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Tuff Cones and Tuff Rings, and Their Stratigraphic Relationships on the Western Side of Cheju Island, Korea

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ABSTRACT: There are several tuff cones and tuff rings, now only apparent on the western shoreline in Cheju Island. The observation of their landform, bedform, particle size and sorting reveals that these deposits are mainly emplaced by base surges and/or slurries originating from Surtseyan eruption which is attributed to explosive hydrovolcanism influenced by interaction of magma with external water. These are subdivided into two groups based on the plateau basalt. It is recognized that the distal limb of early tuff cones and ring at Dangsanbong, Dansan, Sanbangsan and Hwasun (lower group) are overlain by plateau basalt, on which later tuff rigns at Suwolbong and Songaksan(upper group) further extend the distal limb from each vent. The tuff cones and tuff rings are closely associated with the evidences which shelly fragments are comprised within them, and reworked tuffs, raised beach deposits, Sinyangri formation and littoral cones are deposited around them. The evidences suggest that the Surtseyan eruption resulted from direct or indirect interaction of magma with sea water.

INTRODUCTION

Cheju Island, some 90 km off the south coast of the Korean mainland, is a symmetrical shield volcano of elliptical shape, c. 80x40km, covers an area of c.1800 km^2. It comprises an extensive early-stage shield of alkaline olivine basalt flows and less voluminous hawaiite-trachyte flows about the summit (Mt. Halla) of a central volcano, which rises to a height of 1950 m O.D. and dominates the landscape. The volcano lies within the Circum Japan Sea Alkali Province (Won, 1976; Lee, 1982) and is sited on granitic basement (Lee, 1982). These volcanic centers are isolated, mostly distributed along active deep continental faults, and were erupted through continental lithosphere (Zhou and Armstrong, 1982).

The early evolution of the island is poorly understood. Lee(1982) considered a 'primitive island', < 100 m O.D., possibly formed above the granitic basement and that this island was overlain by volcaniclastic sediments (Seogwipo formation). The latter are only locally exposed on the S coast of the island and contain a late Pliocene marine fauna (Kim, 1972). The main island was constructed during Pleistocene times and the last eruptive activity occurred in 1007 A.D. (Lee, 1982). Explosive volcanic activity formed but a minor part of the island's evolution. Even though Lee (1982) estimated that c. 360 parasitic pyroclastic cones occurred on the flanks of the volcano, the volume of their erupted material is almost insignificant when compared to the volume of effusive basalt. However these cones may be an important factor in interpreting the evolution of the island.

The majority of the cones lie high on the flanks of the volcano, particularly in a zone along the long axis of the island, while others are clearly related to the coastal strip. The majority on the flanks of the volcano are cinder cones, typical of Strombolian eruptions, whereas those in the coastal strip are tuff rings and cones, characteristic of Surtseyan activity (Wohletz, 1983; Cas and Wright, 1987). The distribution and form of the latter on the east side of the island was the subject of a previous paper (Kim et al., 1986a,b). This report describes the distribution, landform and stratigraphic relationships of those on the west side of the island (Fig. 1).

TUFF CONES AND TUFF RINGS

Tuff cones and tuff rings are constructed from preatomagmatic activities which have taken place in the sea or a lake, or by contact with ground water. There is a tendency to associate specific magma compositions with two types of such eruptions, based on the compositions of the

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type example used to define the terms originally (basaltic for Surtseyan eruption, rhyolitic for phreatoplinian eruption) (Fisher & Schmincke, 1984; Cas & Wright, 1987). On the western side of the Cheju - do, the constructional forms of tuff cones and tuff rings are largely built up from the deposits of base surges and minor thin ash-falls, which result from Surtseyan eruption. Tuff rings and tuff cones, in addition cinder cones are differentiated by their landform, in particular their weight to width ratios, and their internal geometry and bedforms. Tuff rings have the lowest weight to width ratios of 1:10 to 1:30, tuff cones relatively greater ratios of 1: 9 to 1:11, and cinder cones the greatest ratios of 1:5 to 1:6 from the Fork Rock-Christmas Lake Valley basin, South - Central Oregon(Heiken, 1971). Thick pyroclastic deposits surrounding hydrovolcanic vents range in morphology from steep-sided cinder cones with small apical craters through tuff cones with moderate slopes and much larger craters to tuff rings with very gentle slopes and large craters which extend below the preexisting topographic surface.

According to the data of the volcano studies, tuff rings have thin (less than 50 m) sections of rim beds, small(less than 12°) maximum dips, and most have generally excavated a crater below the existing ground surface. Tuff cones have thick (greater than 100 m) rim deposits, steep (greater than 25°) maximum dips, and craterfloors generally above the preexisting surface (Wohletz & Sheridan, 1983).

On the western side of Cheju-do, the tuff cones and tuff rings are concentrated in the area between Kosanri, Sanbangsan and Mosulpo (Fig. 1). Another ring/cone structure is exposed on Chaguido, a small island to the west of Kosanri. Based on the same plateau basalt as sub-Suwolbong one,morphologically they can be subdivided into two groups:1. Dangsanbong, Dansan, Sanbangsan and Chaguido, and 2. Suwolbong and Songaksan. In addition the form and distribution of littoral cones, and their significance, on the E side of Cheju-do are discussed as Group 3.

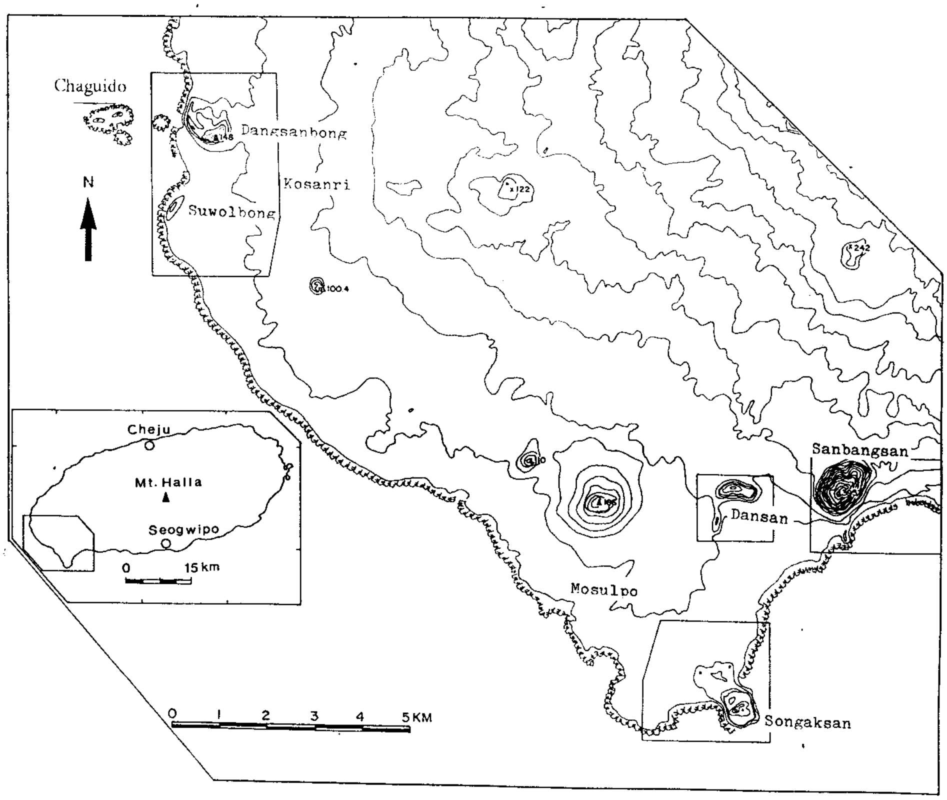

Fig. 1. Index map and topographic map of the western side of Cheju Island with inset showing location of each tuff cone and/or tuff ring.

Group 1

Dangsanbong

Dangsanbon (Fig.1) lies to the N of Kosanri at the western edge of Cheju Island. It has an asymmetric horseshoe form, 1,075 m by 1,125 m, with its open end to the N. From its highest elevation, 148 m O.D. on the southern edge, the rim shallows gradually to 50 m on its W flank and 40 m on its E flank. For much of its length the rim is broadly coincident with the dip reversal and locally to the zone of rim faulting (Fig. 2a). It suggests that the open-ended form was an original feature. In the morphology its form is typically of a tuff cone and bears close comparison with those described on the E side of the island(Kim et al., 1986 b).

Dips on the inner flanks average 20° with maximum 33° , and on the outer flanks average 25° with maximum 40° recorded. Within the tuff cone a late stage cinder cone lies in the crater depression. The cinder cone was breached by basalt effusion which ponded against the inner wall of the tuff cone on its S side and escaped northwards through its open end(Fig. 2a).

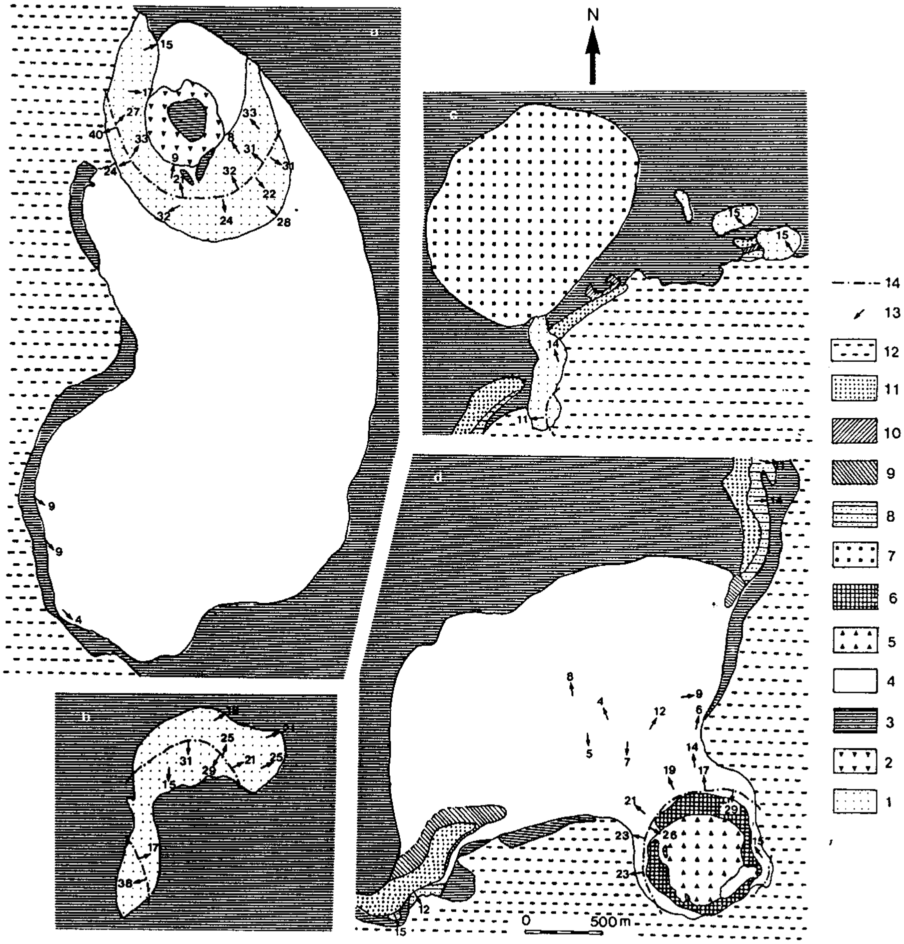

Fig. 2. Geologic map of Dangsanbong tuff cone and Suwolbong tuff ring(a), Dannsan tuff cone and ring (b), Sanbangsan tuff cone and Hwasun tuff complex (c) and Songaksan tuff ring (d). 1. early tuff cones (and ring) (lower group); 2, cinder cone at Dangsanbong ; 3. Plateau basalt ; 4. late tuff ring (upper group) ; 5. cinder cone at Songaksan ; 6. hawaiite 7. trachyte dome ; 8. Sinyangri Formation ; 9. reworking tuff ; 10. raised beach deposits ; 11. sand dune ;12. sea ; 13. mean dip ; 14. dip reversal.

The tuff cone bedforms are dominated by massive ill-sorted beds of mixed coarse pebble to mud grade debris. The subangular to angular lithic clasts are dominantly accidental and of variable basaltic compositions although smaller rounded lapilli, c 1 cm in diameter, of vesiculated basaltic glass are probably juvenile components. The finer fraction, of silt to mud grade, is commonly ochreous coloured, palagonitised vitric dust. Clasts are characterisitically coated with the finer fraction indicating that the debris was water-saturated on emplacement. The competency of the beds increases with the greater percentage of the ash grade material.

The subangular to angular lithic block component occurs as isolated blocks within beds of finer grade debris and also in discrete bands. Most of the evidence suggests they were emplaced in flows although rare instances of ballistic emplacement have been recorded. Bedding is generally well developed in the tuff cone although on close examination bedding plane surfaces are farely well defined.

The thicker beds, up to 1.2 m, are mainly confined to the cone flanks and show crude internal planar stratification picked out by impersistent trains of lapilli and clasts. Plane parallel beds are generally thinner, < 4 cm, and more uniform in grade. Locally such beds have associated low-angle cross-lamination and shallow channels and such features are more commonly observed at the distal end of the western limb.

The form of the tuff cone and the character of the component beds suggest that its construction was dominated by wet surges or slurries caused by access of water to the vent area. Such surges were interspersed with drier surges and some ballistic fallout. When water access to the vent was cut off, Strombolian eruptions were initiated and the central cinder cone was constructed. The last phase was of basalt effusion which in part breached the cinder cone and flows escaped through the open northern end of the tuff cone.

In the cove near Kosanri the eroded outer limb of Dangsanbong tuff cone is exposed in the current sea cliff. Here an older sea cliff in the outer limb is exposed (Fig.3a) with an embankment of coarse block scree comprised of blocks of the tuff cone beds. The scree overlies an old beach sand, c. 2 m above current high tide mark which in turn overlies a basalt flow (Fig.3a;Fig.4).

The latter can be traced along the shoreline, its top at c. high tide mark, from here to Sanbangsan and it underlies both Suwolbong and Songaksan tuff rings (see below). In the cove at Kosanri the top of the scree deposit is overlain by a bed of grey clay, < 2 m thick, which wedges out against it (Fig. 4), and this in turn is overlain by a wedge of tuffs of the Suwolbong tuff ring to the S. On this evidence the construction of the Dangsanbong tuff cone predates the sub-Suwolbong basalt(plateau basalt).

Dansan

The Dansan tuff cone and ring lie about 2 km from the present coastline (Fig.1). Only northern half of the Dansan cone, and an even smaller sector of the Dansan ring, are preserved(Fig.2b). Two sectors of the closely interrelated tuff cone and tuff ring developed from different centers, based on the evidences of respectively bearing its circular dip reversal zone and having its inner and outer slopes (Fig.2b), and direction of ballistic trajectories. The tuff cone rises about 133 m from its base, and the diameter of the original structure was about 350 m calculated from reconstruction of circular dip reversal zone. The smaller sector of tuff ring suggests a structure with a diameter of about 450 m but a height of only about 35 m above the surrounding basalt plateau. Both structures at Dansan are surrounded by younger basalt plateau(Fig.2b). The contact between the northern outer limb of tuff ring and the southwestern inner part of tuff cone indicates that the tuffs of the ring abutted against and overlapped a small cliff line in the cone indicating that the tuff ring is later than the cone.

Sanbangsan and Hwasun

These tuff cones lie respectively to the south and southeast of the Sanbangsan trachyte dome (Fig.2c). Both structures have suffered extensive marine erosion. However a well preserved sector of the Sanbangsna tuff cone (Fig.2c) remains and a cone complex at Hwasun is recognised in small exposures through a raised beach deposit and associated blown sand dune (Fig.2c).

The bedforms and bed constituents of both localities are closely similar to those of the Dangsanbong and Dansan structures. The cliff section and coastal path around the Sanbangsan promontory affords excellent sections of the bed forms, including bands with well developed dune bedding. Also, low in the structure, well exposed bedding planes display shallow channels generally <1 m deep and <1.5 m across, but locally up to 1.5 m deep and 4 m across. The channels are commonly coated with a thin layer (< 3 cm) of fine ash and infilled with a slurry deposit of massive ill-sorted coarse and fine debris.

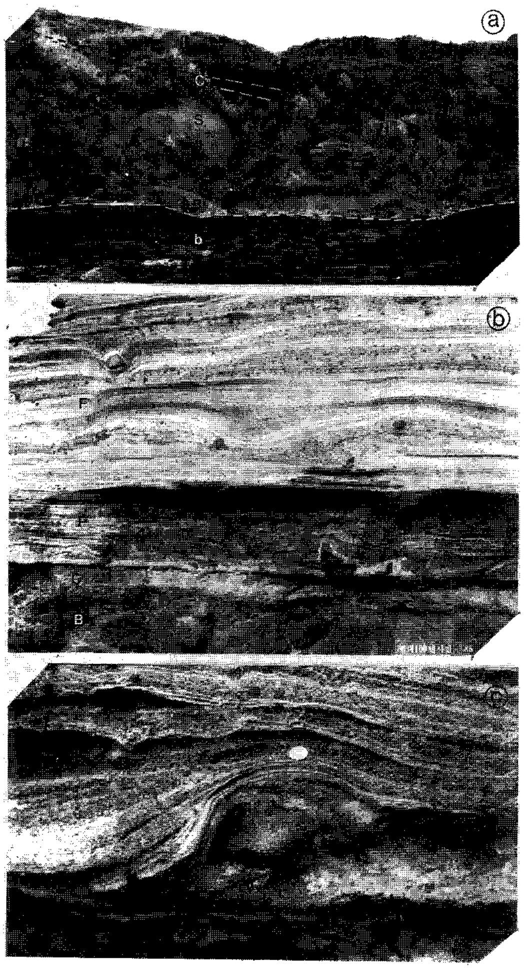

Fig. 3. (a) Scree deposits(S), comprised of blocks of Dangsanbong tuff cone beds, which overlies an old beach sandstone (B) which overlies plateau basalt(b). The scree deposits are overlain by clay bed (C) which in turn is overlain by a wedge of the Suwolbong tuff ring(ST).(b) Clay bed (paleosol) (C),which is overlain in turn by planar beds(P) and flaggy beds(F) characterized by prominent bomb-sag and U-shape channel, mantle the underlying plateau basalt(B) .(c) A big block plastered with the base surge deposits moved from left (NW) to right(SE) at the base of southern sector of Suwolbong tuff ring.

Most distinctive in this well exposed section are the many good examples of faults which developed contemporaneously with the tuff cone construction. These faults increase in frequency towards the zone of dip reversal and conjugate sets are particularly well developed. The narrow zones (< 20 cm) along the faults, in which the adjacent bedding is obliterated, and their impersistence indicate that the faults developed while the beds were unconsolidated.

The relationship of the Sanbangsan tuff cone to the Sanbangsan trachyte dome is well exposed in the roadside section of the S trachyte dome. Scree composed of large trachyte blocks overlies an irregular bed of fine grey ash, up to 5 m thick which in turn overlies beds of the tuff cone. The scree is clearly related to the trachyte dome and consequently the dome postdates the tuff cone. The fine grey ash is considered to reflect an early explosive eruptive phase from the vent subsequently used by the extrusion of the steep-sided trachyte dome.

At the W edge of the Sanbangsan tuff cone the edge of the outward dipping flank is overlain by the sub-Suwolbong basalt, and thus, as in the case of Dangsanbong (see above), its construction predates the basalt flow.

Group 2

Suwolbong

Suwolbong is the eastern sector remnant of a large tuff ring whose vent lay to the west of the current coastline (Fig.1). The sector lies mainly to the village of Kosanri. It is well exposed in a continuous sea cliff section. The sector is 2,500 m long and 600 m wide (Fig.2a) and its highest elevation is 78 m O.D.

The sector comprises well bedded basaltic tuffs which dip at <10°. The tuffs are dominated by the planar bedded and sandwave facies of Wohletz and Sheridan (1979) and are typical of pyroclastic surge deposits (Fig.3b,c). Beds thin gradually and systematically from the thickest section, coincident with a reduction of maximum grain size Ballistic blocks comprise a distinctive component of the sequence, some isolated and elsewhere concentrated in layers and bands. A thin bed <10 m of Strombolian fallout ash has been determined high in the sequence and also as a thin cover to the main accumulation of tuff ring beds.

The beds comprise variable proportions of ash, lapilli and blocks. The ash and lapilli generally represent juvenile debris whereas most of the blocks are accidental. The most distinctive and common lapilli are <1 cm, rounded and composed of finely vesiculated basaltic glass. Less common are equant lapilli size non-vesiculated basalt fragments. Similarly blocks are dominantly of basalt composition although texturally variable. The most distinctive accidental fragments are volcaniclastic sandstones, mudstones and shell fragments.

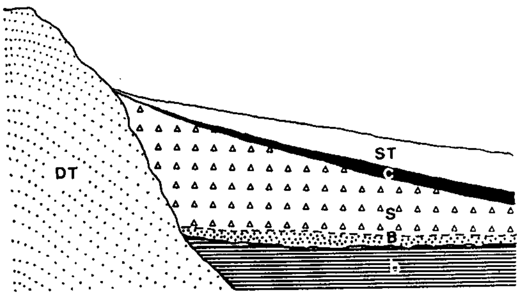

Fig. 4. Diagrammatic section showing the relationship of the Dangsanbong tuff cone to plateau basalt and Suwolbong tuff ring in the cove of Kosanri. DT, Dangsanbong tuff cone ; b, plateau basalt ; B, beach sandstone ; S, scree deposits ; C, clay bed ; ST, Suwolbong tuff ring.

The bedforms and their lateral variation of the sector have recently been studied in detail by Sohn & Chough(1989). The construction of the tuff ring was interpreted to be dominated by dry base surge deposition and the facies variations were related to variable explosivity in the vent and transport. The main accumulation was by relatively dilute and dry surges(Sohn & Chough, 1989).

The centre of the tuff ring is postulated to lie c. 1.4 km from highest point of the sector. This postulation was made from the evidence of ballistic trajectories and bed thinning.

For most of its length the tuffs of the sector overlie dark grey-brown clay, 0.5-2 m thick, which mantles the underlying basalt(Fig.3b). The clay contains irregular oxidation bands, and distinctive rings adjacent to the upper surface. The top of the basalt lies close to current high tide mark. However the top of the basalt beneath the clay shows clear evidence of earlier marine reworking. To the southern edge of the sector the clay is deposited about large <1.5 m marine eroded basalt boulders. The thickness of the clay, its relationship to the overlying beds of the tuff ring and to the underlying basalt and the local evidence of contained basalt boulders, together clearly indicate that it is a sedimentary deposit. The most reasonable suggestion is that it represents a tidal flat deposit.

Songaksan

Songaksan lies at the tip of the southwestern promontory of Cheju Island (Fig.1). It comprises a tuff ring with a central Strombolian cinder cone complex (Fig.2d). Marine erosion of the southern outer rim of the tuff ring affords excellent exposures in the sea cliff and although the ring has been completely eroded in places the structures are largely complete.

The tuff ring is symmetric. The rim, 800 m in diameter, is 80 m O.D. at its highest elevation. On its N side the outer limit of the deposits is at least 2 km from the centre of the tuff ring (Fig. 2d). Dip reversals and the ring fault zone coincide with the crest of the tuff ring for much of its length. Dips on the outer flank average 16°, with maximum 28°, and on the inner flank average 28°, with maximum 41° From the western rim the outer flank beds shallow from 28° to <10° over 1.2 km(Fig.2d) and coincidentally the total thickness decreases from 80 m to <1 m. The decrease in total thickness results from decreasing thickness and wedging out of individual beds.

The tuff ring comprises planar and sandwave bedded basaltic tuffs which compare closely (Fig. 5a, b, c) in lithology and bed forms with those at Suwolbong. They are clearly the products of pyroclastic surge. The rim fault zone is well exposed at the western edge of the tuff ring (Fig.2d). The faults are impersistent and their development during construction is indicated by the local plastering of subsequent surge deposits on fault planes which were temporarily exposed. The distal expression of the tuff ring beds are observed to overlie the sub-Suwolbong basalt in the small cliff sections in the bays to the N and W of the tuff ring. The basalt is recognised in the beach closer to the tuff ring, and apparently underlies the latter.

On the W side of the Songaksan tuff ring bedding plane surfaces exposed in the current beach show bird footprints. The preservation of these prints occurs as a result of them being rapidly overlain by subsequent surge beds of the tuff ring. It suggests that at this time their location, 1.2 km away from the eruptive centre, was above the high tide level.

The tuff ring encloses a central Strombolian cinder cone complex(Fig.2d) comprising a large cone with smaller satellite cones about its southern periphery. The large cone is 500 m in outer diameter and 104 m high and was breached by effusive hawaiite in a number of places on its flanks and close to its summit. The hawaiite was apparently contained within the moat between the cinder cone and the inner flank of the tuff ring(Fig.2d). The top surface of the hawaiite within the moat is planar.

In the samll bay in the SE sector, where the tuff ring has apparently been removed by erosion, the moat hawaiite is exposed, up to 35 m hick, in the cliff section. Here surge beds of the inner flank of the tuff ring, up to 3 m thick

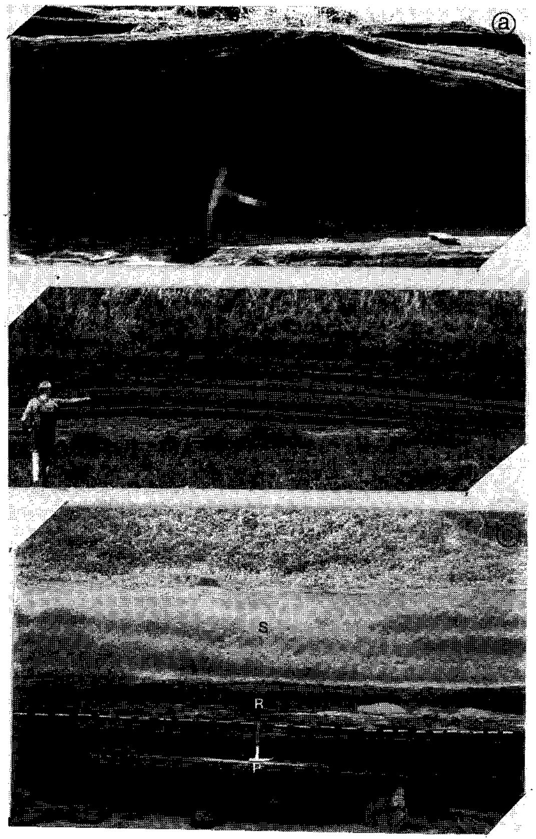

Fig. 5. (a) Close up of a dune along eastern shoreline of the Songaksan tuff ring. Dune built up from planar bed surface. Lower part broad-crested with very low angle stoss- and lee-side dips, tend to become steeper ascending to upper part. Current directed from left (W) to right (E). (b) Planar beds show slightly antiform, reflecting the underlying topography. (c) Reworked tuffs (50 cm) (R), overlain by sand dune(S), overlie planar beds (130 cm) (P) in the western edge of distal limb of the Songaksan tuff ring.

younger plateau basalt. In the cove near Kosanri overlie the hawaiite. Such a relationship would suggest the these beds postdated the hawaiite. However it would be difficult to conceive that a reversal back to Surtseyan activity after Strombolian activity and quiescent hawaiite effusion would not have entirely demolished the cinder cone complex.

A more reasonable explanation of these relationships would be that the surge beds overlying the hawaiite represent a dislodged raft from the inner wall of the tuff ring. Such a displacement would be facilitated 1. by pressure on the tuff ring wall by the accumulation of hawaiite in the moat, 2. the deeper conduits of the ascending magma extended into the ring fault fracture system at depth with this movement being transmitted along the faults to the surface and causing instability and possibly 3. breaching of the tuff ring wall with the escape of the hawaiite lowering the level of the moat and dislodging the raft of the tuff ring wall.

Such an interpretation is supported by evidence of a higher stand of the moat hawiite in the vicinity and a possible lava tube aligned radially in the hawiite exposed in the cliff section.

On the N to NW sides of the Songaksan tuff ring the surge deposits mantle the irregular topography of an earlier cinder cone complex. Shallow excavations (< 3 m) across this surface expose only planar bedded surge deposits with possibly some thin fallout ash beds. However two deeper excavations vertically expose coarse Strombolian deposits of blocks and scoriae.

Similarly the distal surge deposits of the Songaksan tuff ring overlie a coarse boulder beach deposit, about 2 m above current high tide level, in the small cliff of the bay on the N side of the tuff ring.

Group 3

Littoral cone

On the E side of Cheju-do, in the vicinity of Sinyangri Peninsula and E of Jimibong littoral conse are commonly distributed in close proximity to the current coastline. Locally these cones are well exposed in small recently eroded cliffs. However the topography of the immediately adjacent ground, behind the shoreline, indicates that they are of more common occurrence.

The cones are up to 100 m in outside diameter and up to 33 m high. Their cores generally comprise oxidised spatter basalt accumulations and commonly small hornitos in a central cavity can be distinguished. In the larger cones basaltic scoriae, crudely bedded, up to 30 m thick accumulated about the central vent. Such cones are particularly well developed at the tip of Sinyangri Peninsula and here the feeder basalt tubes to the cone's development are well exposed in the sea cliffs. In the adjacent basalt reefs there is no indication, such as pillows or hyaloclastites, of subaqueous emplacement. However it is difficult, if not impossible, to explain the cone construction without invoking interaction between a lava tube and water. The extremely restricted distribution of the littoral cones so close to the coastline suggests the water was marine.

The basalt flow is extensively exposed about the peninsula and is commonly overlain, on a marine eroded surface, by the Sinyangri Formation.

RELATIONSHIP OF TUFF RING/CONE TO ASSOCIATED SEDIMENTS

West of Seogwipo in the SW corner of Cheju Island there are three distinct associations of sediments with the tuff ring/cones. An understanding of the nature of this association is important in considering the evolution of the stratigraphy.

Seogwipo Formation

The type locality of this formation lies in the coastal cliff section on the W side of the estuary on the SW side of Seogwipo. It has been previously described by Kim(1972) .To the W of Seogwipo there has been no clear determination of the Seogwipo Formation. The dips in the type section are <10 and generally to the NW, and as a result it is unlikely that the beds of the type section are further exposed in this direction.

What can be interpreted from the type section is that the beds represent a marine volcaniclastic deposit of Upper Pliocene(Kim, 1 972; Kim et al., 1989) and that their thickness, up to 59 m above current high tide level, represents the minimum post-Pliocene uplift.

Sinyangri Formation

The type section of this formation lies on Sinyangri Peninsula near Seongsan on the E edge of Cheju Island. The formation was indentified to be Pleistocene by foraminiferas (Kim, 1969).

The formation comprises coarse volcaniclastic sandstones and conglomerates and locally contains abundant faunas. Its occurrences both on Sinyangri on the E side of the island, and in the bay W of Sanbangsan tuff ring and the W side of the island are identical. It occurs entirely below current high tide level and the beds are concordant with the current shoreline with steep foreset lamination directed seawards.

The state of lithification suggests it is considerably older than consolidated `recent' beach deposits.

However the extremely uniform development of the Sinyangri Formation, and its consistent level across the island (some 80 km), would indicate that there has been no significant net movement of Cheju-do, relative to sea level, since its accumulation.

RAISED BEACH DEPOSITS AND SAND DUNES

On the N side of Songaksan tuff ring the surge beds of the latter overlie raised boulder and shelly beach deposits as on the S side of Suwolbong(see above), c.2 m above current high tide level. Similar unconsolidated beds are locally exposed at the back of the current beach on the W side of the tuff ring. The beach deposits consist of sandstone, siltstone and conglomerate, containing shell and coral etc, deposited about large c. 0.4 -1 m rounded basalt boulders. These demonstrate clear evidence of earlier marine reworking. Both these deposits are overlain by blown sand which apperars to be related to a coastline older than the current coastline(Fig.2c)..In the distal tuff ring deposits on the W side of Songaksan tuff ring an older sea level stand is recognised at an irregular channelled surface overlain by marine reworkded tuff ring beds (Fig. 5c). Further W the evidence of marine reworking, dominated by symmetrical wave ripples, becomes progressively better developed (Fig. 5c). This surface of marine reworking lies c. 1-2 m above current high tide level.

Similar unconsolidated raised beach deposits, associated with 'old' sand dunes partly cover the eroded tuff cone complex at Hwasun. Here pebbly sands up to 6 m thick overlie marine eroded basalt. The raised beach deposit lies entirely above the present-day beach, between c. 3 m to 9 m above current high tide level.

DISCUSSION AND CONCLUSION

Tuff rings and tuff cones are small volcanoes produced by the explosive eruption resulting from the interaction of mamga with external water (Sheridan & Wohletz, 1981, 1983; Wohletz & Sheridan, 1983; Kokelaar, 1986; Wohletz, 1986) These are mainly emplaced by pyroclastic surge originating from hydromagmatic (Surtseyan) eruption (Waters & Fisher, 1971; Fisher, 1979; Cas & Wright, 1987). These tuff rings and tuff cones can be subdivided into two groups: Dangsanbong, Dansan and Sanbangsan, lower group; Suwolbong and Songaksan, upper group, based on the plateau basalt in the W side of Cheju - do.

The outer limbs at Dangsanbong, Dansan, Sanbangsan and Hwasun are overlain by the

the eroded outer limb of Dangsanbong tuff cone is overlain by the similar basalt above low tide mark. The basalt can be traced along the shoreline, its top at high tide mark from here through Songaksan to Sanbangsan and it underlies both Suwolbong and Songaksan tuff rings of which the distal limb extend further from the vent. On this evidence Dangsanbong tuff cone, Dansan tuff cone and ring, Sanbangsan tuff cone and Hwasun tuff complex predate the plateau basalt which postdate both Suwolbong tuff ring and Songksan tuff ring.

The distributions of the hydrovolcanic tuff rings and cones close to the W and E coastlines of Cheju-do argues strongly in favour for the water which affected their eruption being marine. Even the structures which are furthest from the current coastline, viz. Dansan and Dusanbong, 2 km and 1.2 km respectively, can be projected to current sea level (Fig. 1) with their resultant profile being closely comparable to Ilchulbong and Dangsanbong. Also at both Dansan and Dusanbong the form of the outer flanks strongly suggests they have been subjected to marine erosion.

Further evidence to support the tuff ring/cone development being the result of a marine or a closely marine setting, is shown in 1. the marine reworking of the distal edge of Songaksan tuff ring, 2. the ancient sea cliff exposed in the current cliff in Dangsanbong, 3. the close association of the tuff ring and cones with raised beach deposits and old sand dunes, 4. marine faunas in the tuff ring deposits and 5. the close association of all the tuff ring and cones with the basaltic marine sandstones and conglomerates, locally with rich shelly faunas, of the Sinyangri Formation.

Thus the evidence from the tuff ring and cones suggests that the sea level at the time of their construction was closely similar if not identical to its current position. A similar conclusion is drawn from the evidence of the littoral cones, developed from basalt flows, which are tightly restricted to the current shoreline on the E of the island. These basalt flows are overlain by, and thus perdate, the Sinyangri Formation.

A direct association of tuff ring and cones with the Seogwipo Formation is not recognised. That this should be the case is probably to a large extent the result of the extremely restricted outcrop of the formation, to the vicinity of Seogwipo, at the centre of the S coast of Cheju-do. The supposed determination of the formation in boreholes N and E of Mosulpo is probably erroneous - it is more likely that these deposits are simply tuff cone beds or tuff ring beds locally reworked. The evidence of the Seōgwipo Formation in its type section indicates uplift of at least 60 m since its accumulation.

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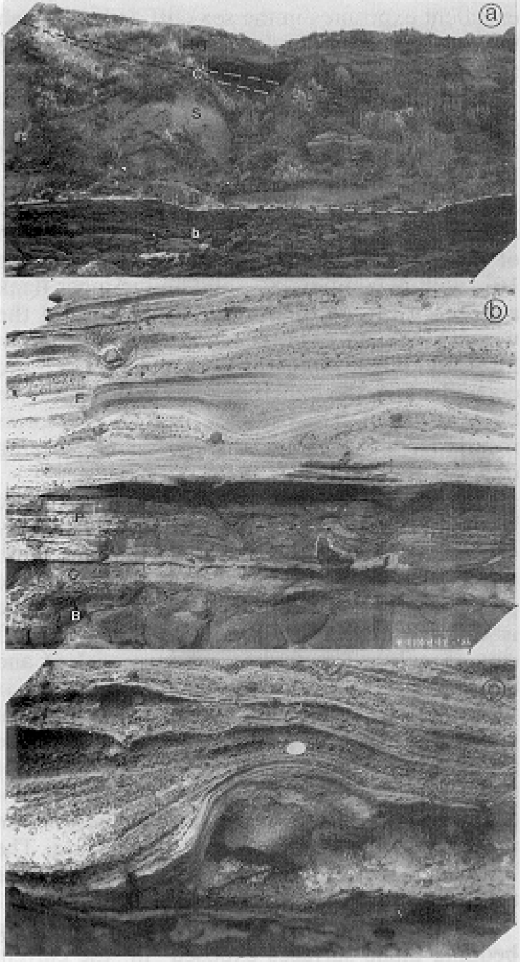
濟州道 西部의 凝灰丘 및 凝灰環 과 이들의 層序 關係

黃尙九 · 黃載河 · 金東鶴 · M.F. Howells

요 약: 濟州道 西部 海岸地帶에는 여러개의 凝灰丘와 凝灰環이 分布한다. 이들은 landform, bedform, 粒度와 分級 등에 의하면 마그마에 外部물이 流入 되므로서 써쩨이언분출을 할때 發生하는 基底써지와/ 혹은 슬러리로부터 퇴적된 產物이며, 周圍의 臺地狀 玄武岩을 기준하여 先後期의 2개의 群으로 나뉘어진다. 唐山峰, 簞山,山房山과 和順의 것들은 이들의 distal limb 이 臺地狀 玄武岩에 덮혀 있어 先期임이 명확하며, 반면 水月峰과 松岳山 凝灰環 은 玄武岩臺地 위에서 이의 distal limb 이 수 km 뻗쳐 있어 後期임이 명확하다. 또한 凝灰丘 및 凝灰環 은 그 內部에 海棲貝을 함유하며, 그 周圍에 再移動 凝灰岩, 牽引海濱堆積層과 新陽里層이 퇴적되어 있고 沿岸丘가 형성되어 있는 등의 證拳들에 의하면 海水가 써쩨이언분출에 直間接으로 流入되었음을 시사한다.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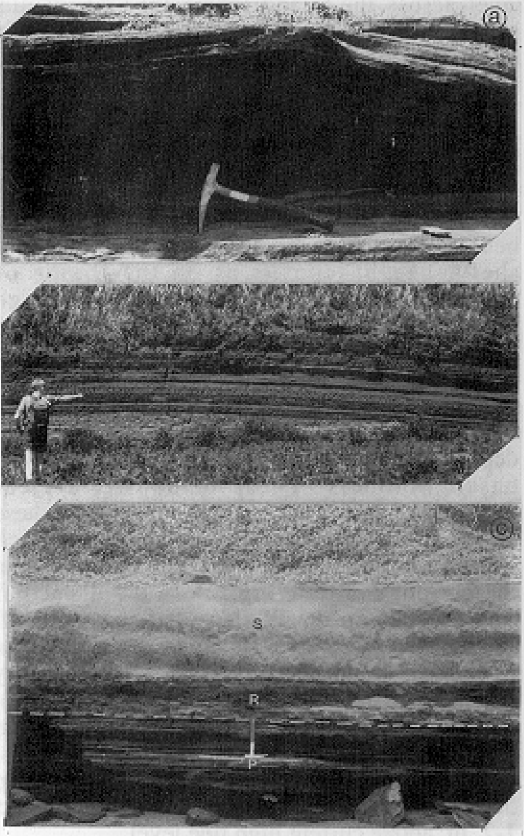
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