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The Development and Luminescence Chronology of a Coastal Dune from the *Shindu* Dunefield, *T'aean* Peninsula

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신두리 지역의 전사구(前砂丘)에 대한 OSL 연대 측정 및 지형 발달

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Abstract : Luminescence dating of a coastal dune from the *Shindu* dunefield on the *T'aean* Peninsula shows that deposition of the dune structure began about 500 - 600 years ago. The lower section of the dune has remained stable since then but the upper part yields an age of about 30 years, suggesting reactivation or additional deposition since the 1970's. The two samples that were collected from the lower part of the dune at depths of 3.5 m and 2.0 m below the surface differ by an age interval of about 50-70 years. This indicates a net depositional rate of around 2.5 cm a year which is relatively slow for a coastal dune. Whilst only one dune structure has been dated for the time being and even though the dunefield was probably established much earlier in the Holocene, the OSL ages obtained demonstrate that some dunes in the area could be younger than 1000 years. Such chronologies point to a dynamic environment where the dune structures are not permanently fixed. Sedimentological properties of the dune sands are consistent with those of particles initially deposited under subaqueous conditions and then later transported by wind.

Key Words : *Shinduri* dunefield, coastal dune, luminescence dating, Holocene

요약 : 태안반도 신두리 일대에 분포하는 전사구 퇴적물에 대한 OSL 연대측정결과, 조사 지점에서의 사구사 퇴적은 대략 500~600년 전에 시작되었다. 이후 사구층 하부는 안정상태를 유지했으나, 상부(지표에서 1m)의 연대가 약 30년전인 것으로 보아 1970년대 이후 재퇴적되었을 것으로 추정된다. 한편, 사구 표면으로부터 3.5m와 2m 깊이에서 채취한 두 개의 시료는 50~70년 정도의 연대차이가 있다. 이에 의하면 사구사의 순(純)퇴적율은 연간 약 2.5cm로 추정되는데, 이는 해안사구로서는 비교적 느린 것이다. 본 조사에서 연대를 추정한 사구사 퇴적층은 1개 지점에 불과하지만, 이를 토대로 볼 때, 지난 1,000년간 상당한 양의 사구사가 퇴적되었거나 재이동되었음을 알 수 있다. 이러한 사실은 사구가 홀로세(Holocene) 동안에도 매우 역동적으로 움직이고 있음을 시사한다. SEM 및 입도분석을 토대로 볼 때, 사구사는 수중환경에서 쌓인 이후 바람에 의해 재운반되어 퇴적된 모래 입자의 특성과 잘 부합된다.

주요어 : 신두리 사구, 전사구, OSL 연대측정, 홀로세

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1. Introduction

Significant sections of the *T'aean* Peninsula coastline are backed by coastal dunes that result from sand blown by onshore winds and is trapped by vegetation. Such dunes function as defensive barriers for the coastline during periods of potentially damaging wave action or storm activity. They also shield the land behind the ridges from saltwater intrusion and windy conditions, thus, permitting the development of more diverse vegetal communities in the coastal zones. During periods of erosion, the dunes also provide sand to replenish the beach.

Coastal zones, however, are sensitive geomorphic environments. The destruction of vegetation on the dune by extreme weather events such as storms or drought may result in the erosion of particular points on the dune ridge, leading to the development of blowouts (Goldsmith, 1978; Hesp, 2002). Vegetation on the dunes may also be destroyed by human interferences that may include motor vehicle use, animal grazing, excessive pedestrian traffic or setting of fires. On the *T'aean* coast, significant anthropogenic interference has been in the form of sand mining (Park and Chang, 2002) which was outlawed within the confines of the National Park in 1999. Motor vehicle damage is also evident on some sections of the coast. In order to mitigate the effects of these environmentally deleterious activities, authorities in the *T'aean* National Park have been conducting rehabilitation programs ranging from revegetation campaigns to the erection of protective barriers such as seawalls and sand fences. Attempts have also been made to reconstruct the dune ridges and fill up the blowouts (Park and Chang, 2002).

A missing component that would otherwise complement the restorative efforts being waged on the *T'aean* coast is an insight into the long term stability of the eolian dunes in the region. Knowledge about the chronological development of the coastal dunes beyond historical accounts is lacking and this constrains the capacity of planners to make predictions or forecasts regarding the rates of recovery that should be expected. Previous age estimates of the dunes have generally been unspecific. For instance, suggestions have frequently been made that coastal dunes which comprise light colored sands are Holocene in age and that they overlie older red tinted sandy deposits that date from the Last Interglacial (Kahng, 2003). More recently, Park and Chang (2002) have also provided a reconstruction of the spatial evolution of some dunes in the area using remotely sensed data. Their study, however, is limited by the availability of remote sensing imagery which only go back to the 1960's, making it impossible analyze changes older than fifty years.

This paper presents the initial results of a continuing study that aims to provide absolute chronologies for the development of coastal dunes on the *T'aean* Peninsula using luminescence dating methodology. From the luminescence ages, it will be possible to determine, more accurately, both the spatial and temporal evolutionary patterns of the dunefields. It will also be feasible to ascertain depositional rates and response mechanisms of the dune structures. All these parameters are imperative pre-requisites for effective restorative and planning activities. The following section briefly outlines the morphodynamics of coastal dunes and terminologies used in their study after which the study area and the work carried out are presented.

1) Morphodynamic Aspects of Coastal Dunes

Various classification methods have been suggested to describe foredunes but, generally, they belong two main subtypes: incipient foredunes and established foredunes (Hesp, 2002). Incipient foredunes are those shore parallel eolian ridges that are still in their early developmental stages. The term 'embryo dunes' is used by some to describe the same structures (Hesp, 2002). Morphological aspects of the incipient foredune depend on several variables that include the type of vegetation. With time, incipient foredunes evolve to form established foredunes.

Established foredunes are recognizable by their more complex morphology, height, width, geographical position and age (Hesp, 2002).

Broad schemes have been formulated that try to characterize the long term spatio-temporal evolutionary trends of coastal environments (Hesp, 1988; Carter, 1988; Arens and Wiersma, 1994). Such models portray foredunes going through phases of stability, erosion or progradation (Hesp, 2002). In principle, five erosional cycle stages have been identified (Figure 1). A stage refers to a state in which the dune may remain for a significant period of its existence. However, the progression is reversible if, for instance, a change in climate leads to the re-establishment of vegetation on the dune surface (Hesp, 2002).

Stage 1 of foredune development is the phase during which there is the establishment of a beach parallel structure that is well vegetated. In stages 2 to 5, progressive loss of vegetation results in sand being transported further up the dune structure and onto the lee side (Nickling and Davidson-Arnott, 1990). In principle, stages 1, 2 and 3 are characterized by dunes that continue to increase in size or height. stage 5, however, is highly erosive to the extent that the foredune may disappear altogether or retreat

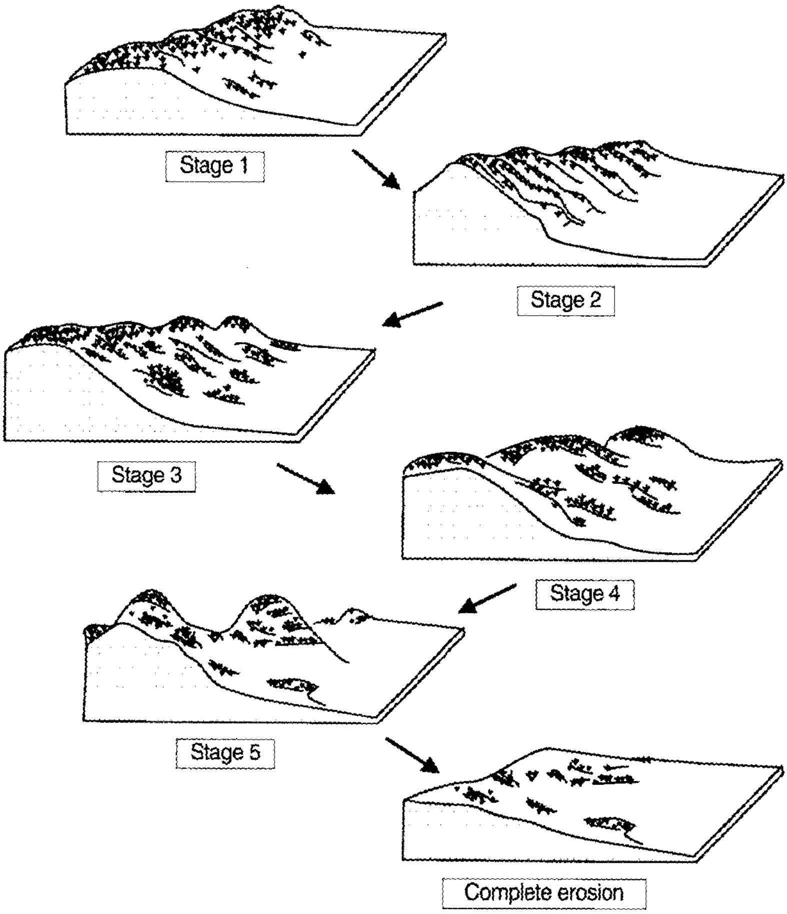


Figure 1. Main morpho-ecological developmental stages of foredunes as proposed by Hesp (2002).

landward (Giles and McCann, 1997). Erosion of the foredune largely occurs through the development of blowouts.

The formation of a new incipient foredune in the foremost beach position may result in the isolation of an established foredune. The established foredune, thus, becomes a relict foredune (Hesp, 2002) that is essentially disconnected from processes that occur at the leading beach front. Over periods of decades to millennia, the continued progradation of the beach may result in the formation of wide foredune plains (Hesp, 1999, 2002).

A term that is also commonly used to describe dunes located behind the foredune is secondary dune (back dune is also used in old literature). The term, however has no precise definition and seems to imply different things to different people. When used in geologic terminology, a secondary dune structure is strictly one derived from a so-called primary dune (Davies, 1977). For that reason, sediment mounts resulting from blowout deflation would be described as secondary dunes. When used in an ecological context, on the other hand, any dune lying landward of the foredune that faces the ocean is considered to be a secondary dune. Relict foredunes (Hesp, 2002) as well as blowouts would both fall under this category. Thus, the term secondary dune is ambiguous and has no morphogenetic connotation (P. Hesp, personal communication, June 2004). Some workers prefer not to use the term at all.

2. Study Area and Sample Collection

The *Shindu* dunefield is situated on the northwestern coast of the *T'aean* Peninsula (Figure 2). The study area lies about 1.5 km northwest of the town of *Shindu*. At the study site, a foredune plain displays different generations of foredunes including incipient, established and relict foredunes as well as other dune structures formed by deposits accumulating from the deflation of blowouts.

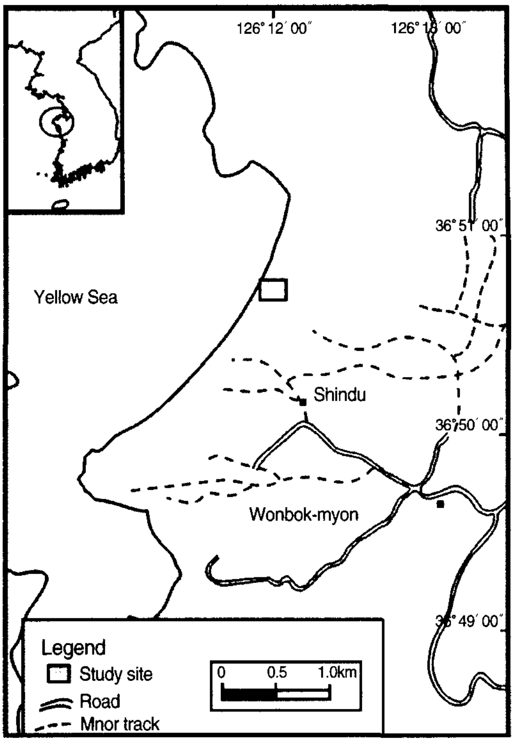


Figure 2. Location of the study area.

Several dune structures show zones where vegetation has been destroyed, particularly due to the use of motor vehicles and this may possibly lead to the development of blowouts in the future. Some blowout structures also seem to be seasonal structures that develop during the winter when the vegetation cover recedes.

The dune structure that was sampled in this study (Figure 3) is located about 40 meters from the current beach plain at GPS coordinates N 36° 50′ 44″4‴, and E 126° 12′ 00″4‴. The altitude at the dune summit is about 21 m and a blowout has developed on a section on the seaward slope of the dune. A pit was excavated from within the blowout to expose a vertical profile of the original dune (Figure 4). Disturbed and slumped sediments were excluded by identifying the original depositional laminations that were still intact.

Samples for luminescence dating should not be exposed to sunlight and, thus, samples were retrieved from the freshly excavated section by

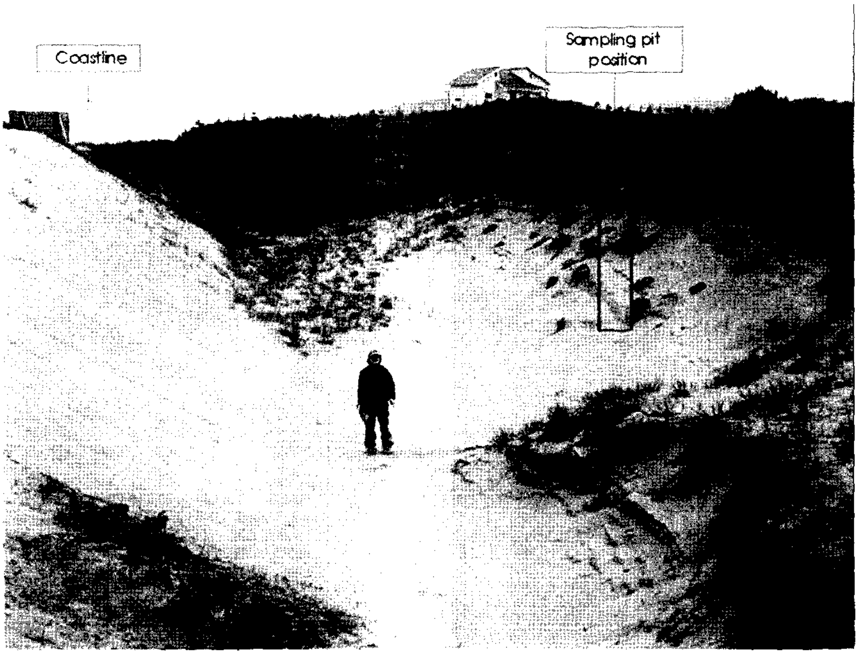


Figure 3. Dune structure sampled in this study illustrating the position where a sampling pit was excavated (see Figure 4)

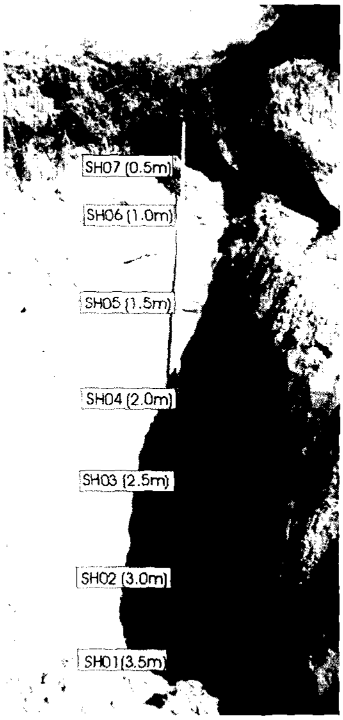


Figure 4. Sampling pit with sample positions indicated. Only samples SH01, SH04 and SH06 were dated using luminescence methodology.

inserting stainless steel tubes approximately 25 cm long and 6 cm in diameter into the sediment wall and capping the ends with aluminum foil after which the samples were stored in dark containers and transported to the laboratory. A total of seven samples were collected at 50 cm intervals starting from the dune base. In this exploratory study, only the samples collected from depths of 1, 2 and 3.5m were submitted for dating using the luminescence dating method. Samples were also collected for sedimentological analysis.

3. Sedimentological Analysis

To establish the sedimentological properties of the sediments under investigation and to ascertain their suitability for luminescence dating, representative samples from the study site were investigated using grains size analysis. In addition, scanning electron microscopy studies were also carried out on selected samples.

1) Grain Size Analysis

Sample preparation for grain size analysis followed the standard procedure that is used in granulometric assessments (Carver, R. E., 1971). Figure 5 is a plot of cumulative frequency versus grain size in phi(ϕ) units for sample SH07. Statistical analysis using graphic measures (Folk and Ward, 1957) shows that the sands from the sampled dune are relatively well sorted with a mean particle size of about 203 μm which is in the fine sand category. These findings are accordant with results reported by Seo (2001) who carried out a much larger granulometric study in the *Shinduri* dunefield. Data from other coastal regions (Ahlbrandt, 1979) also show that coastal dunes frequently possess particle sizes in the range 125-250 μm. The skewness in very low with a near symmetrical distribution about the mode and the kurtosis is normal (mesokurtic).

It should be noted that the granulometric properties of coastal dune sands are determined by two main variables: the grain size distribution of the source sediments at the beach and the wind strength at the locality. Because of abundant sediment supply on beaches and high energy winds that characterize most coastal environments (Pye and Tsoar, 1990), sand depositional rates on coastal dunes can be up to 10 times higher than rates found on inland deserts (Illenberger and Rust, 1988).

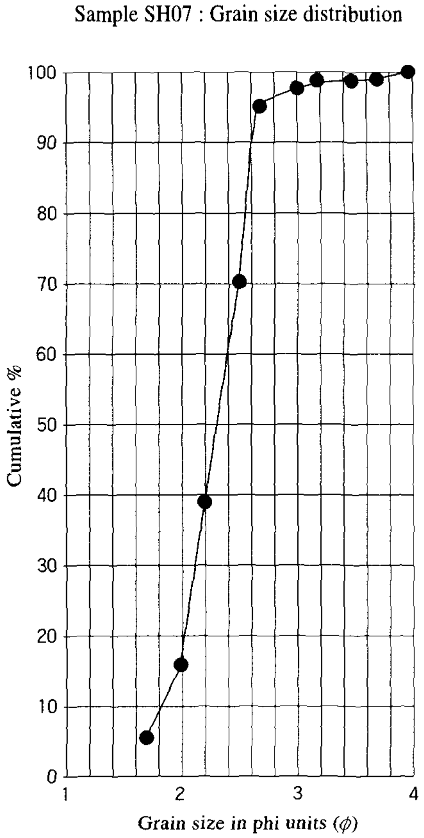


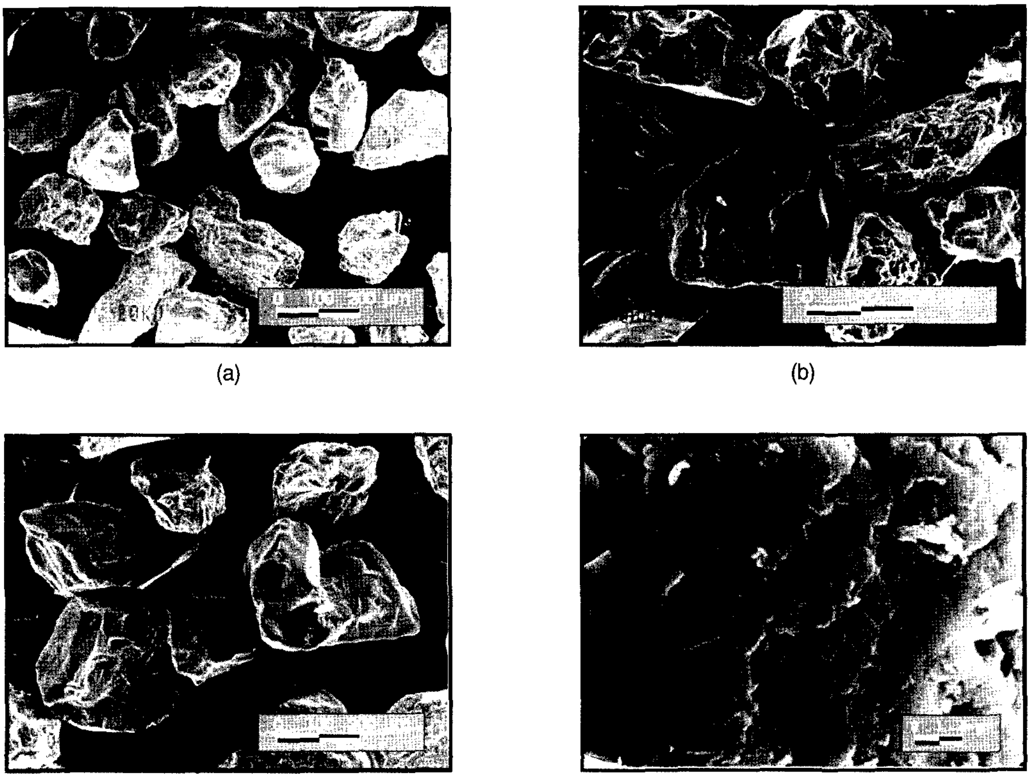
Figure 5. Grain size analysis plot.

2) SEM Analysis

(1) Coastal dune grain morphology and surface properties

Numerous studies (Krinsley *et al.*, 1964; Margolis and Krinsley, 1971; Setlow and Karpovich, 1972; Mazzulo et al., 1986; Marshall, 1987) have demonstrated that grains from major depositional environments can be differentiated on the basis of their shape and surface textural properties (Williams and Thomas, 1989). However, it is not practical to use surface features and shapes of grains as the only criteria in determining depositional and transport history of sediments because surface features that arise from abrasion during transport under many environments can be similar. Nonetheless, it is possible to identify shape and textural suites that are associated with some sedimentary environments.

Analysis of quartz grains from coastal environments has demonstrated (Margolis and Krinsley, 1971) that mechanical V shaped depressions are frequently observed on beach sediments. Beach deposits have also been reported (Williams and Thomas, 1989) to display a range of other features including various types of conchoidal fractures as well as cracks. Sediments transported by wind, on the other hand, are described as generally rounded (Margolis and Krinsley, 1974) due to mechanical abrasion. Close-up images of the surfaces also dis-



(a) (b)

(c) (d)

Figure 6. SEM images. The particles retain some degree of angularity but noticeable on most grains is abrasion of edges. With time, the abrasion eventually leads to rounding of the grains. Some grains display cracks whilst many show extensive conchoidal fracturing. (a) Grains in the size range 90-180 μm. Note the chemical etching evident on some grain surfaces. (b) Grains in the size range 180-250 μm. (c) Grains in the size range 250-300 μm. (d) Close-up of a grain surface showing precipitated silica.

play abrasion features called upturned plates. Laboratory simulation has demonstrated that upturned plates can be generated very rapidly (Krinsley and Wellendorf, 1980) particularly when wind velocities are high.

Williams and Thomas (1989) analyzed barrier island sediments from the Long Island (New York), and noted that about 30 % of the coastal dune sediment particles were rounded. A majority of the grains (>80 %) had cracks. Also identified were crescent shaped depressions ascribed to impacts. Abrasion of edges was observed on about half the grains. Solution or precipitation textures were also identified on a majority (70 %) of particles.

(2) SEM sample preparation and analysis

After separating a representative portion of the sample, organic matter and calcium carbonate were eliminated using hydrogen peroxide and hydrochloric acid respectively.

Wet sieving was used to eliminate silt and clay fractions. Sediment particles greater than 63μm were then allowed sit in warm HCl to effect the removal of any surface coatings on grains, for instance ferrous oxides. This is a necessary step if the true surface textures are to be examined. Afterwards, dry sieving was carried to partition the sample into three fractions: 90-180μm , 180-250μm and 250 - 355μm . About 50 to 100 quartz grains were selected from each fraction under microscope. The grains were mounted on sample holders and then coated with graphite. Grain imaging was performed at the National Center for Inter-University Research Facilities using a JSM-840A scanning electron microscope.

Figure 5 (a-d) illustrates some of the images that were obtained. In summary, the grains from the three grain size ranges (90-180μm , 180-25μm and 250 - 355) are generally sub-angular. There does not seem to be much variation in angularity with size. Many grains show edges that have been reduced by abrasion. Close-up images display very few features that could be described as upturned plates. Some grains showed precipitation and solution features. These findings are consistent with the results obtained by other investigators (Williams and Thomas, 1989) who have analyzed coastal dune sediments. In contrast, inland desert eolian deposits are characterized by a high proportion of rounded grains, particularly the medium and coarse particle size ranges. A plausible explanation for the limited degree of rounding in the grains from the *Shindu* coastal dune deposits is that the distance over which the particles have been transported by wind (less than 100m) is short. Thus, the grains have had limited exposure to direct impact.

There are also well developed cracks on many grains. Such cracks have been reported on both beach and dune deposits (Williams and Thomas, 1989). Conchoidal fractures are observed on a significant proportion of the particles. These are probably the result of abrasion that occurred during sub-aqueous transport at the beach. The grains from the investigated foredune, therefore, possess features associated with an eolian environment as well as textures inherited from a beach environment. Generally, however, the results of the grain size analysis and SEM study demonstrate that the dune sands from *Shindu* comprise particle size ranges and grain morphologies that are appropriate for dating using luminescence techniques.

4. Luminescence Dating

1) Principles of Luminescence Dating

Improvements in luminescence dating methodology over the last two decades have transformed the technique into the method of choice for determining burial ages of clastic sediments transported by wind. The procedure was initially developed for archaeological dating of fired artifacts (Aitken, 1985; Botter - Jensen, 1997; Prescott and Robertson, 1997; Wintle, 1997) such as pottery, tiles or bricks. Central to the operation of the technique is a property possessed by semiconducting materials that enables mineral grains, particularly quartz and feldspar, to acquire and store energy emanating from decaying radioactive isotopes within the immediate surroundings of the grain (Aitken, 1985). The energy is stored as trapped electrons within defects in the crystal lattice of the mineral grains (Aitken, 1985; McKeever, 1995). It had been noted at an earlier stage that if the mineral grains were heated, the accumulated energy could be released in the form of light in a process called luminescence. Luminescence that is stimulated by heating is termed thermoluminescence (TL). With time, it was discovered that by measuring the released luminescence energy accurately, in conjunction with determining the rate at which the radioactive energy was acquired by the mineral grains, an age representative of the time period that had elapsed since the last heating process occurred could be calculated (Aitken et al., 1964, 1968; Mejdal, 1969).

A significant development with respect to sediment dating emerged when it was recognized that most of the electron traps in which the luminescence energy is stored are also sensitive to sunlight (Prescott and Robertson, 1997). This implied that exposure to sunlight during transport had the capacity to empty the grains of all previously accumulated energy in a manner similar to firing or heating. Once the grains were deposited and buried (shielded from sunlight), luminescence energy could accumulate again. Based on this principle, luminescence dating was subsequently applied to the determination of burial ages of detrital grains that had experienced exposure to sunlight (Wintle and Huntley, 1980). Eolian dune sands and loess deposits are exceptionally suitable for dating using luminescence techniques because the sub-aerial exposure that they experience during transport ensures that, prior to burial, they are completely emptied of previously acquired luminescence energy.

With time, investigators (Huntley et al., 1985) discovered that, since the electron traps in the mineral grains were light-sensitive, it was also possible to use a light source to stimulate energy release during measurement (optical stimulation). Typically, optical filters would be employed to discriminate between light used to stimulate energy release and the luminescent light emitted by the grain (Botter - Jensen, 1997; Wintle, 1997; Aitken, 1998). Refinement of the stimulating light sources and measurement procedures led to the introduction of optically stimulated luminescence (OSL) dating which rapidly developed into a robust technique that offered distinct advantages over the TL method (Smith et al., 1990; Stokes, 1992, 1999; Wintle, 1993, 1997; Duller, 1995; Prescott and Robertson, 1997; Aitken, 1998).

Today, luminescence dating continues to evolve and, besides dating of archeological and eolian sediments, the techniques are also used to provide chronological constraints for the deposition of fluvial sediments (Berger, 1995; Murton et al., 1997), lacustrine deposits (Berger and Anderson, 1994; Dutkiewicz and Prescott, 1997) and sediments baked by lava flows (Pilleyre et al., 1992; Forman et al., 1994). Comprehensive reviews of developments in luminescence dating techniques over the last decade have been provided by Berger (1995), Duller (1996), Botter - Jensen (1997), Prescott and Robertson (1997), Wintle (1997), and Stokes (1999). Benefits for geomorphological research and palaeoenvironmental reconstruction that have arisen from developments in luminescence dating are noteworthy. By enabling the direct dating of a wide variety of detrital sediments, the method permits chronological control that is essential in ascertaining rates of geomorphological processes over extended periods of time (Stokes, 1999). It has also enhanced the possibilities for quantitatively analyzing palaeoenvironmental dynamics of eolian systems in ways not previously possible (Prescott and Robertson, 1997).

2) Laboratory Preparation and Analysis

As described earlier, three samples were selected for luminescence dating in this exploratory study: Sample SH01 from a depth of 3.5m, Sample SH04 from a depth of 2m and Sample SH06 from a depth of 1m. In order to determine the burial age or luminescence age of a sample, two main parameters need to be determined: total energy received by the sample during burial (determined as an equivalent dose) and the rate at which this energy was accumulated (the dose rate).

(1) Determination of the equivalent dose (D_e)

Sample preparation was carried out in a dark room under subdued light. The coarse grain technique that uses pure quartz separates was adopted for determining the equivalent dose. To obtain pure quartz, HCl was added to the sample to eliminate carbonates and hydrogen peroxide was used to remove organic materials. The sample was then sieved to retain grains in the size range 125~250 μm. The sample was later treated in 40 % HF to eliminate the outer 10 μm that had received alpha dose. This process also digested most feldspars from the sample. The absence of feldspar contamination was checked using infrared stimulation, and only those samples that showed IRSL (InfraRed Stimulated Luminescence) less than 10 % of OSL (conventionally, luminescence stimulated by a blue-Light Emitting Diode (LED)) were used for dating.

Quartz OSL signals were measured using Riso a Risf TL/OSL-DA-15A automated luminescence measurement system (Botter-Jensen et al., 2000)

Table 1. Summary of measured dose rates, equivalent doses and OSL ages[1]

Sample Number & Depth	Dose Rate(mGy/Yr)	Equivalent Dose	Water Content	Aliquots used	OSL Age(Yr)
SH01 (3.5m)	2.97±0.08 (2.25±0.06)	1.32±0.03	3.0 (31.8)	36	445±15 (587±20)
SH04 (2.0m)	3.09±0.08 (2.37±0.06)	1.23±0.03	3.2 (30.9)	36	398±14 (520±18)
SH06 (1.0m)	2.98±0.08 (2.29±0.06)	0.084±0.001	3.9 (31.4)	18	28±1 (37±1)

[1]Numbers in brackets indicate the values calculated on the basis of the saturated water content

installed at the Korea Basic Science Institute. The system is equipped with a $^{90}Sr/^{90}Y$ beta source that delivers a dose of 0.1 Gy · s^{-1} to the samples. A blue-LED (470±30nm) array was used as a stimulation light source and this transmits a power density of about 50mW · cm^{-2}. A green long pass GG-420 filter was used in front of the blue-LEDs, and the photon detection was through 7.5 mm Hoya U-340 filter.

In order to determine the equivalent dose of the samples, the Single-Aliquot Regenerative dose (SAR) protocol (Murray and Wintle, 2002, 2003) was implemented.

As indicated in several recent works on very young samples (Ballarini et al., 2003), it has frequently been the case that, when conducting the preheating treatment using the conventional SAR protocol, significant thermal transfer of electrons occurs from shallow light insensitive traps to OSL traps. Therefore, as a precaution, 36 aliquots of each sample were used to investigate the thermal transfer effect in the preheat range 180°C to 280°C (20°C intervals and 6 aliquots for each preheat temperature). Only those aliquots that showed no dependency on preheat temperature were chosen for D_e estimation and further statistical analysis.

Increasing D_e with preheat temperature (240°C~280°C) was only noticed in Sample SH06. Samples SH01 and SH04 displayed no significant thermal transfer effect on D_e.

(2) Dose Rate Determination

The luminescence energy that accumulates in the mineral grains usually emanates from decaying radionuclides of naturally occurring elements such as potassium (^{40}K), uranium (^{238}U), thorium (^{232}Th) and rubidium (^{87}Rb). Cosmic rays also contribute a smaller but notable fraction. In this study, the dose rates were obtained by measuring the radionuclide concentrations of the sediments using a low-level high resolution gamma spectrometer installed at the Korea Basic Science Institute. The data suggested by Olley et al. (1996) were applied in order to convert the radionuclide concentrations to dose rates. The dose rate was adjusted on the basis of the present water content as well as the saturated water content using the attenuation factor given by Zimmerman (1971). Contribution of cosmic rays to the dose rate was assumed to be 0.13Gy/ka, which is the usual value applied to the sample when the depth from the surface, geographic latitude and longitude of the sampling position are not known with precision.

(3) Results

Sample SH01 which was collected from the lower part of the dune profile, 3.5 m below the dune summit, yielded an age of 445 + 15 years. If we were to assume saturated water content, the calculated dose rate would be lower (2.25±0.06 mGy/Yr) and, thus, the age of the sample would be older at 587 + 20 yr. Sample SH04 from 1.5 m below the dune summit yielded an age of ca. 398 years (or 520 years, assuming saturated water content).

The uppermost sample was collected from 1 m below the surface and yielded an age of 28 + 1 yr (or

37 years if saturated).

5. Discussion

Using the classification scheme suggested by Hesp (1988), the dune system at the study site is around developmental stage 3. This is evidenced by fact that the studied dune experienced some vertical growth over the past 30 years. In addition, the development of blowouts is indicative of sediment transport landward, away from the coast .

The luminescence chronologies demonstrate that the lower part of the dune was deposited about 500-600 years ago. The sample from the middle part of the dune profile was dated at about 400-500 years. Since the two bottom samples are separated by about 1.5m, a net depositional rate of about 2-3 cm per year can be calculated for the lower part of the dune. For coastal depositional environments, this sedimentation rate is very low. Investigators working on coastal dunes on the Dutch coast (Arens, 1996) have reported depositional rates in excess of 40 cm over a period of less than six months. It should be noted, however, that the net depositional rate may include periods of both erosion and deposition. Thus, the rate is not a direct reflection of processes occurring at any one time.

The age of about 30 yrs that was obtained from the uppermost sample suggests that there was a chronological break in deposition. It is plausible that the age represents a more recent period of reworking or deposition that is distinct from the main event during which the lower part of the dune was emplaced. The lower part of the dune has remained undisturbed since about 400-500 years ago.

Since only one dune structure has been dated from the *Shindu* dunefield, it is not yet possible to give an approximate age for all the dunes that exist in the area. It is plausible to assume that the dunefield was probably established during the early part of the Holocene. However, the ages obtained from the dune dated in this study show that some of the dune structures are younger than 1000 years. The location of the dated dune and current sand mobilization in other parts of the dunefield may lead one to speculate that more dunes of comparative age exist the study area. This view can only be proven by additional dating work at a much larger scale.

6. Conclusions

This exploratory study has successfully demonstrated that luminescence dating can be used to provide reliable age estimates for depositional processes in the *Shindu* dunefied. The sand deposits in this region comprise predominantly quartz whose sedimentological properties are consistent with those of most sandy beach deposits. Additional dating exercises need to be carried out to establish the depositional chronologies of other dune structures in the area. Samples should also be obtained from the red tinted sands that lie lower in the stratigraphy so that absolute age estimates from these deposits can also be determined using luminescence dating methods. These studies will contribute immensely to the efforts that are being made to establish the environmental dynamics of the coastal regions of *T'aean.*

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