7	3.2937	86.4	0.84171	150	90.725	0.5	2.6%
HN-211201-2-31	0.0533	0.0064	0.0978	0.0109	0.0135	0.0003	94.8	10.1251	86.6	2.1584	339	275.893	0.9	8.6%
HN-211201-2-21	0.0535	0.0051	0.0976	0.0081	0.0136	0.0003	94.6	7.50237	86.9	2.14882	350.1	216.64	1.4	8.1%
HN-211201-2-85	0.0507	0.0019	0.0947	0.0033	0.0136	0.0002	91.9	3.04274	87.0	0.96494	228	89.8	1.3	5.3%
HN-211201-2-79	0.0473	0.0018	0.0887	0.0035	0.0136	0.0002	86.3	3.2459	87.0	1.19192	65	88.88	1.1	-0.9%
HN-211201-2-55	0.0510	0.0020	0.0956	0.0037	0.0136	0.0002	92.7	3.46971	87.1	1.19056	239	90.7275	3.2	6.0%
HN-211201-2-57	0.0501	0.0064	0.0882	0.0071	0.0136	0.0005	85.9	6.64676	87.1	2.90126	198	274.035	2.7	-1.5%
HN-211201-2-86	0.0516	0.0020	0.1812	0.0070	0.0255	0.0003	169	6.05064	162	1.66208	333	88.875	0.4	4.1%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211202-1-01	0.0530	0.0014	0.1129	0.0030	0.0154	0.0001	109	2.71004	98.3	0.77216	328	24.9975		9.49%
YD-211202-1-03	0.0519	0.0015	0.1096	0.0032	0.0152	0.0001	106	2.91107	97.3	0.76856	283	68.51		7.85%
YD-211202-1-06	0.0521	0.0017	0.1026	0.0032	0.0143	0.0001	99.2	2.95364	91.2	0.82669	300	75.9175		8.01%
YD-211202-1-07	0.0530	0.0018	0.1082	0.0035	0.0148	0.0002	104	3.23372	94.7	1.02234	328	108.323		9.25%
YD-211202-1-08	0.0481	0.0014	0.1012	0.0030	0.0152	0.0001	97.9	2.78894	96.9	0.80491	106	70.365		0.93%
YD-211202-1-09	0.0508	0.0015	0.1047	0.0030	0.0149	0.0001	101	2.72684	95.4	0.75853	235	66.655		5.64%
YD-211202-1-10	0.0462	0.0013	0.0967	0.0028	0.0151	0.0001	93.7	2.56458	96.9	0.89019	5.7	66.66		-3.38%
YD-211202-1-11	0.0501	0.0017	0.1068	0.0036	0.0154	0.0002	103	3.33375	98.4	0.98235	198	77.765		4.47%
YD-211202-1-14	0.0485	0.0014	0.1018	0.0029	0.0151	0.0001	98.4	2.68694	96.8	0.81366	124	66.66		1.61%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211202-1-15	0.0487	0.0014	0.1034	0.0029	0.0153	0.0001	99.9	2.71255	98.0	0.79698	200	66.6575		1.95%
YD-211202-1-21	0.0472	0.0012	0.1006	0.0027	0.0154	0.0001	97.4	2.49961	98.3	0.8457	57.5	62.96		-0.98%
YD-211202-1-24	0.0495	0.0013	0.1060	0.0027	0.0155	0.0001	102	2.46123	99	0.78335	169	59.2475		3.26%
YD-211202-1-25	0.0482	0.0013	0.1007	0.0027	0.0151	0.0001	97.5	2.45621	96.4	0.76034	109	62.955		1.05%
YD-211202-1-27	0.0494	0.0013	0.1054	0.0028	0.0153	0.0001	102	2.55264	98.1	0.8577	169	61.1		3.56%
YD-211202-1-28	0.0466	0.0014	0.1003	0.0029	0.0155	0.0001	97.1	2.7178	99.2	0.88288	27.9	70.365		-2.14%
YD-211202-1-29	0.0505	0.0016	0.1072	0.0032	0.0149	0.0001	103	2.97862	96	0.81801	217	78.69		7.67%
YD-211202-1-30	0.0478	0.0013	0.0995	0.0027	0.0150	0.0001	96.4	2.51186	95.9	0.77628	100	60.18		0.51%
YD-211202-17-12	0.0495	0.0020	0.1817	0.0074	0.0266	0.0003	170	6.3481	169	2.07744	169	93.505		0.16%
YD-211202-17-13	0.0487	0.0018	0.1781	0.0065	0.0266	0.0003	166	5.59622	169	1.88978	200	88.875		-1.75%
YD-211202-17-16	0.0521	0.0036	0.2171	0.0138	0.0305	0.0005	199	11.4858	194	3.07033	300	157.388		2.95%
YD-211202-17-17	0.0553	0.0038	0.1997	0.0124	0.0267	0.0005	185	10.4797	170	2.89258	433	153.688		8.16%
YD-211202-17-18	0.0498	0.0016	0.1748	0.0054	0.0254	0.0003	164	4.70984	162	1.65737	183	75.9125		1.16%
YD-211202-17-19	0.1148	0.0023	5.1290	0.0996	0.3214	0.0026	1841	16.5531	1797	12.5984	1877	40.8975		4.27%
YD-211202-17-20	0.0466	0.0031	0.1726	0.0116	0.0272	0.0005	162	10.0309	173	2.94794	33.4	155.54		-6.98%
YD-211202-17-21	0.0524	0.0021	0.1886	0.0073	0.0261	0.0003	175	6.24952	166	1.75298	302	90.73		5.22%
YD-211202-17-22	0.0544	0.0017	0.2349	0.0072	0.0311	0.0002	214	5.90326	198	1.41774	391	70.3625		7.78%
YD-211202-17-24	0.0564	0.0048	0.1939	0.0134	0.0258	0.0006	180	11.3599	164	3.58237	478	158.313		8.59%
YD-211202-17-25	0.0493	0.0015	0.1861	0.0057	0.0272	0.0002	173	4.87708	173	1.24325	161	72.21		0.10%
YD-211202-17-28	0.0707	0.0023	1.2142	0.0388	0.1243	0.0012	807	17.8145	755	6.80521	950	66.665		6.40%
YD-211202-17-29	0.0507	0.0018	0.1905	0.0066	0.0273	0.0003	177	5.62426	174	1.75352	228	81.4675		1.94%
YD-211202-17-30	0.0558	0.0043	0.1971	0.0127	0.0272	0.0005	183	10.7932	173	3.08499	443	174.053		5.16%
YD-211202-17-31	0.0519	0.0048	0.1256	0.0100	0.0180	0.0004	120	9.05167	115	2.43347	280	214.788		4.12%
YD-211202-17-32	0.0677	0.0025	0.9868	0.0334	0.1065	0.0013	697	17.056	652	7.6188	861	108.333		6.42%
YD-211202-17-33	0.0507	0.0023	0.1975	0.0087	0.0284	0.0003	183	7.36606	180	1.87462	228	107.393		1.38%
YD-211202-17-35	0.1338	0.0033	7.5640	0.1866	0.4099	0.0039	2181	22.1773	2215	17.8699	2150	42.7475		-3.00%
YD-211202-17-36	0.0527	0.0054	0.1169	0.0102	0.0162	0.0003	112	9.25477	104	2.20236	317	233.305		7.66%
YD-211202-17-37	0.0517	0.0018	0.1950	0.0065	0.0274	0.0003	181	5.5194	174	1.94458	272	79.6175		3.73%
YD-211202-17-38	0.0541	0.0030	0.2022	0.0107	0.0274	0.0004	187	9.05247	174	2.61177	376	127.765		6.73%
YD-211202-17-39	0.0506	0.0035	0.1904	0.0125	0.0276	0.0004	177	10.6821	176	2.78403	233	167.57		0.78%
YD-211202-17-4	0.0535	0.0019	0.2065	0.0070	0.0280	0.0003	191	5.85195	178	1.59797	350	49.995		6.62%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 1σ	$^{207}Pb/^{235}U$	Er. 1σ	$^{206}Pb/^{238}U$	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211202-17-40	0.0507	0.0022	0.1921	0.0086	0.0274	0.0003	178	7.31998	174	2.09328	233	101.835		2.22%
YD-211202-17-42	0.0513	0.0019	0.1930	0.0069	0.0273	0.0003	179	5.91374	174	1.74553	254	89.8		3.12%
YD-211202-17-44	0.0540	0.0020	0.1992	0.0073	0.0268	0.0003	184	6.18774	170	1.86931	369	83.325		7.59%
YD-211202-17-45	0.0482	0.0041	0.1724	0.0131	0.0266	0.0005	162	11.3605	170	3.05144	109	192.56		-4.98%
YD-211202-17-46	0.0554	0.0013	0.5318	0.0124	0.0693	0.0006	433	8.25147	432	3.51316	432	53.6975		0.22%
YD-211202-17-47	0.0483	0.0025	0.1796	0.0088	0.0272	0.0003	168	7.61081	173	2.15479	122	112.94		-3.09%
YD-211202-17-5	0.0499	0.0019	0.2498	0.0095	0.0362	0.0004	226	7.73757	229	2.28619	187	88.875		-1.35%
YD-211202-17-50	0.0504	0.0053	0.1830	0.0195	0.0252	0.0003	171	16.7149	161	1.94728	217	225.9		5.88%
YD-211202-17-53	0.0672	0.0033	0.8383	0.0400	0.0909	0.0011	618	22.0834	561	6.46433	843	99.07		9.29%
YD-211202-17-54	0.0767	0.0026	1.5824	0.0512	0.1492	0.0014	963	20.1458	897	7.61776	1115	62.4975		6.93%
YD-211202-17-55	0.0464	0.0014	0.1686	0.0051	0.0262	0.0003	158	4.39384	167	1.59123	17	70.365		-5.48%
YD-211202-17-59	0.0497	0.0022	0.1838	0.0078	0.0268	0.0003	171	6.72342	170	1.88506	189	101.835		0.58%
YD-211202-17-6	0.0531	0.0056	0.1982	0.0214	0.0262	0.0005	184	18.1469	166	2.84393	332	240.713		9.34%
YD-211202-17-60	0.0465	0.0039	0.1718	0.0116	0.0273	0.0005	161	10.0364	174	3.25015	33.4	179.605		-7.94%
YD-211202-17-63	0.0567	0.0053	0.2051	0.0164	0.0272	0.0006	189	13.7905	173	3.76199	480	207.383		8.70%
YD-211202-17-64	0.0579	0.0033	0.3793	0.0211	0.0477	0.0008	327	15.5611	301	5.09771	528	127.76		7.94%
YD-211202-17-66	0.0545	0.0038	0.1972	0.0135	0.0263	0.0005	183	11.4194	167	2.98438	394	154.615		8.42%
YD-211202-17-68	0.0520	0.0026	0.4375	0.0224	0.0607	0.0005	368	15.817	380	3.31257	283	116.65		-3.14%
YD-211202-17-7	0.0495	0.0030	0.2441	0.0151	0.0353	0.0004	222	12.323	223	2.22833	169	136.093		-0.73%
YD-211202-17-70	0.1564	0.0034	9.0916	0.1961	0.4200	0.0037	2347	19.7915	2260	16.8143	2417	37.035		6.48%
YD-211202-17-71	0.0751	0.0024	1.8842	0.0583	0.1819	0.0020	1076	20.5482	1077	10.9337	1070	70.53		-0.69%
YD-211202-17-72	0.0534	0.0030	0.1898	0.0101	0.0260	0.0004	176	8.62623	166	2.35569	343	125.913		6.20%
YD-211202-17-73	0.0623	0.0019	0.8347	0.0266	0.0973	0.0015	616	14.7535	598	8.52517	683	64.8075		2.90%
YD-211202-17-74	0.1547	0.0026	9.1412	0.1752	0.4254	0.0039	2352	17.6106	2285	17.8859	2399	29.0125		4.76%
YD-211202-17-75	0.0496	0.0022	0.1814	0.0077	0.0266	0.0003	169	6.62294	169	1.75127	176	97.2075		0.17%
YD-211202-17-79	0.0661	0.0019	1.0099	0.0288	0.1104	0.0008	709	14.5385	675	4.43653	809	65.7375		4.78%
YD-211202-17-8	0.1116	0.0020	5.2923	0.0973	0.3421	0.0024	1868	15.7534	1897	11.4852	1825	33.0275		-3.94%
YD-211202-17-80	0.0495	0.0015	0.1832	0.0056	0.0268	0.0002	171	4.82809	170	1.42422	172	70.3575		0.35%
YD-211202-17-81	0.1136	0.0020	5.0323	0.0840	0.3199	0.0023	1825	14.1909	1789	11.3202	1858	30.4025		3.68%
YD-211202-17-82	0.0519	0.0034	0.1160	0.0069	0.0167	0.0003	111	6.24444	107	2.09444	280	156.46		4.37%
YD-211202-17-83	0.1117	0.0019	4.5998	0.0774	0.2974	0.0021	1749	14.093	1678	10.4106	1828	31.1725		8.18%
YD-211202-17-87	0.0609	0.0019	0.7176	0.0216	0.0856	0.0008	549	12.7499	529	4.88006	635	68.505		3.59%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	207Pb/206Pb	Er. 1σ	207Pb/235U	Er. 1σ	206Pb/238U	Er. 1σ	207U-235Pb age (Ma)	Er. 1σ	206U-238Pb age (Ma)	Er. 1σ	207U-206Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211202-17-88	0.1129	0.0021	4.6975	0.0856	0.3004	0.0021	1767	15.3079	1693	10.4652	1847	33.49		8.30%
YD-211202-17-89	0.1826	0.0036	13.8830	0.2738	0.5491	0.0051	2742	18.7702	2822	21.3098	2677	32.0975		-5.41%
YD-211202-17-90	0.0516	0.0013	0.1825	0.0045	0.0256	0.0002	170	3.87017	163	1.40015	333	57.4		4.18%
YD-211202-17-91	0.0586	0.0015	0.5451	0.0136	0.0674	0.0005	442	8.95433	421	3.04083	550	52.7675		4.75%
YD-211202-17-92	0.0519	0.0016	0.1872	0.0057	0.0261	0.0002	174	4.86001	166	1.33074	280	70.3625		4.60%
YD-211202-17-93	0.0648	0.0015	1.0711	0.0248	0.1194	0.0010	739	12.1444	727	5.89013	769	48.1425		1.69%
YD-211202-17-94	0.0695	0.0025	1.0817	0.0396	0.1128	0.0013	744	19.3115	689	7.54346	922	75.16		7.46%
YD-211202-17-95	0.0543	0.0019	0.2572	0.0088	0.0342	0.0003	232	7.14075	217	2.13033	383	75.9175		6.59%
YD-211202-17-96	0.0513	0.0015	0.1862	0.0058	0.0262	0.0002	173	4.92442	166	1.54339	257	68.505		3.98%
YD-211202-17-97	0.0544	0.0044	0.2014	0.0161	0.0267	0.0004	186	13.6087	170	2.71485	387	186.088		8.76%
YD-211202-17-98	0.0474	0.0032	0.1648	0.0117	0.0251	0.0003	155	10.1659	160	1.80795	77.9	155.53		-3.10%
YD-211202-3-1	0.0493	0.0015	0.1834	0.0056	0.0268	0.0002	171	4.78375	170	1.47334	161	72.21		0.38%
YD-211202-3-10	0.0492	0.0023	0.2458	0.0119	0.0362	0.0005	223	9.68026	229	3.22082	154	109.243		-2.67%
YD-211202-3-100	0.0513	0.0030	0.2445	0.0132	0.0342	0.0005	222	10.8034	217	3.18455	254	136.093		2.31%
YD-211202-3-12	0.0495	0.0013	0.2318	0.0057	0.0339	0.0003	212	4.71194	215	1.7622	172	61.1		-1.51%
YD-211202-3-13	0.1316	0.0032	6.8181	0.1402	0.3747	0.0029	2088	18.2662	2051	13.5355	2120	42.2875		3.26%
YD-211202-3-14	0.0501	0.0015	0.2456	0.0076	0.0354	0.0003	223	6.20945	224	2.12083	198	102.763		-0.64%
YD-211202-3-15	0.0535	0.0017	0.2141	0.0051	0.0289	0.0002	197	4.28047	184	1.35253	350	70.365		6.69%
YD-211202-3-17	0.0518	0.0017	0.2491	0.0080	0.0348	0.0003	226	6.49873	221	2.11335	276	75.9125		2.23%
YD-211202-3-18	0.0547	0.0017	0.2057	0.0068	0.0272	0.0003	190	5.69653	173	1.79244	398	76.845		8.96%
YD-211202-3-19	0.0507	0.0013	0.2333	0.0061	0.0332	0.0003	213	4.98345	211	1.74414	228	61.1		1.01%
YD-211202-3-2	0.0529	0.0012	0.2842	0.0060	0.0387	0.0003	254	4.73628	245	1.9935	324	51.8475		3.67%
YD-211202-3-20	0.0546	0.0021	0.2070	0.0082	0.0274	0.0003	191	6.89732	174	2.03107	394	87.0275		8.88%
YD-211202-3-21	0.0568	0.0032	0.2608	0.0130	0.0344	0.0005	235	10.4794	218	3.36021	487	125.908		7.34%
YD-211202-3-22	0.0534	0.0018	0.2566	0.0088	0.0347	0.0003	232	7.11551	220	2.04214	346	49.995		5.19%
YD-211202-3-23	0.0519	0.0015	0.2630	0.0073	0.0366	0.0003	237	5.89092	232	1.76618	280	64.8075		2.24%
YD-211202-3-25	0.0551	0.0020	0.2907	0.0102	0.0381	0.0004	259	8.00949	241	2.39987	417	74.9925		6.98%
YD-211202-3-26	0.0499	0.0019	0.2449	0.0094	0.0353	0.0003	222	7.69151	224	1.96259	191	88.875		-0.65%
YD-211202-3-27	0.0556	0.0026	0.2873	0.0138	0.0373	0.0004	256	10.9128	236	2.5923	435	105.545		8.01%
YD-211202-3-29	0.0533	0.0034	0.2077	0.0115	0.0288	0.0004	192	9.66076	183	2.7035	343	144.425		4.43%
YD-211202-3-3	0.0488	0.0019	0.2257	0.0088	0.0334	0.0004	207	7.28648	212	2.33645	200	92.5775		-2.44%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 1σ	$^{207}Pb/^{235}U$	Er. 1σ	$^{206}Pb/^{238}U$	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211202-3-31	0.0496	0.0025	0.1906	0.0097	0.0278	0.0003	177	8.25026	177	2.02458	176	124.983		0.27%
YD-211202-3-34	0.0546	0.0015	0.2643	0.0073	0.0350	0.0003	238	5.88751	222	1.74047	394	62.955		6.89%
YD-211202-3-35	0.0501	0.0028	0.1929	0.0105	0.0283	0.0004	179	8.91008	180	2.4347	211	133.315		-0.38%
YD-211202-3-36	0.0533	0.0021	0.2546	0.0101	0.0348	0.0004	230	8.17684	220	2.76674	343	88.88		4.33%
YD-211202-3-38	0.0525	0.0016	0.2678	0.0082	0.0370	0.0004	241	6.53759	234	2.18681	306	68.5125		2.68%
YD-211202-3-39	0.0535	0.0025	0.2537	0.0113	0.0346	0.0004	230	9.15893	219	2.56299	354	105.545		4.49%
YD-211202-3-4	0.0503	0.0013	0.2623	0.0067	0.0376	0.0003	237	5.36017	238	1.90063	206	59.25		-0.61%
YD-211202-3-40	0.1673	0.0032	9.9074	0.2011	0.4280	0.0040	2426	18.7901	2297	17.8878	2531	31.7875		9.27%
YD-211202-3-41	0.0532	0.0017	0.2527	0.0078	0.0344	0.0003	229	6.34211	218	1.96278	339	37.96		4.79%
YD-211202-3-45	0.0476	0.0021	0.1720	0.0073	0.0262	0.0003	161	6.34207	167	1.69698	79.7	109.25		-3.56%
YD-211202-3-46	0.0521	0.0018	0.2607	0.0090	0.0362	0.0004	235	7.2716	229	2.2417	300	79.62		2.49%
YD-211202-3-47	0.0493	0.0016	0.2368	0.0077	0.0348	0.0003	216	6.29256	220	1.96747	167	77.765		-2.09%
YD-211202-3-49	0.0523	0.0016	0.2633	0.0080	0.0363	0.0003	237	6.46058	230	2.01038	298	67.585		3.04%
YD-211202-3-51	0.0514	0.0012	0.2587	0.0061	0.0363	0.0003	234	4.94241	230	1.62044	261	55.5475		1.57%
YD-211202-3-52	0.0531	0.0017	0.2590	0.0084	0.0352	0.0003	234	6.77079	223	1.88226	332	74.0675		4.53%
YD-211202-3-53	0.0494	0.0017	0.2233	0.0077	0.0327	0.0003	205	6.41131	207	1.74251	169	86.0975		-1.38%
YD-211202-3-54	0.0523	0.0032	0.2361	0.0139	0.0329	0.0004	215	11.4021	209	2.62419	302	140.72		2.93%
YD-211202-3-56	0.0519	0.0014	0.2514	0.0068	0.0350	0.0003	228	5.50485	222	1.76272	283	62.955		2.71%
YD-211202-3-57	0.0543	0.0016	0.1897	0.0057	0.0252	0.0002	176	4.87318	160	1.47969	383	69.4375		9.08%
YD-211202-3-58	0.0545	0.0023	0.1965	0.0083	0.0261	0.0003	182	7.07586	166	1.60072	391	94.435		8.90%
YD-211202-3-62	0.0504	0.0012	0.2502	0.0059	0.0359	0.0003	227	4.75909	227	1.65648	213	89.8		-0.25%
YD-211202-3-63	0.0512	0.0011	0.2707	0.0057	0.0382	0.0004	243	4.57152	242	2.23792	250	43.5125		0.67%
YD-211202-3-64	0.0487	0.0016	0.1724	0.0056	0.0256	0.0002	162	4.87056	163	1.25879	132	77.765		-1.04%
YD-211202-3-66	0.0541	0.0022	0.2544	0.0096	0.0341	0.0004	230	7.74848	216	2.24014	376	90.7325		6.12%
YD-211202-3-69	0.0529	0.0021	0.2580	0.0102	0.0354	0.0004	233	8.20512	224	2.35382	324	90.73		3.90%
YD-211202-3-70	0.0507	0.0019	0.2384	0.0090	0.0340	0.0003	217	7.41503	215	2.13337	228	91.6525		0.76%
YD-211202-3-71	0.0551	0.0027	0.2527	0.0102	0.0334	0.0004	229	8.2853	212	2.46168	417	107.398		7.51%
YD-211202-3-72	0.0528	0.0013	0.2785	0.0068	0.0380	0.0003	249	5.39612	241	2.05784	320	57.4025		3.51%
YD-211202-3-73	0.0528	0.0019	0.2313	0.0082	0.0317	0.0005	211	6.75928	201	3.00078	320	79.6225		4.65%
YD-211202-3-74	0.0508	0.0011	0.2660	0.0057	0.0378	0.0003	239	4.57926	239	1.93096	232	45.36		0.17%
YD-211202-3-75	0.0516	0.0012	0.2619	0.0063	0.0366	0.0003	236	5.05225	232	1.90118	333	53.6975		1.77%
YD-211202-3-76	0.0547	0.0027	0.2692	0.0123	0.0357	0.0004	242	9.84094	226	2.78529	467	111.1		6.51%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	207Pb/206Pb	Er. 1σ	207Pb/235U	Er. 1σ	206Pb/238U	Er. 1σ	207U-235Pb age (Ma)	Er. 1σ	206U-238Pb age (Ma)	Er. 1σ	207U-206Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211202-3-77	0.0535	0.0025	0.2617	0.0114	0.0353	0.0004	236	9.14243	223	2.54479	350	107.398		5.32%
YD-211202-3-81	0.0570	0.0034	0.2535	0.0142	0.0329	0.0005	229	11.5046	208	2.86281	500	133.315		9.11%
YD-211202-3-82	0.0519	0.0011	0.2402	0.0054	0.0336	0.0003	219	4.4082	213	1.8006	283	49.995		2.63%
YD-211202-3-85	0.0499	0.0016	0.2125	0.0072	0.0310	0.0005	196	6.04608	197	2.84165	191	71.285		-0.59%
YD-211202-3-86	0.0520	0.0034	0.2454	0.0151	0.0354	0.0006	223	12.3204	224	3.46501	287	151.833		-0.51%
YD-211202-3-88	0.0480	0.0048	0.1770	0.0149	0.0280	0.0005	165	12.8593	178	2.9362	98.2	222.19		-7.62%
YD-211202-3-89	0.0557	0.0022	0.2680	0.0113	0.0347	0.0005	241	9.07234	220	3.13806	443	88.88		8.71%
YD-211202-3-9	0.0510	0.0013	0.2653	0.0067	0.0375	0.0003	239	5.40072	237	1.77927	239	54.62		0.70%
YD-211202-3-90	0.0531	0.0024	0.2450	0.0107	0.0335	0.0004	223	8.70699	212	2.3326	332	101.843		4.52%
YD-211202-3-91	0.0560	0.0028	0.2525	0.0119	0.0330	0.0005	229	9.62166	209	3.19339	454	111.1		8.53%
YD-211202-3-92	0.0559	0.0046	0.1900	0.0122	0.0252	0.0005	177	10.4166	161	2.94089	450	187.94		9.05%
YD-211202-3-94	0.0508	0.0029	0.1968	0.0099	0.0284	0.0005	182	8.41041	180	2.86455	235	134.24		1.09%
YD-211202-3-95	0.0513	0.0015	0.2377	0.0068	0.0335	0.0003	217	5.54535	213	1.8861	254	66.655		1.82%
YD-211202-3-97	0.0504	0.0019	0.2453	0.0096	0.0351	0.0004	223	7.79012	222	2.42168	213	87.025		0.17%
YD-211202-3-98	0.0476	0.0019	0.1766	0.0067	0.0270	0.0003	165	5.76459	172	1.91873	79.7	88.88		-4.18%
YD-211202-4-01	0.0488	0.0012	0.1036	0.0026	0.0153	0.0001	100	2.36905	97.8	0.8065	200	57.4025		2.25%
YD-211202-4-02	0.0493	0.0011	0.1052	0.0025	0.0154	0.0001	102	2.27692	98.2	0.74078	161	53.695		3.27%
YD-211202-4-04	0.0509	0.0014	0.1080	0.0029	0.0153	0.0001	104	2.67723	97.9	0.80714	235	61.1		5.98%
YD-211202-4-07	0.0488	0.0012	0.1031	0.0025	0.0153	0.0001	100	2.30731	97.7	0.82012	200	55.55		1.99%
YD-211202-4-08	0.0529	0.0012	0.1097	0.0024	0.0150	0.0001	106	2.2049	95.9	0.85546	324	48.1425		9.24%
YD-211202-4-10	0.0513	0.0015	0.1074	0.0030	0.0152	0.0001	104	2.7852	97.1	0.76588	254	66.655		6.28%
YD-211202-4-13	0.0510	0.0017	0.1057	0.0029	0.0149	0.0001	102	2.64206	95.6	0.76168	239	74.9875		6.35%
YD-211202-4-14	0.0478	0.0014	0.0992	0.0027	0.0150	0.0001	96.0	2.4859	95.7	0.70756	100	73.14		0.27%
YD-211202-4-15	0.0472	0.0015	0.0980	0.0029	0.0150	0.0001	94.9	2.70128	96.0	0.84003	57.5	74.07		-1.12%
YD-211202-4-16	0.0463	0.0015	0.0988	0.0032	0.0154	0.0001	95.7	2.926	98.3	0.71037	13.1	87.03		-2.78%
YD-211202-4-17	0.0507	0.0016	0.1055	0.0032	0.0150	0.0001	102	2.91365	95.8	0.73507	228	65.73		5.86%
YD-211202-4-18	0.0479	0.0015	0.0988	0.0030	0.0149	0.0001	95.7	2.79746	95.1	0.72321	94.5	72.215		0.67%
YD-211202-4-19	0.0483	0.0014	0.1007	0.0029	0.0150	0.0001	97.4	2.66606	96.2	0.71636	122	73.14		1.20%
YD-211202-4-21	0.0512	0.0024	0.1062	0.0059	0.0147	0.0001	102.5	5.40723	94.4	0.76436	250.1	76.8425		7.90%
YD-211202-4-22	0.0481	0.0013	0.0988	0.0027	0.0148	0.0001	95.6	2.48315	95.0	0.71666	102	64.81		0.67%
YD-211202-4-24	0.0494	0.0013	0.1014	0.0028	0.0149	0.0001	98.1	2.54439	95.0	0.81375	165	62.9525		3.11%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 1σ	$^{207}Pb/^{235}U$	Er. 1σ	$^{206}Pb/^{238}U$	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211202-4-25	0.0510	0.0016	0.1057	0.0032	0.0150	0.0001	102	2.97476	95.9	0.84505	243	70.36		5.95%
YD-211202-4-27	0.0484	0.0013	0.1010	0.0027	0.0151	0.0001	97.7	2.51427	96.5	0.69042	120	64.8075		1.20%
YD-211202-4-28	0.0470	0.0012	0.0982	0.0025	0.0151	0.0001	95.1	2.28623	96.7	0.85573	55.7	53.7		-1.65%
YD-211202-4-29	0.0463	0.0012	0.0944	0.0024	0.0148	0.0001	91.6	2.23395	94.6	0.78061	13.1	62.96		-3.29%
YD-211202-5-1	0.0491	0.0052	0.1719	0.0154	0.0267	0.0006	161	13.3314	170	3.90452	154	229.595		-5.30%
YD-211202-5-10	0.0567	0.0055	0.2083	0.0157	0.0276	0.0006	192	13.2132	176	3.76813	480	215.558		8.57%
YD-211202-5-100	0.0462	0.0033	0.0732	0.0051	0.0119	0.0001	71.7	4.80089	76.3	0.92952	9.4	166.65		-6.36%
YD-211202-5-11	0.0553	0.0022	0.1827	0.0069	0.0242	0.0003	170	5.91285	154	2.1722	433	95.36		9.45%
YD-211202-5-12	0.0506	0.0012	0.2178	0.0048	0.0312	0.0003	200	4.01703	198	1.68963	233	51.8425		1.12%
YD-211202-5-14	0.0471	0.0024	0.1737	0.0086	0.0270	0.0003	163	7.45784	171	1.96473	57.5	114.805		-5.45%
YD-211202-5-15	0.0547	0.0036	0.2446	0.0164	0.0328	0.0006	222	13.3741	208	3.93328	467	143.505		6.40%
YD-211202-5-16	0.0523	0.0023	0.2281	0.0094	0.0319	0.0004	209	7.75077	203	2.3156	298	98.1325		2.85%
YD-211202-5-18	0.0523	0.0019	0.1987	0.0077	0.0275	0.0003	184	6.50567	175	1.63699	298	85.175		5.00%
YD-211202-5-19	0.0492	0.0058	0.1747	0.0155	0.0267	0.0008	163	13.3614	170	5.08144	167	246.26		-3.97%
YD-211202-5-2	0.0510	0.0077	0.1779	0.0207	0.0262	0.0009	166	17.8138	167	5.62719	243	324.04		-0.23%
YD-211202-5-20	0.0551	0.0018	0.2084	0.0070	0.0275	0.0003	192	5.8681	175	1.88008	417	74.0675		9.14%
YD-211202-5-21	0.0523	0.0027	0.1874	0.0092	0.0264	0.0003	174	7.91069	168	2.18357	298	118.5		3.84%
YD-211202-5-22	0.0483	0.0028	0.2200	0.0124	0.0336	0.0008	202	10.3394	213	5.07613	122	120.35		-5.44%
YD-211202-5-23	0.0535	0.0034	0.1946	0.0118	0.0270	0.0004	181	10.0684	172	2.75366	350	146.278		4.71%
YD-211202-5-24	0.0533	0.0023	0.2507	0.0103	0.0343	0.0004	227	8.39829	217	2.64909	343	96.285		4.24%
YD-211202-5-25	0.0509	0.0045	0.2057	0.0137	0.0309	0.0008	190	11.5523	196	5.16837	239	205.53		-3.35%
YD-211202-5-26	0.0521	0.0062	0.1910	0.0190	0.0276	0.0006	177	16.1942	176	3.90243	300	238.865		0.97%
YD-211202-5-27	0.0502	0.0024	0.2327	0.0107	0.0337	0.0004	212	8.80549	214	2.717	211	111.095		-0.70%
YD-211202-5-28	0.0557	0.0054	0.2068	0.0145	0.0280	0.0007	191	12.2136	178	4.52342	443	214.788		6.87%
YD-211202-5-29	0.0486	0.0015	0.1886	0.0059	0.0281	0.0003	175	5.01625	178	1.58638	128	76.8425		-1.68%
YD-211202-5-3	0.0569	0.0084	0.1889	0.0242	0.0267	0.0008	176	20.6919	170	5.12853	487	329.588		3.36%
YD-211202-5-30	0.0488	0.0032	0.2343	0.0152	0.0347	0.0005	214	12.5134	220	3.35574	200	83.32		-2.97%
YD-211202-5-31	0.0507	0.0026	0.2375	0.0117	0.0344	0.0005	216	9.57992	218	3.20948	228	116.65		-0.78%
YD-211202-5-33	0.0487	0.0015	0.1787	0.0055	0.0267	0.0003	167	4.76618	170	1.96204	200	74.99		-1.61%
YD-211202-5-34	0.0531	0.0036	0.2054	0.0125	0.0286	0.0004	190	10.5186	182	2.68496	345	155.535		4.13%
YD-211202-5-35	0.0518	0.0058	0.1693	0.0142	0.0251	0.0006	159	12.2942	160	3.94134	276	246.27		-0.62%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211202-5-36	0.0476	0.0015	0.1785	0.0059	0.0272	0.0003	167	5.10365	173	1.90483	79.7	74.07		-3.82%
YD-211202-5-37	0.0551	0.0031	0.2002	0.0107	0.0264	0.0004	185	9.05789	168	2.33457	413	129.618		9.34%
YD-211202-5-38	0.0481	0.0019	0.1734	0.0067	0.0262	0.0003	162	5.8004	166	1.62851	102	90.73		-2.54%
YD-211202-5-39	0.0553	0.0046	0.1930	0.0142	0.0262	0.0006	179	12.1202	167	3.50758	433	188.865		6.91%
YD-211202-5-4	0.0523	0.0022	0.1880	0.0080	0.0261	0.0003	175	6.85997	166	1.75776	298	98.1325		5.12%
YD-211202-5-40	0.0486	0.0013	0.2063	0.0057	0.0306	0.0002	190	4.78369	195	1.41552	128	64.8075		-2.18%
YD-211202-5-41	0.0547	0.0042	0.1957	0.0133	0.0262	0.0005	182	11.2736	166	2.90997	467	172.205		8.32%
YD-211202-5-44	0.0530	0.0019	0.2038	0.0073	0.0277	0.0003	188	6.12744	176	1.83176	328	76.845		6.35%
YD-211202-5-45	0.0512	0.0016	0.2091	0.0064	0.0294	0.0002	193	5.37801	187	1.52064	254	65.73		3.04%
YD-211202-5-46	0.0528	0.0027	0.2625	0.0129	0.0363	0.0005	237	10.3674	230	3.11491	320	110.173		2.99%
YD-211202-5-48	0.0558	0.0033	0.2688	0.0152	0.0351	0.0005	242	12.1777	222	2.95806	443	133.32		8.08%
YD-211202-5-5	0.0529	0.0033	0.2437	0.0167	0.0341	0.0008	221	13.6091	216	5.00915	324	136.093		2.43%
YD-211202-5-50	0.0470	0.0021	0.1801	0.0079	0.0274	0.0003	168	6.78885	174	1.99086	55.7	94.435		-3.46%
YD-211202-5-51	0.0512	0.0029	0.1950	0.0108	0.0278	0.0005	181	9.21776	177	2.89302	254	133.315		2.31%
YD-211202-5-52	0.0475	0.0034	0.2221	0.0147	0.0346	0.0005	204	12.1933	219	3.29819	76.0	162.935		-7.67%
YD-211202-5-53	0.0500	0.0014	0.1567	0.0045	0.0227	0.0002	148	3.96875	144	1.12753	195	66.655		2.28%
YD-211202-5-54	0.0582	0.0063	0.2013	0.0160	0.0265	0.0006	186	13.4971	168	3.81021	539	241.638		9.51%
YD-211202-5-55	0.0502	0.0019	0.1890	0.0072	0.0273	0.0003	176	6.14612	174	1.78149	206	88.875		1.28%
YD-211202-5-56	0.0467	0.0020	0.1760	0.0076	0.0272	0.0003	165	6.57687	173	1.90767	35.3	164.795		-5.21%
YD-211202-5-57	0.0494	0.0039	0.1777	0.0123	0.0269	0.0005	166	10.6142	171	2.91081	165	174.045		-2.88%
YD-211202-5-59	0.0557	0.0036	0.1801	0.0105	0.0241	0.0004	168	9.0569	153	2.33916	439	150.908		8.84%
YD-211202-5-6	0.0545	0.0031	0.2008	0.0105	0.0272	0.0004	186	8.84489	173	2.30418	391	132.395		6.96%
YD-211202-5-61	0.0495	0.0037	0.1850	0.0121	0.0272	0.0005	172	10.3433	173	2.95522	169	175.9		-0.40%
YD-211202-5-62	0.0466	0.0024	0.1703	0.0089	0.0265	0.0004	160	7.69373	169	2.39028	28	122.21		-5.64%
YD-211202-5-63	0.0503	0.0026	0.2013	0.0108	0.0289	0.0004	186	9.15128	184	2.67617	206	122.205		1.38%
YD-211202-5-64	0.0539	0.0022	0.2028	0.0077	0.0275	0.0003	187	6.5297	175	2.02223	369	92.5825		6.63%
YD-211202-5-65	0.0543	0.0034	0.1984	0.0115	0.0269	0.0004	184	9.76532	171	2.49718	387	140.728		6.73%
YD-211202-5-66	0.0528	0.0020	0.1915	0.0073	0.0262	0.0002	178	6.21748	167	1.54041	317	119.433		6.10%
YD-211202-5-67	0.0574	0.0041	0.3109	0.0181	0.0400	0.0011	275	14.0103	253	6.51568	509	157.385		7.97%
YD-211202-5-69	0.0499	0.0034	0.1904	0.0105	0.0279	0.0005	177	8.97789	177	2.91562	191	152.758		-0.23%
YD-211202-5-7	0.0530	0.0035	0.1964	0.0123	0.0271	0.0004	182	10.475	173	2.65963	328	152.758		5.25%
YD-211202-5-70	0.0508	0.0066	0.1822	0.0165	0.0271	0.0008	170	14.2068	172	5.1568	235	274.05		-1.48%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 1σ	$^{207}Pb/^{235}U$	Er. 1σ	$^{206}Pb/^{238}U$	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211202-5-72	0.0491	0.0033	0.2077	0.0127	0.0309	0.0005	192	10.6452	196	2.9384	154	151.825		-2.32%
YD-211202-5-73	0.0533	0.0035	0.2577	0.0168	0.0352	0.0006	233	13.5345	223	4.02723	339	149.98		4.33%
YD-211202-5-74	0.0504	0.0031	0.1991	0.0115	0.0288	0.0004	184	9.7353	183	2.73333	213	140.72		0.65%
YD-211202-5-75	0.0494	0.0057	0.1862	0.0166	0.0275	0.0007	173	14.2299	175	4.70052	169	248.115		-0.97%
YD-211202-5-76	0.0539	0.0039	0.2030	0.0132	0.0273	0.0005	188	11.1271	174	2.87768	365	162.943		7.48%
YD-211202-5-79	0.0528	0.0050	0.2434	0.0194	0.0343	0.0008	221	15.8699	217	5.00993	320	210.16		1.72%
YD-211202-5-8	0.0514	0.0066	0.1846	0.0182	0.0287	0.0008	172	15.5992	182	5.31534	261	270.345		-5.92%
YD-211202-5-80	0.0531	0.0050	0.1870	0.0141	0.0268	0.0005	174	12.0214	170	3.29842	345	212.938		2.06%
YD-211202-5-82	0.0514	0.0023	0.1943	0.0091	0.0272	0.0004	180	7.70776	173	2.1991	257	108.318		4.01%
YD-211202-5-83	0.0499	0.0019	0.2368	0.0091	0.0343	0.0003	216	7.47888	218	2.14883	191	92.5775		-0.83%
YD-211202-5-84	0.0524	0.0027	0.1955	0.0093	0.0271	0.0004	181	7.93698	173	2.26277	302	112.02		4.78%
YD-211202-5-86	0.0538	0.0040	0.1885	0.0111	0.0264	0.0005	175	9.4862	168	3.28605	361	166.645		4.28%
YD-211202-5-87	0.0512	0.0015	0.1939	0.0058	0.0274	0.0003	180	4.91939	174	1.69084	250	63.8775		3.33%
YD-211202-5-89	0.0555	0.0015	0.2617	0.0081	0.0339	0.0005	236	6.55702	215	2.8729	432	65.735		8.92%
YD-211202-5-9	0.0484	0.0063	0.1751	0.0166	0.0272	0.0007	164	14.3769	173	4.09987	120	346.25		-5.69%
YD-211202-5-90	0.0499	0.0041	0.1885	0.0134	0.0282	0.0004	175	11.4308	179	2.73189	191	177.75		-2.31%
YD-211202-5-91	0.0658	0.0094	0.2048	0.0227	0.0270	0.0010	189	19.0912	172	6.1454	800	297.665		9.22%
YD-211202-5-92	0.0526	0.0041	0.1890	0.0138	0.0267	0.0005	176	11.7532	170	2.87645	322	179.608		3.34%
YD-211202-5-93	0.0517	0.0031	0.2029	0.0117	0.0287	0.0005	188	9.90366	183	3.1628	272	138.87		2.65%
YD-211202-5-94	0.0565	0.0048	0.2040	0.0141	0.0277	0.0006	189	11.9233	176	3.94126	478	157.23		6.46%
YD-211202-5-95	0.0500	0.0017	0.1932	0.0067	0.0280	0.0003	179	5.69411	178	1.75401	195	76.84		0.85%
YD-211202-5-96	0.0506	0.0041	0.2006	0.0149	0.0287	0.0006	186	12.5949	182	3.62082	233	216.64		1.75%
YD-211202-5-97	0.0493	0.0036	0.1747	0.0119	0.0257	0.0004	163	10.3236	164	2.68797	161	162.935		-0.24%
YD-211203-1-01	0.0467	0.0030	0.0926	0.0058	0.0144	0.0002	89.9	5.35546	92.4	1.25824	35.3	153.69		-2.74%
YD-211203-1-02	0.0521	0.0026	0.0990	0.0044	0.0139	0.0002	95.8	4.04939	89.2	1.24185	287	149.055		6.91%
YD-211203-1-03	0.0484	0.0048	0.0946	0.0078	0.0141	0.0003	91.8	7.23951	90.6	1.84126	117	227.745		1.35%
YD-211203-1-04	0.0466	0.0050	0.0919	0.0086	0.0144	0.0003	89.3	8.04383	92.2	1.98462	33.4	299.96		-3.31%
YD-211203-1-05	0.0494	0.0026	0.0973	0.0052	0.0141	0.0002	94.3	4.77872	90.5	1.18657	165	125.91		4.00%
YD-211203-1-06	0.0475	0.0025	0.0940	0.0050	0.0144	0.0002	91.2	4.6014	92.0	1.18814	72	118.505		-0.88%
YD-211203-1-08	0.0532	0.0053	0.1016	0.0077	0.0144	0.0005	98.2	7.1306	92.5	2.91488	339	225.898		5.90%
YD-211203-1-09	0.0464	0.0031	0.0898	0.0051	0.0141	0.0002	87.3	4.70857	90.5	1.40401	20.5	151.835		-3.71%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211203-1-10	0.0490	0.0048	0.0913	0.0070	0.0142	0.0003	88.7	6.47072	90.9	2.05149	150	214.785		-2.43%
YD-211203-1-11	0.0517	0.0059	0.0938	0.0083	0.0139	0.0003	91.1	7.6888	89.1	1.83931	276	240.715		2.17%
YD-211203-1-12	0.0489	0.0016	0.0978	0.0032	0.0144	0.0001	94.8	3.00525	92.3	0.87714	143	77.765		2.66%
YD-211203-1-14	0.0514	0.0026	0.0990	0.0047	0.0140	0.0002	95.9	4.37823	89.7	1.07146	261	116.65		6.45%
YD-211203-1-16	0.0491	0.0035	0.0964	0.0065	0.0145	0.0003	93.5	6.04066	92.6	1.60926	154	155.53		0.99%
YD-211203-1-17	0.0559	0.0064	0.0972	0.0083	0.0137	0.0003	94.2	7.66344	87.9	2.03442	450	259.225		6.65%
YD-211203-1-18	0.0478	0.0041	0.0861	0.0059	0.0134	0.0003	83.9	5.51463	86.0	1.76966	87.1	192.56		-2.50%
YD-211203-1-20	0.0528	0.0043	0.0984	0.0066	0.0139	0.0003	95.3	6.09168	88.9	1.72626	320	185.163		6.69%
YD-211203-1-21	0.0478	0.0037	0.0887	0.0057	0.0139	0.0004	86.3	5.32938	89.1	2.85033	100	164.79		-3.23%
YD-211203-1-22	0.0555	0.0076	0.1016	0.0119	0.0143	0.0004	98.3	10.9577	91.6	2.55063	432	305.515		6.73%
YD-211203-1-26	0.0476	0.0044	0.0874	0.0067	0.0140	0.0003	85.1	6.23486	89.6	1.6509	79.7	207.38		-5.31%
YD-211203-1-27	0.0499	0.0031	0.0927	0.0056	0.0134	0.0002	90.0	5.17796	85.8	1.19411	191	144.425		4.68%
YD-211203-1-28	0.0466	0.0030	0.0883	0.0050	0.0140	0.0002	85.9	4.68358	89.6	1.30311	31.6	144.43		-4.31%
YD-211203-15-01	0.1417	0.0027	7.8931	0.1466	0.4015	0.0030	2219	16.8023	2176	13.6484	2248	33.335		3.20%
YD-211203-15-02	0.1356	0.0030	7.2679	0.2117	0.3820	0.0057	2145	26.0347	2086	26.4751	2172	38.2725		3.99%
YD-211203-15-04	0.1165	0.0021	5.6306	0.0962	0.3485	0.0023	1921	14.7969	1927	11.2533	1903	37.195		-1.28%
YD-211203-15-05	0.1157	0.0018	5.7772	0.0888	0.3597	0.0025	1943	13.3748	1981	11.6902	1890	27.775		-4.79%
YD-211203-15-06	0.1147	0.0018	5.5981	0.0878	0.3518	0.0021	1916	13.5684	1943	10.275	1876	23.6075		-3.57%
YD-211203-15-07	0.1088	0.0025	4.8252	0.0926	0.3201	0.0022	1789	16.1832	1790	10.5926	1789	42.2875		-0.08%
YD-211203-15-08	0.1188	0.0022	6.4262	0.1161	0.3898	0.0030	2036	15.9371	2122	14.1229	1939	32.8725		-9.42%
YD-211203-15-10	0.0523	0.0028	0.1234	0.0068	0.0170	0.0002	118	6.12048	109	1.35828	302	124.058		7.84%
YD-211203-15-11	0.1176	0.0019	5.7657	0.0972	0.3539	0.0029	1941	14.6425	1953	13.6277	1920	29.7875		-1.72%
YD-211203-15-12	0.1237	0.0021	6.4461	0.1084	0.3767	0.0029	2039	14.85	2061	13.4517	2010	30.245		-2.52%
YD-211203-15-13	0.0545	0.0016	0.2050	0.0060	0.0271	0.0002	189	5.0414	173	1.39414	394	64.8075		8.85%
YD-211203-15-14	0.1450	0.0028	8.4063	0.1608	0.4187	0.0028	2276	17.4235	2254	12.8612	2288	32.7175		1.46%
YD-211203-15-16	0.0515	0.0029	0.1158	0.0057	0.0166	0.0002	111	5.19919	106	1.50664	261	129.613		4.71%
YD-211203-15-17	0.1341	0.0027	8.2225	0.1639	0.4435	0.0031	2256	18.1131	2366	13.9797	2154	35.805		-9.88%
YD-211203-15-20	0.1149	0.0017	5.7249	0.0868	0.3599	0.0022	1935	13.1767	1982	10.606	1880	27.0025		-5.44%
YD-211203-15-21	0.0540	0.0016	0.2022	0.0062	0.0270	0.0002	187	5.19885	172	1.40811	372	68.5125		8.29%
YD-211203-15-22	0.1497	0.0026	9.2404	0.1567	0.4445	0.0029	2362	15.617	2371	13.0688	2342	29.785		-1.21%
YD-211203-15-23	0.1194	0.0020	5.9922	0.1058	0.3615	0.0033	1975	15.427	1989	15.7579	1947	29.9425		-2.15%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211203-15-24	0.0520	0.0027	0.1193	0.0059	0.0167	0.0002	114	5.36668	107	1.48314	283	118.503		6.66%
YD-211203-15-25	0.1143	0.0020	5.2610	0.0905	0.3316	0.0022	1863	14.7245	1846	10.8468	1869	31.48		1.22%
YD-211203-15-26	0.0533	0.0016	0.2792	0.0084	0.0378	0.0003	250	6.6876	239	1.9385	343	37.96		4.35%
YD-211203-15-27	0.0466	0.0016	0.1715	0.0057	0.0267	0.0002	161	4.95351	170	1.41155	27.9	81.475		-5.61%
YD-211203-15-29	0.1165	0.0020	5.3406	0.0902	0.3310	0.0022	1875	14.5058	1843	10.855	1903	30.095		3.13%
YD-211203-15-30	0.1132	0.0018	5.0703	0.0756	0.3238	0.0020	1831	12.7099	1808	9.95985	1851	23.1475		2.30%
YD-211203-15-33	0.0468	0.0021	0.1723	0.0074	0.0268	0.0003	161	6.44071	171	2.15799	42.7	99.99		-5.80%
YD-211203-15-34	0.1164	0.0021	5.1936	0.0940	0.3225	0.0021	1852	15.4636	1802	10.1313	1902	32.1		5.24%
YD-211203-15-35	0.1415	0.0023	8.0716	0.1473	0.4121	0.0040	2239	16.5612	2225	18.2335	2256	28.09		1.38%
YD-211203-15-36	0.1053	0.0031	4.6324	0.0844	0.3180	0.0018	1755	15.2675	1780	8.78818	1720	54.17		-3.47%
YD-211203-15-39	0.1136	0.0020	5.1946	0.0908	0.3300	0.0023	1852	14.9393	1839	11.3505	1857	31.1775		1.01%
YD-211203-15-40	0.0466	0.0028	0.2342	0.0147	0.0363	0.0003	214	12.1276	230	1.84324	27.9	140.725		-7.54%
YD-211203-15-43	0.0496	0.0046	0.2005	0.0190	0.0285	0.0003	186	16.0609	181	1.90712	176.0	199.97		2.30%
YD-211203-15-44	0.0464	0.0028	0.1060	0.0062	0.0165	0.0002	102	5.73834	105	1.36507	20.5	146.28		-2.99%
YD-211203-15-45	0.1228	0.0024	6.3305	0.1351	0.3712	0.0035	2023	18.7686	2035	16.7085	1998	34.255		-1.84%
YD-211203-15-47	0.0560	0.0024	0.2588	0.0107	0.0335	0.0004	234	8.59754	213	2.60812	454	87.955		8.99%
YD-211203-15-50	0.1166	0.0022	5.6951	0.1055	0.3520	0.0026	1931	16.0583	1944	12.5741	1906	34.4175		-2.02%
YD-211203-15-51	0.1137	0.0022	5.1851	0.0995	0.3285	0.0026	1850	16.3907	1831	12.6959	1861	35.495		1.60%
YD-211203-15-53	0.0513	0.0030	0.1234	0.0076	0.0170	0.0002	118	6.89949	108	0.98702	254	132.39		8.20%
YD-211203-15-55	0.1172	0.0022	5.8642	0.1093	0.3605	0.0027	1956	16.2176	1984	12.8121	1914	33.0275		-3.69%
YD-211203-15-58	0.1183	0.0022	5.2890	0.0972	0.3223	0.0024	1867	15.7522	1801	11.5163	1931	33.335		6.75%
YD-211203-15-62	0.0488	0.0024	0.2303	0.0114	0.0340	0.0004	210	9.37115	216	2.37176	200	116.65		-2.45%
YD-211203-15-63	0.1138	0.0019	5.3617	0.0897	0.3395	0.0024	1879	14.3695	1884	11.6253	1861	29.9375		-1.22%
YD-211203-15-65	0.1577	0.0028	9.5634	0.1600	0.4382	0.0034	2394	15.4677	2343	15.2752	2431	29.935		3.64%
YD-211203-15-68	0.0505	0.0027	0.1870	0.0101	0.0270	0.0003	174	8.60519	172	2.15467	220	119.428		1.32%
YD-211203-15-69	0.1111	0.0023	4.6868	0.0960	0.3044	0.0022	1765	17.1785	1713	10.7349	1818	37.6575		5.74%
YD-211203-15-71	0.1132	0.0020	5.2948	0.0986	0.3375	0.0027	1868	15.9613	1875	13.2578	1852	31.6375		-1.25%
YD-211203-15-72	0.1130	0.0020	4.8471	0.0879	0.3095	0.0019	1793	15.3145	1738	9.6085	1848	31.6375		5.94%
YD-211203-15-73	0.1105	0.0019	4.8862	0.0821	0.3190	0.0020	1800	14.223	1785	9.82264	1809	30.555		1.35%
YD-211203-15-74	0.1425	0.0026	7.9631	0.1649	0.4027	0.0039	2227	18.7442	2182	18.182	2257	37.5025		3.35%
YD-211203-15-75	0.1269	0.0027	6.2864	0.1317	0.3578	0.0027	2017	18.403	1972	12.6548	2055	37.655		4.06%
YD-211203-15-76	0.1620	0.0035	10.3588	0.2297	0.4615	0.0040	2467	20.6	2446	17.6743	2476	37.035		1.22%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211203-15-77	0.1141	0.0022	5.1587	0.1010	0.3262	0.0024	1846	16.6955	1820	11.6246	1865	36.265		2.41%
YD-211203-15-78	0.1144	0.0024	5.0958	0.1053	0.3215	0.0024	1835	17.5921	1797	11.8968	1870	37.035		3.89%
YD-211203-15-79	0.1177	0.0022	5.6675	0.1164	0.3470	0.0033	1926	17.7789	1920	16.0514	1921	33.9525		0.05%
YD-211203-15-80	0.1171	0.0021	5.2673	0.0917	0.3247	0.0023	1864	14.9176	1813	11.4749	1922	32.1		5.70%
YD-211203-15-81	0.1172	0.0020	5.7333	0.0938	0.3530	0.0026	1936	14.2005	1949	12.1968	1914	30.095		-1.83%
YD-211203-15-82	0.1113	0.0021	5.1597	0.0995	0.3355	0.0026	1846	16.4516	1865	12.8088	1821	33.49		-2.43%
YD-211203-15-83	0.1198	0.0023	5.9253	0.1135	0.3578	0.0026	1965	16.6981	1972	12.453	1954	33.49		-0.90%
YD-211203-15-84	0.1218	0.0023	5.9089	0.1110	0.3511	0.0026	1963	16.3717	1940	12.3533	1983	33.33		2.20%
YD-211203-15-85	0.0542	0.0017	0.2673	0.0084	0.0357	0.0003	241	6.71312	226	2.025	389	74.9925		5.91%
YD-211203-15-86	0.1283	0.0019	7.0089	0.1059	0.3948	0.0025	2113	13.4976	2145	11.478	2076	27.01		-3.34%
YD-211203-15-87	0.1204	0.0021	5.7219	0.1047	0.3434	0.0028	1935	15.8759	1903	13.7054	1962	30.395		3.02%
YD-211203-15-89	0.1143	0.0018	5.1201	0.0785	0.3235	0.0020	1839	13.0774	1807	9.58436	1933	29.1675		6.56%
YD-211203-15-90	0.1321	0.0026	7.2462	0.1400	0.3965	0.0034	2142	17.3062	2153	15.6509	2126	33.95		-1.28%
YD-211203-15-91	0.0531	0.0029	0.1208	0.0063	0.0167	0.0002	116	5.68764	107	1.37874	332	119.43		7.71%
YD-211203-15-92	0.1432	0.0026	8.4566	0.1555	0.4257	0.0036	2281	16.7673	2286	16.3318	2266	31.635		-0.88%
YD-211203-15-93	0.1152	0.0023	5.5621	0.1170	0.3480	0.0032	1910	18.1463	1925	15.421	1883	31.325		-2.21%
YD-211203-15-94	0.1209	0.0022	5.7546	0.1080	0.3431	0.0026	1940	16.2882	1901	12.7242	1969	33.33		3.46%
YD-211203-15-95	0.1164	0.0019	5.5067	0.0901	0.3411	0.0022	1902	14.1247	1892	10.5062	1902	29.7875		0.51%
YD-211203-15-96	0.1149	0.0019	5.3051	0.0865	0.3333	0.0022	1870	13.9842	1854	10.8082	1877	29.32		1.23%
YD-211203-15-97	0.1147	0.0020	4.9717	0.0837	0.3129	0.0018	1815	14.2847	1755	8.75813	1876	31.1725		6.45%
YD-211203-15-99	0.1171	0.0025	5.1244	0.1094	0.3159	0.0021	1840	18.184	1770	10.3874	1913	38.89		7.51%
YD-211203-2-1	0.0474	0.0017	0.1705	0.0059	0.0261	0.0003	160	5.08686	166	1.85783	77.9	72.215		-3.71%
YD-211203-2-10	0.1240	0.0020	5.8218	0.0914	0.3387	0.0021	1950	13.6722	1880	10.1491	2014	27.775		6.64%
YD-211203-2-12	0.1390	0.0027	7.5028	0.1476	0.3900	0.0030	2173	17.69	2123	13.9346	2215	33.335		4.13%
YD-211203-2-13	0.1164	0.0024	5.3733	0.1105	0.3339	0.0026	1881	17.6555	1857	12.5413	1902	37.0375		2.32%
YD-211203-2-14	0.1175	0.0023	5.3497	0.1030	0.3293	0.0024	1877	16.521	1835	11.6301	1920	34.8775		4.45%
YD-211203-2-15	0.1132	0.0021	5.2212	0.0981	0.3336	0.0025	1856	16.0683	1856	12.0669	1850	33.3375		-0.29%
YD-211203-2-16	0.1159	0.0020	5.4737	0.1050	0.3411	0.0029	1896	16.5204	1892	13.8301	1894	31.7875		0.14%
YD-211203-2-17	0.1703	0.0028	10.9461	0.1813	0.4644	0.0028	2519	15.5038	2459	12.5616	2561	27.78		3.98%
YD-211203-2-18	0.1617	0.0030	10.7321	0.1956	0.4808	0.0044	2500	17.0129	2531	19.3098	2473	31.4825		-2.33%
YD-211203-2-19	0.1359	0.0023	7.3822	0.1274	0.3921	0.0026	2159	15.5053	2133	12.1008	2176	29.6325		2.00%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211203-2-2	0.1280	0.0024	6.2549	0.1120	0.3521	0.0026	2012	15.7407	1945	12.3363	2072	32.2525		6.15%
YD-211203-2-20	0.1157	0.0021	5.3790	0.1004	0.3357	0.0028	1882	16.0385	1866	13.3517	1891	33.025		1.33%
YD-211203-2-21	0.1157	0.0021	5.5817	0.1052	0.3483	0.0027	1913	16.2802	1926	13.0895	1900	33.3325		-1.39%
YD-211203-2-22	0.1190	0.0024	5.2695	0.1042	0.3197	0.0022	1864	16.9283	1788	10.9381	1943	35.9575		7.95%
YD-211203-2-23	0.1193	0.0025	5.7868	0.1228	0.3500	0.0030	1944	18.4271	1935	14.5016	1946	37.0375		0.60%
YD-211203-2-24	0.1261	0.0028	6.3814	0.1417	0.3650	0.0031	2030	19.5396	2006	14.8093	2056	39.195		2.42%
YD-211203-2-25	0.1622	0.0037	10.7422	0.2359	0.4791	0.0042	2501	20.4675	2523	18.3406	2480	38.58		-1.76%
YD-211203-2-26	0.1151	0.0021	5.3220	0.0973	0.3337	0.0021	1872	15.6786	1856	10.3475	1881	33.0225		1.31%
YD-211203-2-28	0.1157	0.0019	5.4172	0.0936	0.3379	0.0023	1888	14.8677	1877	11.239	1892	30.2425		0.79%
YD-211203-2-29	0.1208	0.0022	5.7938	0.1077	0.3464	0.0027	1945	16.1501	1917	12.731	1968	65.275		2.58%
YD-211203-2-3	0.1280	0.0020	6.8353	0.1165	0.3841	0.0039	2090	15.1682	2095	18.0154	2072	27.1625		-1.12%
YD-211203-2-30	0.1178	0.0024	5.3436	0.1148	0.3280	0.0033	1876	18.4127	1829	16.2541	1924	35.6475		4.95%
YD-211203-2-31	0.1302	0.0026	6.5850	0.1327	0.3657	0.0031	2057	17.8181	2009	14.4628	2102	34.8775		4.42%
YD-211203-2-33	0.1245	0.0020	6.4938	0.1076	0.3772	0.0030	2045	14.6499	2063	14.0499	2021	28.8575		-2.08%
YD-211203-2-34	0.1327	0.0021	6.6494	0.1072	0.3620	0.0022	2066	14.2992	1992	10.5116	2200	28.0875		9.47%
YD-211203-2-35	0.1183	0.0021	5.7286	0.1016	0.3499	0.0027	1936	15.3826	1934	12.6995	1931	31.175		-0.13%
YD-211203-2-36	0.1128	0.0022	5.1461	0.1011	0.3295	0.0025	1844	16.7456	1836	11.9205	1856	35.6475		1.05%
YD-211203-2-38	0.1136	0.0019	5.5410	0.0930	0.3518	0.0022	1907	14.4957	1943	10.5248	1858	30.4025		-4.58%
YD-211203-2-39	0.1128	0.0018	5.2558	0.0835	0.3361	0.0021	1862	13.6067	1868	10.0566	1856	28.5525		-0.66%
YD-211203-2-4	0.1111	0.0018	4.9103	0.0762	0.3178	0.0022	1804	13.1506	1779	10.6856	1818	29.015		2.17%
YD-211203-2-40	0.1139	0.0019	5.3440	0.0866	0.3385	0.0025	1876	13.9217	1879	12.1992	1863	29.935		-0.90%
YD-211203-2-41	0.0511	0.0015	0.2604	0.0074	0.0368	0.0004	235	5.9948	233	2.41365	256	60.175		0.82%
YD-211203-2-42	0.1414	0.0028	7.8240	0.1527	0.3985	0.0030	2211	17.6395	2162	13.9401	2256	35.03		4.14%
YD-211203-2-44	0.1130	0.0019	5.2331	0.0872	0.3334	0.0023	1858	14.2615	1855	11.1265	1848	31.6375		-0.38%
YD-211203-2-45	0.1165	0.0020	5.6715	0.1130	0.3496	0.0034	1927	17.2427	1933	16.0361	1903	36.1125		-1.54%
YD-211203-2-46	0.1120	0.0018	4.9100	0.0846	0.3154	0.0029	1804	14.5919	1767	14.0474	1832	29.4775		3.53%
YD-211203-2-48	0.1416	0.0028	7.9621	0.1527	0.4046	0.0031	2227	17.3659	2190	14.0639	2247	33.7975		2.52%
YD-211203-2-49	0.1137	0.0023	5.3827	0.1071	0.3407	0.0028	1882	17.0866	1890	13.6743	1859	36.73		-1.67%
YD-211203-2-5	0.1113	0.0019	5.1174	0.0844	0.3306	0.0026	1839	14.0595	1842	12.4259	1821	31.485		-1.11%
YD-211203-2-50	0.0464	0.0014	0.1665	0.0049	0.0259	0.0002	156	4.28425	165	1.44736	17	70.365		-5.42%
YD-211203-2-51	0.1259	0.0022	7.0756	0.1256	0.4041	0.0032	2121	15.8636	2188	14.6674	2043	30.555		-7.10%
YD-211203-2-52	0.1152	0.0019	5.6783	0.0955	0.3546	0.0029	1928	14.5777	1956	13.9552	1883	34.2575		-3.87%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	^{207}Pb/^{206}Pb	Er. 1σ	^{207}Pb/^{235}U	Er. 1σ	^{206}Pb/^{238}U	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211203-2-53	0.1195	0.0021	5.8387	0.1023	0.3514	0.0025	1952	15.2458	1941	12.1712	1950	32.1		0.45%
YD-211203-2-54	0.1588	0.0032	10.4597	0.2070	0.4739	0.0042	2476	18.4219	2501	18.5427	2444	34.255		-2.33%
YD-211203-2-56	0.0497	0.0064	0.1935	0.0278	0.0257	0.0003	180	23.6802	163	2.0712	189	268.48		9.08%
YD-211203-2-57	0.1117	0.0021	5.1894	0.0921	0.3342	0.0025	1851	15.161	1859	12.1545	1827	33.335		-1.70%
YD-211203-2-58	0.1128	0.0022	5.2438	0.0968	0.3346	0.0024	1860	15.7874	1860	11.7681	1856	35.185		-0.26%
YD-211203-2-59	0.1122	0.0020	5.2305	0.0896	0.3352	0.0026	1858	14.6568	1863	12.4365	1836	63.89		-1.52%
YD-211203-2-6	0.1389	0.0030	7.9952	0.1757	0.4137	0.0045	2230	19.8951	2232	20.536	2214	37.035		-0.81%
YD-211203-2-60	0.0487	0.0058	0.1651	0.0205	0.0236	0.0002	155	17.8891	150	1.52918	132	262.925		3.08%
YD-211203-2-61	0.1199	0.0025	6.1115	0.1217	0.3672	0.0024	1992	17.435	2016	11.542	1955	36.7275		-3.12%
YD-211203-2-62	0.1918	0.0034	14.4171	0.2532	0.5414	0.0041	2778	16.7829	2789	17.3694	2757	29.475		-1.17%
YD-211203-2-63	0.1120	0.0019	5.2081	0.0861	0.3346	0.0021	1854	14.1333	1861	10.4291	1833	31.33		-1.51%
YD-211203-2-64	0.1315	0.0022	7.0065	0.1183	0.3836	0.0027	2112	15.0659	2093	12.6529	2118	29.935		1.17%
YD-211203-2-65	0.0508	0.0016	0.1824	0.0055	0.0259	0.0002	170	4.73649	165	1.29107	232	69.4325		3.04%
YD-211203-2-66	0.1110	0.0022	5.2668	0.1007	0.3411	0.0024	1863	16.3607	1892	11.4557	1817	32.41		-4.13%
YD-211203-2-67	0.1196	0.0025	6.3724	0.1281	0.3838	0.0034	2028	17.6946	2094	15.8972	1950	32.87		-7.36%
YD-211203-2-68	0.1224	0.0022	6.3487	0.1112	0.3732	0.0028	2025	15.4299	2045	13.1533	1991	36.1075		-2.69%
YD-211203-2-69	0.1400	0.0023	8.1547	0.1303	0.4194	0.0024	2248	14.5306	2258	10.9485	2228	28.705		-1.34%
YD-211203-2-7	0.1277	0.0026	6.8510	0.1374	0.3861	0.0040	2092	17.8285	2105	18.4769	2066	35.185		-1.86%
YD-211203-2-70	0.1554	0.0024	8.9438	0.1504	0.4142	0.0032	2332	15.4434	2234	14.5164	2406	21.7575		7.14%
YD-211203-2-71	0.1113	0.0019	5.2680	0.0884	0.3412	0.0026	1864	14.3698	1892	12.5559	1821	30.56		-3.89%
YD-211203-2-72	0.1148	0.0021	5.0254	0.0923	0.3157	0.0023	1824	15.6116	1769	11.1672	1877	33.3325		5.80%
YD-211203-2-73	0.1137	0.0021	5.3363	0.0943	0.3389	0.0024	1875	15.1681	1881	11.4499	1861	31.945		-1.08%
YD-211203-2-74	0.0510	0.0014	0.2591	0.0072	0.0368	0.0004	234	5.83531	233	2.22977	239	64.8025		0.32%
YD-211203-2-75	0.1223	0.0019	6.3204	0.1009	0.3733	0.0028	2021	14.0673	2045	13.107	1991	27.775		-2.72%
YD-211203-2-76	0.1145	0.0018	5.0690	0.0817	0.3199	0.0022	1831	13.7227	1789	10.7472	1872	28.3925		4.42%
YD-211203-2-77	0.1142	0.0019	5.4736	0.0933	0.3461	0.0023	1896	14.6927	1916	11.0264	1933	29.63		0.89%
YD-211203-2-78	0.1454	0.0031	8.6066	0.1881	0.4283	0.0035	2297	19.9467	2298	15.9039	2292	37.0375		-0.26%
YD-211203-2-79	0.1288	0.0024	6.4429	0.1387	0.3615	0.0046	2038	18.9663	1989	21.634	2083	31.6375		4.52%
YD-211203-2-8	0.1122	0.0020	5.0633	0.0878	0.3248	0.0023	1830	14.7476	1813	11.3739	1836	32.7175		1.25%
YD-211203-2-80	0.1138	0.0018	5.3419	0.0898	0.3391	0.0025	1876	14.4292	1882	11.9508	1861	34.2575		-1.14%
YD-211203-2-81	0.1153	0.0018	5.5194	0.0876	0.3454	0.0023	1904	13.7078	1913	11.2111	1885	32.5625		-1.47%
YD-211203-2-82	0.1130	0.0017	4.7302	0.0727	0.3019	0.0018	1773	12.9421	1701	9.11388	1850	27.78		8.06%

Table 4 U-Pb isotopic data for zircon grains in the Yeongdong basin determined by LA-ICP-MS.

Sample name	$^{207}Pb/^{206}Pb$	Er. 1σ	$^{207}Pb/^{235}U$	Er. 1σ	$^{206}Pb/^{238}U$	Er. 1σ	^{207}U-^{235}Pb age (Ma)	Er. 1σ	^{206}U-^{238}Pb age (Ma)	Er. 1σ	^{207}U-^{206}Pb age (Ma)	Er. 1σ	Th/U	Discordance (%)
YD-211203-2-83	0.1268	0.0022	6.4349	0.1130	0.3665	0.0031	2037	15.4986	2013	14.533	2054	25.77		2.00%
YD-211203-2-85	0.1281	0.0026	6.3121	0.1273	0.3550	0.0027	2020	17.7366	1959	12.7045	2073	36.27		5.50%
YD-211203-2-86	0.1151	0.0018	5.3316	0.0836	0.3340	0.0021	1874	13.4715	1858	10.2236	1883	28.2375		1.36%
YD-211203-2-87	0.0487	0.0031	0.1742	0.0112	0.0259	0.0003	163	9.70927	165	1.78798	132	144.42		-1.03%
YD-211203-2-89	0.0495	0.0014	0.2348	0.0063	0.0342	0.0003	214	5.17496	217	1.78289	172	62.95		-1.35%
YD-211203-2-9	0.1130	0.0018	5.2222	0.0840	0.3332	0.0026	1856	13.769	1854	12.7045	1848	29.3225		-0.32%
YD-211203-2-90	0.1162	0.0024	5.4377	0.1078	0.3378	0.0026	1891	17.0476	1876	12.7827	1899	36.73		1.22%
YD-211203-2-91	0.1153	0.0023	5.3416	0.1036	0.3344	0.0023	1876	16.6403	1860	10.9945	1885	35.3375		1.34%
YD-211203-2-92	0.0545	0.0025	0.1536	0.0063	0.0206	0.0003	145	5.56906	132	1.69784	391	110.175		9.34%
YD-211203-2-93	0.1159	0.0018	5.3030	0.0813	0.3302	0.0022	1869	13.1643	1839	10.5236	1894	27.775		2.91%
YD-211203-2-94	0.1260	0.0019	6.9650	0.1253	0.3984	0.0043	2107	16.034	2162	19.9866	2043	26.6925		-5.82%
YD-211203-2-95	0.0539	0.0016	0.1925	0.0060	0.0257	0.0002	179	5.13878	164	1.41741	369	68.51		8.41%
YD-211203-2-96	0.1295	0.0024	6.2032	0.1141	0.3453	0.0028	2005	16.1361	1912	13.6045	2092	32.565		8.58%
YD-211203-2-97	0.0514	0.0014	0.1940	0.0053	0.0272	0.0002	180	4.52148	173	1.36876	261	64.8025		3.89%
YD-211203-2-98	0.1303	0.0026	6.9826	0.1346	0.3872	0.0035	2109	17.1777	2110	16.2178	2102	36.2675		-0.35%
YD-211203-2-99	0.1550	0.0024	10.1508	0.1563	0.4722	0.0037	2449	14.3319	2493	16.4083	2402	25.46		-3.81%