**INTRODUCTION**

Welcome to Busan! Busan, a bustling city of approximately 3.6 million residents, is located on the southeastern tip of the Korean Peninsula (Fig. 1). The size of Busan is 768,408 km² which is 0.8% of the whole land of the Korean Peninsula. The natural environment of Busan is a perfect example of harmony among mountains, rivers, and sea. Its geography includes a coastline with superb beaches and scenic cliffs, mountains which provide excellent hiking and extraordinary views, and hot springs scattered throughout the city. You can enjoy four distinct and beautiful seasons in Busan. Many tourists visit Busan all year round because of the nice weather and beautiful scenery.

![Fig. 1. Location of Busan and photographs showing major tourist attractions.](image)

Busan is the second largest city in Korea. Its deep harbor and gentle tides have allowed it to grow into the largest container handling port in the country and the fifth largest port in the world. As for its geopolitical location, the city comes at the southern tip of a strip that connects Asia, Siberia, and Europe. It also serves as a main gateway to the Pacific Ocean. This location places the city at the center of international sea transportation. The city's natural endowments and rich history have resulted in Busan's increasing reputation as a world class city of tourism and culture, and it is also becoming renowned as an international conventions (from http://english.busan.go.kr).

A geopark is a unified area with geological heritages of international significance. Busan became a national geopark of Korea in November 2013. Three Korean islands (Dok-do, Ulleung-do, Jeju-do) were also certified as national geoparks in December 2012. Busan is, however, the first geopark located inland in Korea. The geopark initiative was launched by UNESCO in response to the perceived need for an international initiative that recognizes sites representing an earth science interest. In this field excursion, we can review the geology of Busan and tour the Busan National Geopark.
02 GEOLOGICAL BACKGROUND OF BUSAN
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The Korean Peninsula, located on the eastern Eurasian continental margin, is an important tectonic link between eastern China and the Japanese Island Arc (Fig. 2A). Busan is located in the southeasternmost part of the Cretaceous Gyeongsang Basin wherein several NNE-trending major faults, such as Yangsan, Dongnae, and Ilgwang faults belonging to the Yangsan Fault System, are developed. Detailed explanations are as follows.

Fig. 2. (A) Tectonic outline of the eastern Eurasian margin (modified after Xu et al., 1987; Ren et al., 2002; Ihoh et al., 2006). (B) Distribution of Cretaceous sedimentary basins (greenish areas) in the Korean peninsula (after Chough and Sohn, 2000). (C) Simplified geological map (modified from Hwang et al., 1996; Kim et al., 1998; Choi et al., 2002) and key beds (modified from Jeong et al., 2005; Jeon and Sohn, 2008; Hwang and Woo, 2009) of the Gyeongsang Basin.
02.1 GYEONGSANG BASIN

In the Cretaceous, the Korean Peninsula was located behind the volcanic arc, induced by oblique subduction of the proto-Pacific (Izanagi/Kula) plate (Chough et al., 2000; Chough and Sohn, 2010). A large nonmarine sedimentary basin named the Gyeongsang Basin formed in the southeastern part of the peninsula, whereas a number of small basins formed in the southwestern part (Fig. 2B). These small basins are interpreted to have formed by sinistral, brittle shearing at the releasing fault bends and stepovers along several strike-slip faults and then terminated in the Late Cretaceous when the Izanagi plate changed in the direction of motion, resulting in orthogonal subduction against the Asian continent (Chun and Chough, 1992; Ryang and Chough, 1997; Lee, 1999; Lee and Chough, 1999; Chough et al., 2000; Kim et al., 2003, 2009; Chough and Sohn, 2010). The extension mode of the Gyeongsang Basin, however, is still uncertain, although it is interpreted as a backarc basin produced by oblique subduction of the proto-Pacific plate underneath the Eurasia plate (Chough et al., 2000; Chough and Sohn, 2010).

The Gyeongsang Basin comprises three subbasins: Yeongyang, Uiseong, and Miryang subbasins from north to south (Chang, 1975; Fig. 2C). The Yeongyang subbasin is demarcated from the Uiseong subbasin by the Andong Fault System (Won et al., 1978) or Cheongsong Ridge (Chang, 1975; Kang and Lee, 2008), and Uiseong and Miryang subbasins are bounded by the Palgongsan Fault (Chang, 1977; Chang and Park, 1997; Fig. 2C).

The basin was filled by alluvial, fluvial, and lacustrine deposits with subduction-related magmatic rocks. They are subdivided into (1) the non-volcanic sedimentary strata of the Sindong Group, (2) the partly volcanic strata of the Hayang Group, (3) dominantly volcanic strata of the Yucheon Group, and (4) the Bulguksa intrusive rocks in ascending order, according to their occurrence and the amounts of volcanic materials (Chang, 1975; Choi, 1986; Chang et al., 2003; Fig. 2C). Recently, Chough and Sohn (2010) suggested that the volcanic and plutonic rocks constituted a volcanic arc platform (Gyeongsang Volcanic Arc) and that sedimentary rocks located in the west of the arc are backarc strata (Gyeongsang Backarc Basin).
02.2 **YANGSAN FAULT SYSTEM**

NNE or NE-trending tectonic lines distributed in the eastern part of the Eurasia plate, such as the Tan-Lu Fault in China and Median Tectonic Line in Japan, can give important clues to understand tectonic regime and to reveal the volcanic activities and crustal deformations in the East Asia during the Cretaceous to Neogene. Especially, the NNE-trending Yangsan Fault System (abbreviated as YFS), located in the eastern part of the Gyeongsang Basin, appears to have played a significant role in crustal deformation and sedimentation in the Gyeongsang Basin during the late Cretaceous and Paleogene. The YFS is composed of the Jain, Miryang, Moryang, Yangsan, Dongnai, and Illwang faults, from west to east (Fig. 2C). Among them, the Yangsan Fault is the most conspicuous strand of the YFS and is traced for more 200 km with a few km-thick fractured zone.

Many studies, such as structural, geophysical, petrological, and magnetic anisotropy researches, reported that the YFS underwent the multiple deformations in the Cretaceous to Quaternary (Chang et al., 1990; Kim, 1992; Chang, 2002; Chang and Chang, 1998; Hwang et al., 2004, 2007a,b, 2008a,b, 2012; Cho et al., 2007, Choi et al., 2009; Kang and Ryoo, 2009; etc.) due to the change of the movement directions.
and subduction angles of the proto-Pacific plate (Xu et al., 1987; Maruyama et al., 1997; Zhang et al., 2003; Chough and Sohn, 2010). The magnetic fabric study of the granite rocks adjacent to the Yangsan Fault documented that the granitic rocks were emplaced within the NW-trending extensional fissures produced secondarily by the sinistral movement of the Yangsan Fault during 70 to 60 Ma (Cho et al., 2007). Meanwhile, the dextral movement of the Yangsan Fault, showing ca. 21 km horizontal offset, was produced by a NE-SW compressional stress according to fault slip data (Chang and Chang, 1998) after ca. 48 Ma based on the laterally separated granitic body (Hwang et al., 2004, 2007a). In addition, K-Ar ages of the Dongnue Fault gouges are 57.5 to 40.4 Ma (Choo and Chang, 2000). Several studies also reported that some segments of the YFS recently reacted as reverse faults under the current E-W compressional stress regime (Kyung et al., 1999; Kim and Jin, 2006; etc.).

Fig. 4. Geological map of the Dadaepo Basin (modified after Chang et al., 1983).

02.3 GEOLOGY OF BUSAN

The geology of Busan area is composed of (1) the dacitic and andesitic volcanic rocks of the Yucheon Group intercalated with (2) the tuffaceous sedimentary rocks of the Dadaepo and Taejongdae formations, (3) the rhyolitic rocks of the Yucheon Group, (4) the Bulguksa Granitic Rocks intruding into the earlier rocks, and (5) the Quaternary alluvium, in ascending order (Fig. 3). The Dadaepo Basin, located in the southeastern part of Busan, is interpreted as an intraarc pull-apart basin produced by sinistral movement of the Yangsan and Dongnai faults (Chough and Sohn, 2010; Cho et al., 2011). Detailed explanations of the Dadaepo Basin are as follows (Section 2.4).
02.4 DADAEOPO BASIN LOCATED BETWEEN THE YANGSAN AND DONGNAE FAULTS

The Dadaepo Basin was isolatedly extended between the NNE-trending Yangsan and Dongnae faults (Fig. 4). The basin fill, named the Dadaepo Formation, comprises channelized conglomerates and sandstones that are intercalated in dominantly purple mudstones in the lower part. The upper part of the formation is dominated by fine- to coarse-grained tuffaceous sandstones and olive to dark gray mudstones with abundant volcanic interbeds. The formation unconformably overlies dacitic rocks of about 94 Ma and is overlain by basaltic andesite of about 69 Ma (Ar-Ar age). The overall configuration of the strata of the Dadaepo Formation indicates a syn-depositional tilting of the basin floor toward north-northeast. A number of outcrop-scale faults are observed in the basin fill, of which the majority is normal faults including syn-depositional growth faults, trending northwest. Orientations of mafic (magmatic) and clastic dikes, interpreted to be approximately contemporaneous with the accumulation of the Dadaepo Formation, are also nearly parallel to the strikes of the outcrop-scale normal faults. All these extensional structures, therefore, consistently indicating the NE-SW extension of the basin, are obliquely intersected at an angle of 40°-60° with the bounding Yangsan and Dongnae faults of the basin. It is, thus, concluded that the Dadaepo Formation was deposited in a pull apart basin that was subsided by the NNE-trending sinistral strike-slip faulting in the southeastern part of the Korean Peninsula during the Campanian of the late Cretaceous, due to the north-northwestward oblique subduction of the proto-Pacific (Izanagi/Kula) or Pacific plate under the eastern margin of the Eurasian plate (Fig. 5).
03 BUSAN NATIONAL GEOPARK
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Geopark is a new system for development of local economy through conservation, education, and tourism and has scientific importance for the earth sciences and outstanding scenic values. The Busan National Geopark was certificated by the Minister of Environment of Korea in November 2013. Certified 12 geosites, located in coast, mountain, and estuary, are as follows (Fig. 6). The Nakdonggang estuary geosite, the largest present delta in Korea, has diverse estuary landforms and sedimentary structures. The Morundae, Dusong peninsula, Songdo peninsula, and Dudo island geosites, located in the Dadaepo Basin, provide a basis for the interpretation of tectonic setting, deformation history, sedimentary environment of the SE Korea during the Late Cretaceous. The Taejongdae geosite has a variety of coastal erosion features and uplift landforms. The Oryukdo and Igidae geosites have various geoheritages related to the Yucheon volcanism in the Late Cretaceous with later coastal erosion landforms. The Jangsan geosite shows also a variety of geoheritages concerning the late Cretaceous rhyolitic volcanism. The Geumjeongsan geosite located in mountain area has gorgeous granite weathering landforms. The Orbulicar gabbrro geosite is the 267th Natural Monument of Korea. The Baekyangsan include geoheritages associated with Cretaceous lake deposits.

All the geosites in Busan show the geodiversities, and have been posted on previous researches or used in academic purposes, so that their academic values have been demonstrated. The Busan National Geopark also has a significant advantage of urban geopark in accessibility to the geosites through public transportation, well-equipped education system, and tourism infrastructures in Busan metropolitan city. The inhabitants can thus develop the local economy by preserving the geoheritages and nature resources and participating in the geopark operation. Consequently, the geopark will play a leading role in satisfying diverse demands of recent tourism as a successful urban geopark (Kang et al., 2014).
Fig. 6. Overview map with distribution and characteristics of geosites and their geheritages in the Busan National Geopark.
04 GEOSITES OF THE BUSAN NATIONAL GEOPARK
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The Busan National Geopark is divided into 4 districts, and is composed of a total of 12 geosites (Fig. 7).

![Map of Busan National Geopark](image)

Fig. 7. The range and location of the Busan National Geopark.

04.1 NAKDONGGANG ESTUARY

**Nakdonggang estuary** is the largest modern delta in Korea, where Nakdong River meets the South Sea. Well-formed small and large sized deltas have been good habitats for migratory birds. It was thus designated as the Precious National Treasure No. 179. Various estuary landforms and sedimentary features such as offshore bars, beaches, dunes, wetlands are scattered all over the Nakdonggang estuary geosite. Education and tourism infrastructures such as the Nakdonggang Estuary Eco Center and Amisan Observatory are also well-established.
Fig. 8. (A) Nakdonggang Estuary Eco Center. The center provides various informations of geology, topography, and ecology of the estuary to visitors. (B) Bird observatory installed in the center. (C) Electric cart for visitors served from the center. (D) Amisan Observatory exhibits geology, estuary, and history of the estuary. (E) Offshore bars seen from the Amisan Observatory.

`04.2 MORUNDÆ`

The Morundae geosite is a land-tied island (tombolo) that is connected to land only by a spit of beach materials. The geology of the area comprises sedimentary rocks of the Dadaepo Formation such as conglomerate, sandstone, siltstone, and mudstone and the Quaternary terrace deposits. We can also observe typical geological features, such as syn-depositional normal fault, clastic dike, flower structure in strike-slip fault zone, en echelon calcite veins, sand pipes by seismic shock (liquefaction), conglomerates and chert clast, and comb structure. In addition, there are various attractions such as Dadaepo beach, Dadaepo Sunset Fountain of Dream, Dadaepo shell mound, and Dadaepo Gaeksa.

Fig. 9. (A) Quaternary terrace deposit between alluvium and the lower Dadaepo Formation. (B) Neptunian type clastic dikes. (C) NW-trending normal faults showing horst type. (D) Chert clasts in conglomerates. (E) NW-trending syn-depositional normal faults showing half-graben type.
04.3 DUSONG PENINSULA

In the Dusong peninsula geosite, we can see distinctive geoheritages such as andesitic sill, conjugate normal fault, compound calcrite deposit, reduction spot, petrified wood fragment, clastic dike, paleo-seismic structure, and dinosaur egg fossil along a developed geotrail. In particular, clastic dikes show intriguing injected structures such as root zone, branched system, and bridged segment.

Fig. 10. (A) Andesitic sill intruding the lower Dadaepo Formation and xenolith (insert in right-top). (B) Graben type-conjugate normal faults. (C) Outcrop photographs of clastic dikes showing cross-cutting relationship (left). They also show branched system (right). (D) Compound calcrite deposits and reduction spot (insert in right-bottom) in the lower Dadaepo Formation. (E) Paleo-seismic structures showing sandy ball-and-pillow type and pillar structure (insert in right-top). (F) Dinosaur egg fossil in the lower Dadaepo Formation.

04.4 SONGDO PENINSULA AND DUDO ISLAND

The Songdo peninsula and Dudo geosites provide a basis for the interpretation of evolution history of the Dadaepo Basin. In these sites, we can observe a lot of typical geological features, such as cross-bedding, cut and fill structure, ripple mark, reduction spot, syn-depositional fault, clastic dike, magmatic dike and sill, dinosaur egg fossil, and so on. They have high scientific and educational values. There are also various tourist sites such as Songdo Beach and Amnam Park near to these geosites.
Fig. 11. (A) Deck facilities built in geotrail course. (B) Outdoor exhibition of rocks and minerals. (C) The upper Dadaepo Formation and overlying basaltic andesite (lava flows). (D) Cross-stratified tuffaceous sandstone with volcanogenic clasts. (E) Angular calcite nodules in purple mudstone. (F) Fossils of dinosaur egg nest in purple sandstones. (G) Dudo Island geosite. (H) The Lower Dadaepo Formation unconformably overlying the volcanic basement of the basin. (I) Tuff breccia (the volcanic basement).

04.5 TAEJONGDAE

The Taejongdae geosite, designated as the national cultural heritage scenic spot No. 17, is located at the southern end of the Yeongdo Island. The geosite shows a typical uplift landform and associated coastal erosion features and has a high scientific value about the Quaternary crustal uplift in the Korean Peninsula. Furthermore, fascinating geological features are observed in this site, such as negative flower structure produced by sinistral strike-slip faulting, orbicular hornfels, slump structure within tuffaceous sedimentary rocks, and composite (felsic and mafic) magmatic dikes. Various tourist sites such as National Maritime Museum, Dongsam-dong Shell Midden Museum, and Jagalchi market are also located near to the site.

Fig. 12. (A) Panoramic view of the Taejongdae geosite with the Yeongdo Lighthouse. (B) Close-up of orbicular hornfels. (C) Slump structure in the tuffaceous sediments (Taejongdae Formation). (D) Uplifted notch (arrow) formed by undercutting due to wave erosion. (E) Wave-cut platforms (terraces) showing the Quaternary crustal uplift of SE Korean Peninsula during the Quaternary, SE Korea.
04.6 ORYUKDO AND IGIDAE

The Oryukdo, designated as the national cultural heritage scenic spot No. 24, and Igidae geosites have various geoheritages associated with the Yucheon volcanism during the Late Cretaceous and later coastal erosion landforms. In these geosites, we can observe tuffaceous sedimentary rocks, andesitic volcanic breccia, copper mine produced along fault damage zone, marine potholes, sea cave, sea cliffs along the geotrail. These sites are the most famous geosites because of the easy accessibility and outstanding scenery.

Fig. 13. (A) Panoramic view of the Oryukdo (from left to right: Deungdaeseom, Gulseom, Songgotseom, Suriseom, Solseom and Bangpaseoseom). (B) Oryukdo Skywalk. (C) Marine potholes on a wave-cut platform. (D) Sea cave formed by erosion due to wave and current. (E) Intermediate dike bearing hornblende megacrysts intruding volcanic breccia. Close-up of the hornblende phenocrysts in upper right corner. (F) Tuffaceous sedimentary rocks observed along sea cliff.

04.7 JANGSAN

The Jangsan (634 m) geosite is close to the Haeundae Beach that is the Busan’s No. 1 beach. The Jangsan mountain is interpreted as a volcanic cauldron which is a relict structure of the late Cretaceous volcanic activities. A variety of geoheritages and landforms are also discovered in the mountain, such as block stream, Yangun falls, and spherulitic rhyolites known as 'flower stone'.
04.8 GEUMJEONGSAN

Geumjeongsan (801.5 m), considered as a representative mountain in Busan, has gorgeous granite weathering landforms and geological structures such as tor, inselberg, and block stream. These structures are located along the Geumjeongsanseong Fortress, the largest fortress in Korea. Various tourist sites such as Beomeosa Temple, Geumjeongsanseong Fortress, Geumgang Park, and Dongnae Spa are also located near to the site.

Fig. 14. (A) Spherulitic rhyolite. (B) Rhyolite showing flow structure. (C) Block stream formed by an accumulation of boulder and angular blocks. (D) Yangun falls.

Fig. 15. (A) Panoramic view of inselbergs and tors developed along the Geumjeongsansung Fortress. (B) Geumsaem (gnamma) formed by long-term weathering on granite rock. (C) Tor formed by intense weathering related to vertical and sheeting joints. (D) Wonhyobong composed of group of pinnacle tors. (E) Block stream formed by an accumulation of boulder and angular blocks.
04.9 ORBICULAR GABBRO

The orbicular gabbro, designated as the Natural Monument No. 267, is the sole orbicular gabbro in South Korea. Because the orbicular gabbro is only reported less than 10 sites in the world, it has very high geological value and capability of tourism resources. This site thus will be a leading site of the Busan National Geopark through the proper protection system and trail course. The orbicules in the site are classified into four types such as proto-orbicules, single-shell orbicules, multi-shelled orbicules, and complex orbicules, according to the state of growth and the number of shells. The orbicules have cores of chiefly plagioclase and olivine which are surrounded by alternating plagioclase-rich and olivine- or augite-rich shells.

Fig. 16. (A) Panoramic view of orbicular gabbro. (B) Proto-core. (C) Single-shelled orbs. (D) Multi-shelled orbs.

04.10 BAEKYANGSAN

The Baekyangsan (642 m) geosite, composed of the Cretaceous sedimentary rocks (Icheonri Formation), andesitic lava, andesitic pyroclastic rocks, tuffaceous sedimentary rocks, rhyolitic pyroclastic rocks, intrusive rocks. Especially, limestone caves and calcic paleosols, lying at hillside of the mountain, are observed in the lacustrine sedimentary strata. In addition, there are several experience centers in this geosite, providing various natural and ecology experience activities such as wetland and forest experiences.
Fig. 17. (A) Limestone cave in the lacustrine sedimentary strata. (B) Calcrete deposits in the tuffaceous sediments. (C) Tuffaceous sediments. (D) Sungji-gok falls.
05 HAEDONG YONGGUNGSA (TEMPLE)
HAEDONG YONGGUNGSA (TEMPLE)

Haedong Yonggungsa Temple is situated on the coast of the north-eastern portion of Busan. This superb attraction offers visitors the rare find of a temple along the shore line; most temples in Korea are located in the mountains. Haedong Yonggungsa Temple was first built in 1376 by the great Buddhist teacher known as Naong during the Goryeo Dynasty. Haesu Gwaneum Daebul (Seawater Great Goddess Buddha), Daeungjeon Main Sanctuary, Yongwangdang Shrine, Gulbeop Buddhist Sanctum (enclosed in a cave), and a three-story pagoda with four lions can all be seen looking out over the ocean.

![Fig. 23. Photographs of the Haedong Yonggungsa.](image)

The main sanctuary of the temple was reconstructed in 1970 with careful attention paid to the colors that were traditionally used in such structures. On the right-hand side, inside the cave, is a uniquely designed Buddhist sanctum, while situated just in front of the main sanctuary is a three-story pagoda with four lions. The four lions are symbolizing joy, anger, sadness, and happiness. Other special sites at the temple are the 108 stairs and stone lanterns lining the rocky landscape. After going down the 108 steps, one will be delighted with the beauty of the temple. Midway down the 108 steps one can stop and enjoy the calming sounds of the waves, and view the majestic sunrise.

Many people often come to this spot on New Year’s Day to make a wish for the new year as they watch the sun come up. April is an especially beautiful time of year with cherry blossoms in full bloom. The birth of Buddha is also celebrated in the fourth month of the lunar calendar and offers a spectacular night view as the temple area is aglow with lit lanterns (from http://english.visitkorea.or.kr/).
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