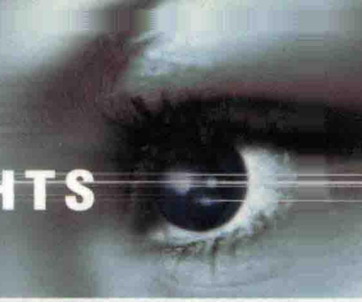

ELSEVIER INSIGHTS

GEOLOGY AND SEDIMENTOLOGY OF THE KOREAN PENINSULA

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Geology and Sedimentology of the Korean Peninsula

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Geology and Sedimentology of the Korean Peninsula

Preface

Geology is the study of dynamic processes of the Earth. What causes uplift of mountains and subsidence of ocean basins? How are the rocks in the high mountains weathered and transported and eventually deposited in sedimentary basins? How have the surface environments changed and what forces have driven the changes? Geology focuses on the constituent materials and their formative processes as well as the life forms. A geological study starts with a field observation of outcrops or the constituent materials, including sediments, rocks, strata, and fossils. An accurate description of the constituent materials and their spatial and temporal relationships is most important for accurate interpretation of dynamic processes. The study commonly employs laboratory analyses whose results are commonly displayed as conceptual drawings or models, which explain how a natural system is built or behaves.

An initial geological survey of the Korean Peninsula was made in 1884 by a German geologist, C. Gottsche, followed by an extensive Japanese investigation of rocks, minerals, and fossils for the exploitation of economic mineral deposits, which helped establish stratigraphy and the outline of geological structures (Kobayashi, 1927, 1933, 1967; Tateiwa, 1976). A syllabus entitled *Geology of Korea* was first published by the Geological and Mineral Institute of Korea (Reedman and Um, 1975). It contained an outline of geological history based on the description of major rock units in the southern part of the peninsula, an account of geological mapping (1:50,000 scale) about 70% of the country. Another version was edited at the occasion of the Pacific Science Congress in Seoul (Lee, 1987a), primarily based on the notion of geosyncline evolution and crustal deformation.

Since the first publication, tremendous progress has been made in the geological understanding of the Korean Peninsula on land and under the sea with the advances in sophisticated study technique and reinforcement of research personnel. The number of research scientists in geosciences has been more than tripled in academic and research institutions. An updated review of tectonic and sedimentary evolution of the Korean Peninsula was made at the turn of the new millennium in view of the unifying theory of plate tectonics (Chough et al., 2000). The plate tectonics theory explains the whole range of geological processes, such as basin subsidence, sedimentation, mountain building, volcanism, and other processes that construct features on the Earth's surface. Plate tectonic processes are understood as controls of the overall architecture and evolution of crust and sedimentary basins.

However, the emergence of the concept of sequence stratigraphy since the late 1970s has brought a fundamental difference in thinking about the evolution of sedimentary basins. The principal tenet of sequence stratigraphy was that a change in relative sea level results in a change in stratal patterns. Sequence stratigraphic interpretations helped reveal the effect of sea-level controls on nearshore sedimentation and stratal architecture in a chronological framework. Recent development reveals, however, that there is significant variability in the expression of sequence stratigraphic units. This book summarizes the state of the art of the dynamic processes and environmental changes in the Korean Peninsula on land and under the sea during the Phanerozoic Era. The main focus is on the evolution of sedimentary basins, i.e., from sedimentary facies to plate tectonics.

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Contents

1 Introduction

1.1 Geological Questions

The Korean Peninsula consists of scenic mountains and valleys that run one after another (Figures 1.1–1.3). These features have descended from crustal deformation and the associated plutonic and volcanic activities. Rivers run through the valleys, carrying sediments mostly toward the west and the south, forming floodplains. Where the rivers meet the coastal plain, estuaries form. Along the western and southern coasts of the peninsula, tidal flats are extensive, rivaling those of the North Sea and the Bay of Fundy. The Yellow Sea is a shallow (55 m on average) epicontinental sea, surrounded by the landmass of China and Korea. Off the western and southern coasts of the peninsula, there are more than 3000 islands. However, the eastern continental shelf is narrow and transitional to a bowl-shaped deep basin, the Ulleung Basin, and the Korea Plateau, which are dotted by numerous volcanic seamounts and islands, including the Ulleung and Dok islands (Figure 1.4). The volcanic island of Jeju comprises a central crater, about 360 scoria cones, and tuff rings and cones.

The Korean Peninsula comprises denudation remnant of deformed basement rocks and sedimentary successions, concealing a long history of crustal deformation (Figure 1.5). Sedimentary rocks especially contain records of environmental change through Earth's history, including climate change, the rise and fall of sea level, and the movement of tectonic plates over millions of years. The peninsula presents a number of fundamental questions as to its origin and dynamic processes. What constitutes the scenic mountains and ridges? When and how did these mountain chains form? Was it due to the collision of the tectonic plates? How often was the continent submerged under the sea throughout Earth's history? How are the rocks in the peninsula linked to those of China and Japan? What are the origins of the deep basins and submarine plateaus in the East Sea? How did the continent under the Yellow Sea form and evolve? How would the coastal areas be affected by sea-level change over timescales of a few decades to centuries? These are commonly asked questions regarding dynamic processes and environmental changes of the Korean Peninsula on land and under the sea.

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Figure 1.1 Satellite image of the Korean Peninsula. The peninsula consists largely of mountains (about 65%). There are about 3000 islands off the south and west coasts. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this book.)
Source: GOCI/COMS RGB Color Composite Image processed by Korea Ocean Satellite Center/Korea Ocean Research and Development Institute.

1.2 Sedimentary Facies Analysis

Sedimentary rocks are important constituents (more than 50%) of the crust of the Korean Peninsula. Sedimentary rocks (and sediments) are characterized by grain size and sedimentary structures, i.e., sedimentary facies, defined as a depositional unit characterized by a particular combination of grain size (lithology) and sedimentary (physical and biological) structures (Figure 1.6). Each unit of sedimentary facies represents distinct depositional processes that act on the sediments in particular environments (Figure 1.7). Genetically related facies can form a group, defined as a facies association or a sequence that has some environmental significance. An analysis of sedimentary facies thus leads the way to diagnosing depositional processes and environments (Dalrymple, 2010).

Sedimentary facies analysis is essential to the study of stratigraphy, which is primarily concerned with the recognition of distinct bodies of rocks in a chronological framework. A lithostratigraphic unit is defined by its lithologic characteristics in stratigraphic position relative to other bodies of sedimentary rock. A sedimentary rock unit can also be characterized by its fossil contents, biostratigraphy. Various other methods have also been used to define stratigraphic units, including magnetostratigraphy and chemostratigraphy.

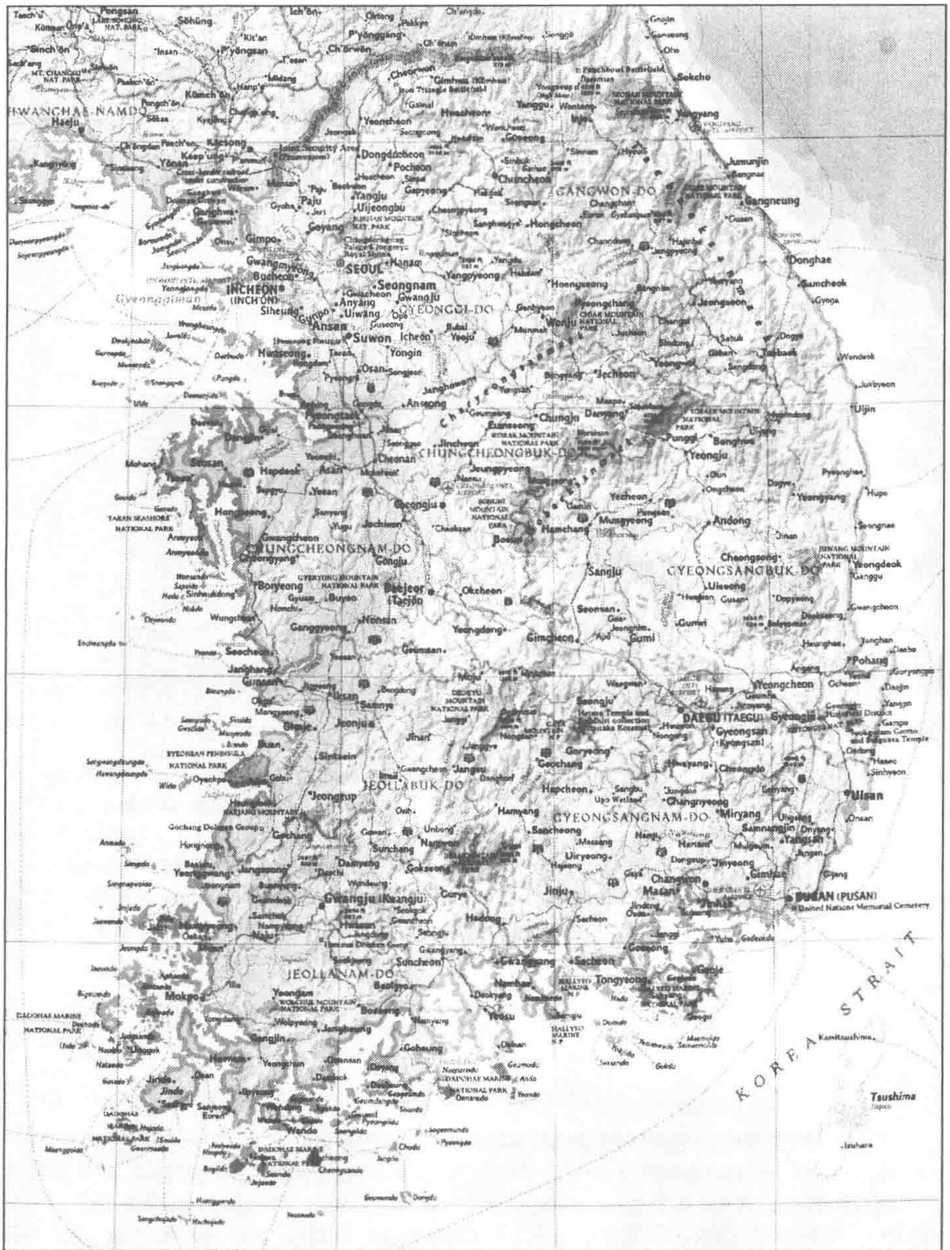

Figure 1.2 Geographic map of South Korea.
Source: National Geographic (2003) by permission of the National Geographic Society.

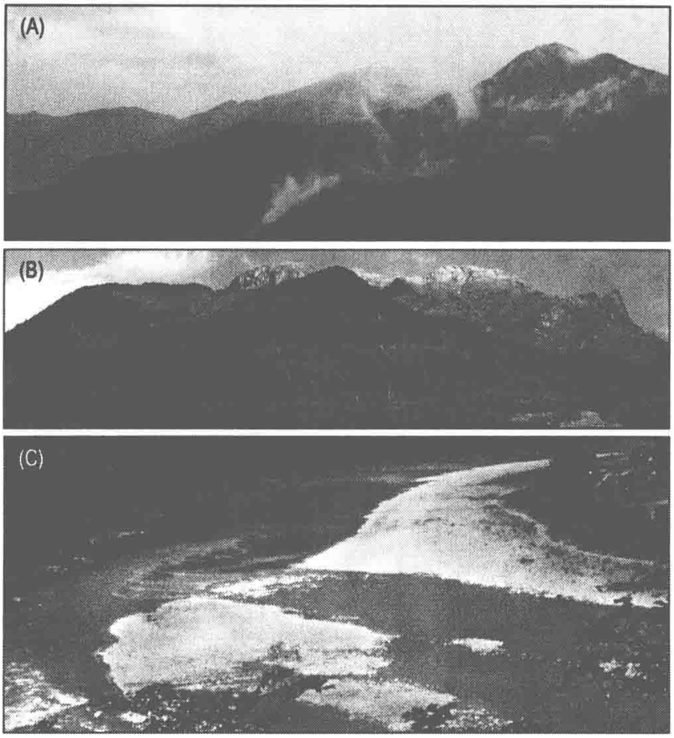

Figure 1.3 (A) View of a mountain chain in the southeast of Taebaek city, Gangwon Province. The ridges comprise sedimentary rocks (limestone and sandstone) that formed in shallow water environments during the Paleozoic (about 520–250 Ma) and deformed in the Mesozoic (ca. 250–150 Ma). The mountains represent remnant of continuous denudation for the last 150 million years. (B) Snow covered Wolak mountain in the background. It consists of granite intruded into metasedimentary rocks. (C) The meandering East River showing mid-channel and sidebars of gravelly sands.

Sedimentary facies analysis leads to an understanding of controls on basin evolution, including tectonics, climate changes, and sea-level changes (Miall, 2000, 2010). Plate movement causes subsidence of the crust, which provides the space for the accumulation of sediments. Sedimentary basins are commonly formed according to the plate tectonic regime: divergent, convergent, transcurrent, intraplate, and hybrid settings. Subsidence is induced by a thinning of the crust due to stretching, erosion, and magmatic withdrawal as well as tectonic and sedimentary loading and others (Busby and Azor, 2011). Uplift/subsidence also affects climate changes and the amounts of sediment supply. Along with these factors, sea-level changes control depositional processes and environments, especially in the shoreline and shallow waters.

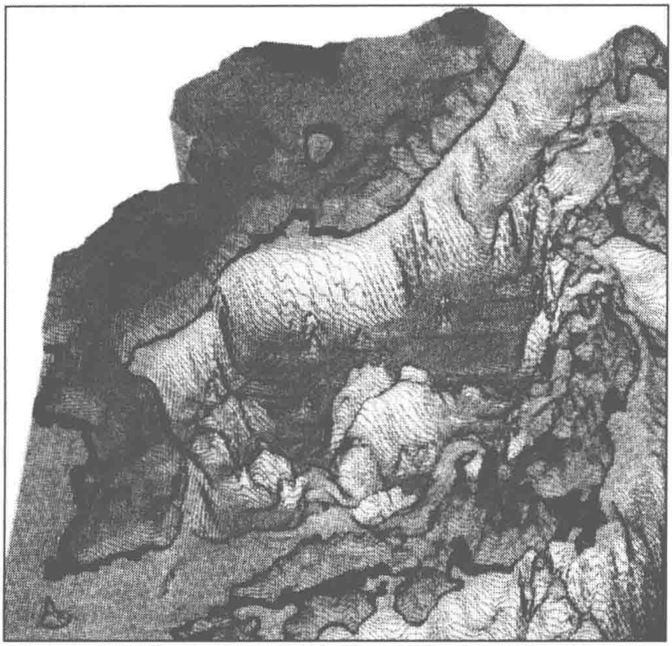

Figure 1.4 Topographic relief of the Korean Peninsula and the northeast Asian margin.
Source: Courtesy of K. Tamaki.

Sedimentary facies analysis eventually leads to sequence stratigraphy, which is the study of rock relationships within a chronostratigraphic framework of repetitive, genetically related strata bounded by surfaces of erosion or nondeposition, or their correlative conformities (Posamentier et al., 1988; Van Wagoner et al., 1990). Sequence stratigraphic analysis focuses on the geometric characters of stratal patterns and identifications of key surfaces to determine the chronological order of basin fills (Catuneanu, 2006; Emery and Myers, 1996). The underlying tenet of sequence stratigraphy was that a change in sea level would result in a change in stratal patterns, which could be compared among basins worldwide. This deductive generic view of sequence stratigraphy has hampered, however, to further process-based sedimentological approach to an integrated basin analysis. The high variability of bounding surfaces and stratigraphic units requires inductive analysis for individual rock records (Catuneanu et al., 2009, 2010). Modern sequence stratigraphy focuses on the changes in stratal stacking patterns in response to varying accommodation and sediment supply through time (Catuneanu et al., 2010; Miall, 2010). Attention is now given to the specifics of how stratal architecture can throw light on depositional processes and allogenic controls.

Over the past 30 years, extensive sedimentary facies analyses have been made in major sedimentary basins of the Korean Peninsula, including the siliciclastics, carbonates, and mixed siliciclastic–carbonate successions as well as the nonmarine