The Eocene Volcaniclastic Sejong Formation, Barton Peninsula, King George Island, Antarctica: Evolving Arc Volcanism from Precursory Fire Fountaining to Vulcanian Eruptions

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Abstract. The Sejong Formation (100–200 m thick) represents a newly recognized Eocene volcaniclastic unit in Barton Peninsula, King George Island, West Antarctica. Detailed field mapping and lithofacies analysis indicate that the formation can be subdivided into three distinct facies associations (FA): (1) spatter/cinder-cone association (FA I), (2) volcaniclastic-apron association (FA II), and (3) distal-apron association (FA III). FA I, occurring at the base of the formation, comprises massive and jointed basalt lavas, which pass laterally into basaltic agglomerates and agglutinates through a transitional zone of fractured basalt lava flows. These field relations suggest fire-fountaining (Hawaiian) to Strombolian eruptions and subsequent emplacement of "ponded" lavas filling the vents of small-scale spatter/cinder cones at the precursory phase of arc volcanism in Barton Peninsula. FA II, unconformably overlying FA I, is represented by very thick, tabular beds of basaltic to andesitic, welded to non-welded, tuff breccias and lapilli tuffs, emplaced by pyroclastic flows (largely block-and-ash flows), with rare intervening andesite lava flows. FA II indicates onset of the main-phase of explosive and effusive eruptions (Vulcanian), probably associated with repetitive extrusions and collapses of lava domes at the summit crater of a stratovolcano, and thereby formation of large volcaniclastic aprons. The changes in eruption styles probably resulted from generation of more evolved (intermediate) magma, possibly due to compositional differentiation of the parental magma, and interaction of the magma with groundwater. FA III is intercalated with FA II as thin lenses and is characterized by fluvial red sandstone/siltstone couplets, locally alternating with channelized mass-flow conglomerates. FA III represents active hydrologic remobilizations during inter-eruptive periods and thereby development of ephemeral streams and floodplains in lowlands on and beyond the distal volcaniclastic aprons. These eruptive and depositional processes indicate a full emergence (subaerial setting) of the King George Island during the Eocene.

Introduction

The volcanic succession in Barton Peninsula, King George Island, Antarctica (Fig. 5.7-1), has been regarded as an early-stage stratiform complex formed in a volcanic-arc setting (Barton 1965; Birkenmajer 1980; Smellie et al. 1984). It consists of a lower volcaniclastic succession (the Sejong Formation, 100–200 m thick) and an upper succession (ca. 200–300 m thick) of basaltic-andesite lava flows, with an intervening succession of lava/tuff alternations (Fig. 5.7-2; Tokarski 1988; Jin et al. 1991; Birkenmajer 1998; Lee et al. 2002). Plant leaf fossils indicate deposition of the Sejong Formation during the Late Paleocene to Eocene under warm climatic conditions (Tokarski et al. 1987; Chun et al. 1994). Radiometric ages of the lavas indicate more specifically an Eocene age (Jwa et al. 1992; Willan and Armstrong 2002). Numerous previous studies of Barton Peninsula have centered on the hydrothermal history, chemistry, geochronology, palaeofloras and structure (see Willan and Armstrong 2002 for summary), with few studies addressing stratigraphic variations, styles of volcanism, or depositional processes (Yoo et al. 2001). This study focuses on the Sejong Formation and attempts to reconstruct the early volcano-sedimentary evolution, based on detailed lithofacies analysis and field mapping. A revision of the stratigraphy is proposed; the basaltic rocks that were previously attributed to late-stage intrusions (dikes or plugs; Tokarski 1988; Birkenmajer 1998) are reassessed as lava/agglomerate complexes at the base of the Sejong Formation and are designated as the Chottae Member.

Lithofacies and Facies Associations

Based on composition, texture (coherent *versus* clastic) and grain size, ten lithofacies are identified in the Sejong Formation: basaltic lava (lithofacies BL), basaltic agglutinate (BAu), basaltic agglomerate (BAo), basaltic tuff breccia (BTB), basaltic lapilli tuff (BLT), andesitic lava (AL), andesitic tuff breccia (ATB), andesitic lapilli tuff (ALT), reworked conglomerate (C), and sandstone/siltstone couplets (S/Z) (Table 5.7-1). These rocks can be grouped into three facies associations based on the constituent facies, facies sequences, and their field relationships. Each facies association records formation in distinct eruptive and/or depositional environments: (1) spatter/cinder cones (Facies Association (FA) I), (2) volcaniclastic apron (FA II), and (3) distal apron to floodplain (FA III).

Facies Association I

FA I comprises basaltic rocks that form irregular to semicircular patches in map view (Fig. 5.7-2). These units were

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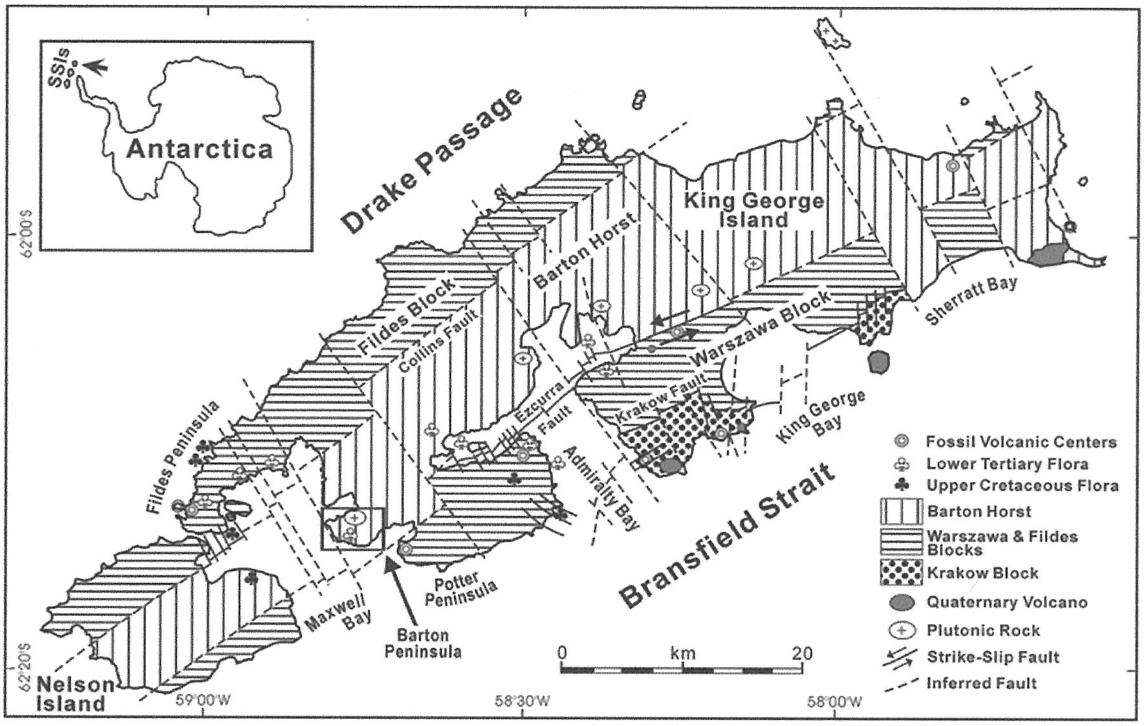

Fig. 5.7-1. Tectonic units of King George Island (redrawn from Birkenmajer 1983). Location of King George Island is given in *inset*. Sites of plutonic rocks and Quaternary volcanoes are based on Barton (1965) and Willan and Armstrong (2002). Study area (Barton Peninsula) is denoted by *arrowed box*. *SSIs:* South Shetland Islands

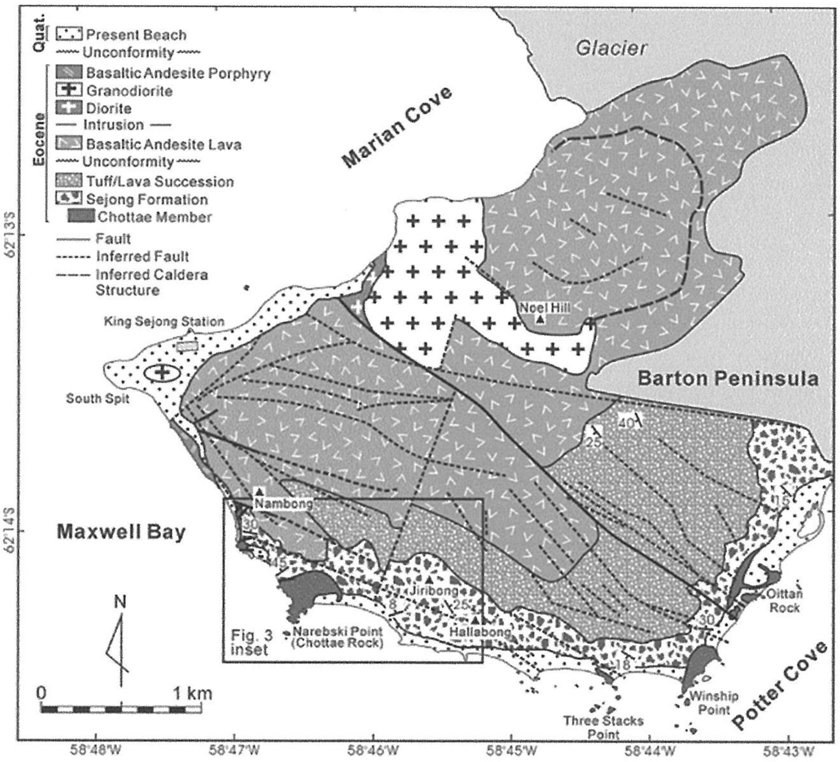

Fig. 5.7-2.
Geological map of Barton Peninsula, modified after Lee et al. (2002) and Willan and Armstrong (2002). Subsurface caldera structure is delineated, based on Armstrong (1995)

Table 5.7-1. Description and interpretation of lithofacies of the Sejong Formation

Lithofacies	Description	Interpretation
Basaltic lava lithofacies BL	Either massive or compound; massive lava is vertically to subhorizontally jointed; compound lava consists of thin (<1 m) units that are slightly vesicular and locally fragmented, either blocky or fluidal	Massive lava: vent plug. Compound lava: lava flows (Hawaiian effusion) and local brecciation.
Basaltic agglutinate lithofacies BAu	Interlayered with basaltic lava flows (lithofacies BL); globular, variably vesiculated bombs and less vesicular, globular to angular lapilli; agglutinated texture with flattened and stretched, highly vesicular basaltic spatters with chilled glassy rims	Transitional between fire-fountain and Strombolian eruptions
Basaltic agglomerate lithofacies BAo	Laterally flanking or interlayered with the basaltic lava flows (lithofacies BL); aerodynamically shaped, incipiently to highly vesicular bombs or plastically deformed, fluidal shaped, dense bombs; coarse-grained lapilli tuff matrix	Strombolian eruption
Basaltic tuff breccia lithofacies BTB	Interlayered with basaltic or andesitic deposits (lithofacies BLT, ATB, or ALT); ungraded and disorganized; clast- or matrix-supported; boulder-size blocks common; dense, angular blocky clasts dominant with subordinate amounts of globular, variably vesiculated clasts with ragged margins; purple fine-grained ash matrix	Block and ash flow
Basaltic lapilli tuff lithofacies BLT	Commonly overlying coarser-grained basaltic deposits (lithofacies BAo or BTB); ungraded (or normally graded) and disorganized; matrix supported; dense, angular blocky clasts with sharp edges predominant; purple fine-grained ash matrix	Scoria and ash flow
Andesitic lava lithofacies AL	Porphyritic texture with microcrystalline groundmass; abrupt lobate termination; intense hyaloclastic brecciation	Intermittent effusive eruptions; stubby flows
Andesitic tuff breccia lithofacies ATB	Near-top normally graded; disorganized; matrix supported; dense, angular blocky clasts with sharp edges and occasionally rugged margins predominant; pumiceous clasts rare; green fine-grained ash matrix	Block and ash flow
Andesitic lapilli tuff lithofacies ALT	Ungraded or normally graded; disorganized; matrix supported; dense, angular blocky clasts dominant; minor subrounded clasts; occasional cobble to boulder-size clasts: commonly welded; occasionally inversely graded strata at the base	Ash flow (partly ground surges)
Reworked conglomerate lithofacies C	Interlayered with lithofacies S/Z units; irregularly or sharply based; inverse-to-normally graded; boulder-size clasts common; rounded clasts dominant with common intraclasts; extremely poorly sorted, red sandy siltstone matrix	Reworked debris flow
Sandstone/siltstone couplets lithofacies S/Z	Overall fining-upward stacking with lower sandstone-dominant to upper siltstone-dominant divisions; interstratified with distributional or abruptly graded sandstone-siltstone layers; broadly and shallowly channelized geometry; occasional scours at the base; common penecontemporaneous deformation (flames and contorted layers); plant leaf fossils and burrows	Floodplain with ephemeral shallow channels

formerly regarded as late-stage intrusions (dikes or plugs) (Tokarski 1988; Birkenmajer 1998; Lee et al. 2002; Willan and Armstrong 2002). The lack of distinctive discordant contacts and thermal metamorphism affecting the adjacent volcaniclastic rocks however does not support a late-stage origin. Moreover, the outermost basaltic agglutinates and agglomerates are generally draped, either unconformably or locally conformably, by the volcaniclastic rocks of FA II (Fig. 5.7-3). Furthermore, the identification of a gradational transition from central massive/vertically jointed lava (lithofacies BL) to fringing agglutinates and agglomerates (lithofacies BAu and BAo) via a transitional zone of locally brecciated, either blocky or fluidally, compound lava flows (lithofacies BL) in this study suggests intact preserved spatter/cinder cones (Fig. 5.7-3). The basaltic rocks of FA I can therefore be designated as a new stratigraphic unit (Chottae member) that occupies the base of the Sejong Formation.

The central coherent basalt in the Chottae member is mostly fresh (moderately altered), forming a distinctive edifice and showing vertical to subhorizontal joints arrayed in a fan-shaped fashion (Fig. 5.7-3, cross sections). This suggests emplacement of the basalt as a ponded lava or a plug, filling the vent (or conduit) of a basaltic volcano. The adjacent piles of compound lava flows dip outward, away from the central massive basalt (Fig. 5.7-3, cross sections). Each flow unit is slightly vesicular, particularly at the top. *in situ* fractured lava occurs locally and comprises either slabby or deformed, flow-foliated clasts, or blocky clasts with curviplanar margins, lacking matrix materials. This suggests autobrecciation of lava flows at transitional rheological conditions between aa and pahoehoe flows. In the outermost part, basaltic agglomerates and agglutinates occur, interlayered with the lava flows. Agglutinates are characterized by flattened and stretched, highly vesicular,

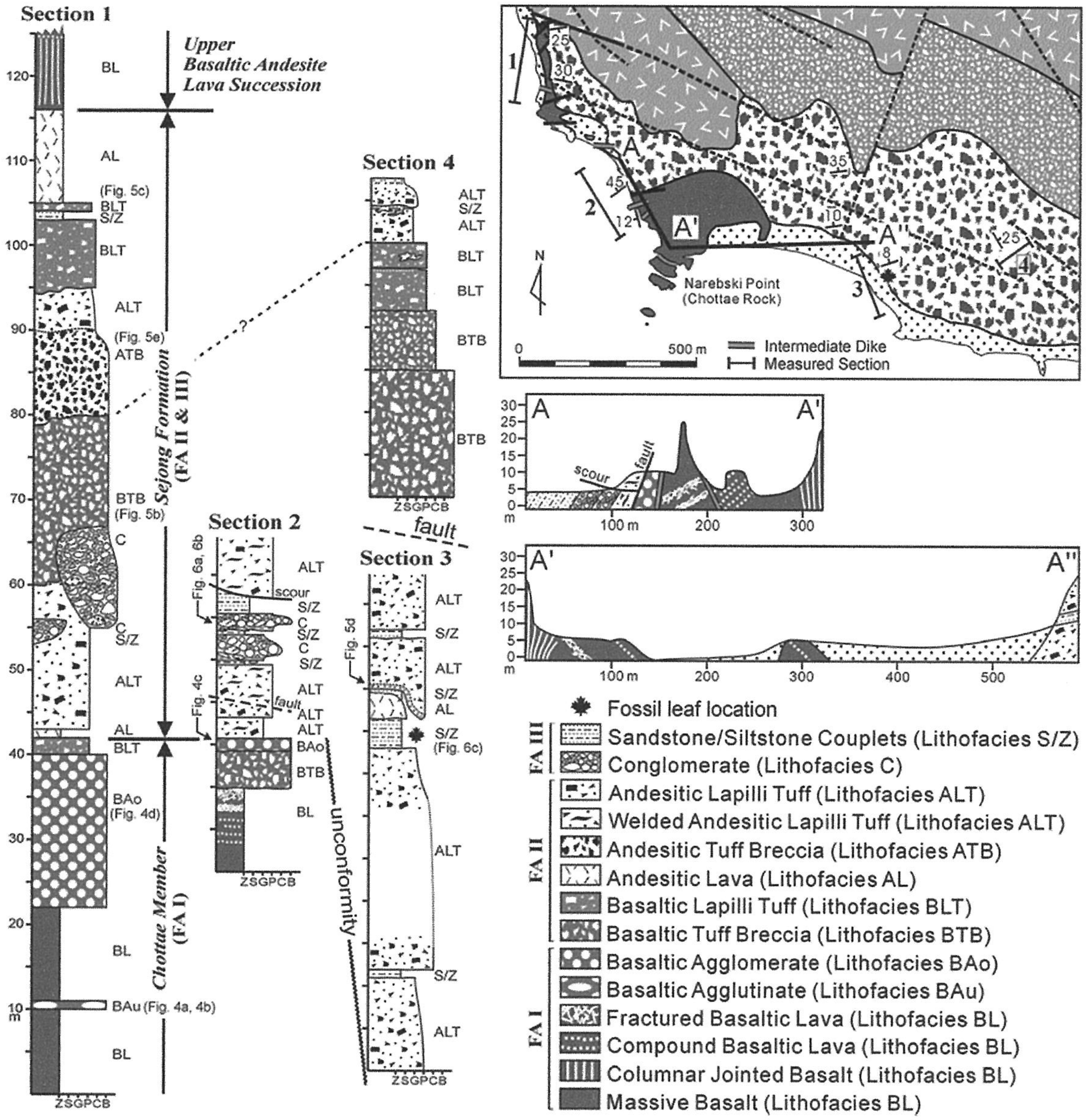

Fig. 5.7-3. Columnar logs and correlation of the Sejong Formation. *Inset map* shows the locations of the measured sections and detailed geological structures in the vicinity (*symbols* as in Fig. 5.7-2)

basaltic spatters with chilled glassy rims between variably vesiculated, either globular or blocky, bombs and lapilli (Fig. 5.7-4a,b), whereas the agglomerates consists mainly of either aerodynamically shaped, vesicular bombs or plastically deformed, fluidal shaped, dense (non- to poorly vesicular) bombs, both set in a coarse-grained lapilli tuff matrix (Fig. 5.7-4c,d). These fabrics indicate ejection of molten lava fragments into the air and subsequent landing in a near-vent area. The sequential transition of lithofacies from ponded lavas, lava flows to agglutinates/agglomerates in FA I suggests Hawaiian fire-fountaining and Strombolian eruptions at basaltic eruptive centers (e.g., spatter or cinder cones) in a subaerial setting and subsequent vent plugging. The lateral persistence of the basaltic agglutinate may indicate a spatter rampart at the initial stage of the eruption. Endogenous dome-like emplacement is unlikely, because there is no evidence of large-scale disruptions or brecciations indicative of mechanical compressions due to succeeding magma pulses.

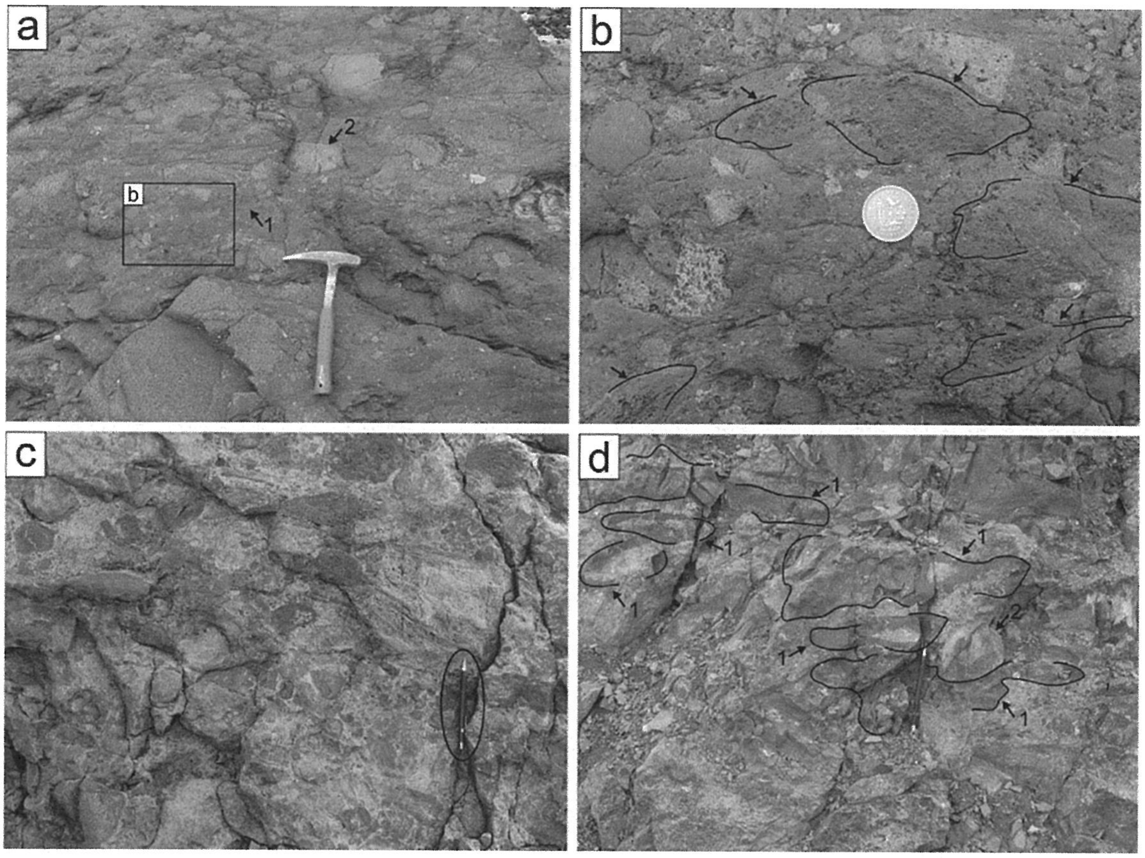

Fig. 5.7-4. Photographs of representative lithofacies of Facies Association I. **a** Basaltic agglutinate (lithofacies BAu) with flattened and stretched spatters (*arrow 1*) aligned subparallel between either globular or blocky, bombs and lapilli (*arrow 2*; *hammer* for scale 32 cm). **b** Close up of **a** spatters (partly *outlined* and *arrowed*) are characteristically highly vesicular in the interior with shiny, glassy chilled rims (*arrows*; *coin* for scale 2.6 cm). **c** Basaltic agglomerate (lithofacies BAo) predominated by variably vesiculated, aerodynamically shaped bombs (*pencil* for scale 14.6 cm). **d** Basaltic agglomerate (lithofacies BAo) with cow-dung-like elongated, locally deformed, dense bombs (*arrow 1*) with variably vesiculated, globular bombs (*arrow 2*; *pencil* for scale 14.6 cm)

Facies Association II

FA II comprises the bulk of the Sejong Formation. It lies unconformably or locally conformably above FA I deposits and is interlayered with the deposits of FA III (Fig. 5.7-3). It consists dominantly of very thick, tabular beds of basaltic to andesitic lapilli tuffs and tuff breccias (lithofacies BLT, BTB, ALT and ATB), and rare intervening lava flows (lithofacies AL). Each volcaniclastic unit is characterized by ungraded (or less commonly normally graded near the top) and disorganized fabrics and is either clast or matrix supported (Fig. 5.7-5). Clasts are dominantly blocky shaped with angular corners and sharp (in places ragged) margins, or less commonly with rounded corners and smooth margins (Fig. 5.7-5). Globular or irregularly shaped clasts are also present but to a subordinate amount (Fig. 5.7-5b). Clasts are mostly dense and non- to poorly vesicular, and are generally free of phenocrysts. Highly vesicular (amygdaloidal), scoriaceous or pumiceous particles are rare. Accidental lithic clasts (altered volcanics, sedimentary rocks and quartz-vein fragments) are locally present (Fig. 5.7-5c). The matrix consists predominantly of vitric materials with a subordinate amount of crystal fragments. Welded texture is common in andesitic lapilli tuffs (lithofacies ALT) (Fig. 5.7-5f). At the bases of some andesitic, cobbly lapilli tuff (lithofacies ALT), thin-bedded granule-size andesitic lapilli tuffs occur that show inversely graded strata (Fig. 5.7-5d), which are reminiscent of the layer 1 or the basal layered deposits in ignimbrites (e.g., Sparks et al. 1973; Valentine et al. 1989). An andesitic lava flow (lithofacies AL) shows an abrupt lobate termination (Fig. 5.7-3, section 3).

The thick-bedded nature, lack of stratification and channel incision, and the ungraded and disorganized fabric collectively indicate emplacements by laminar and/or

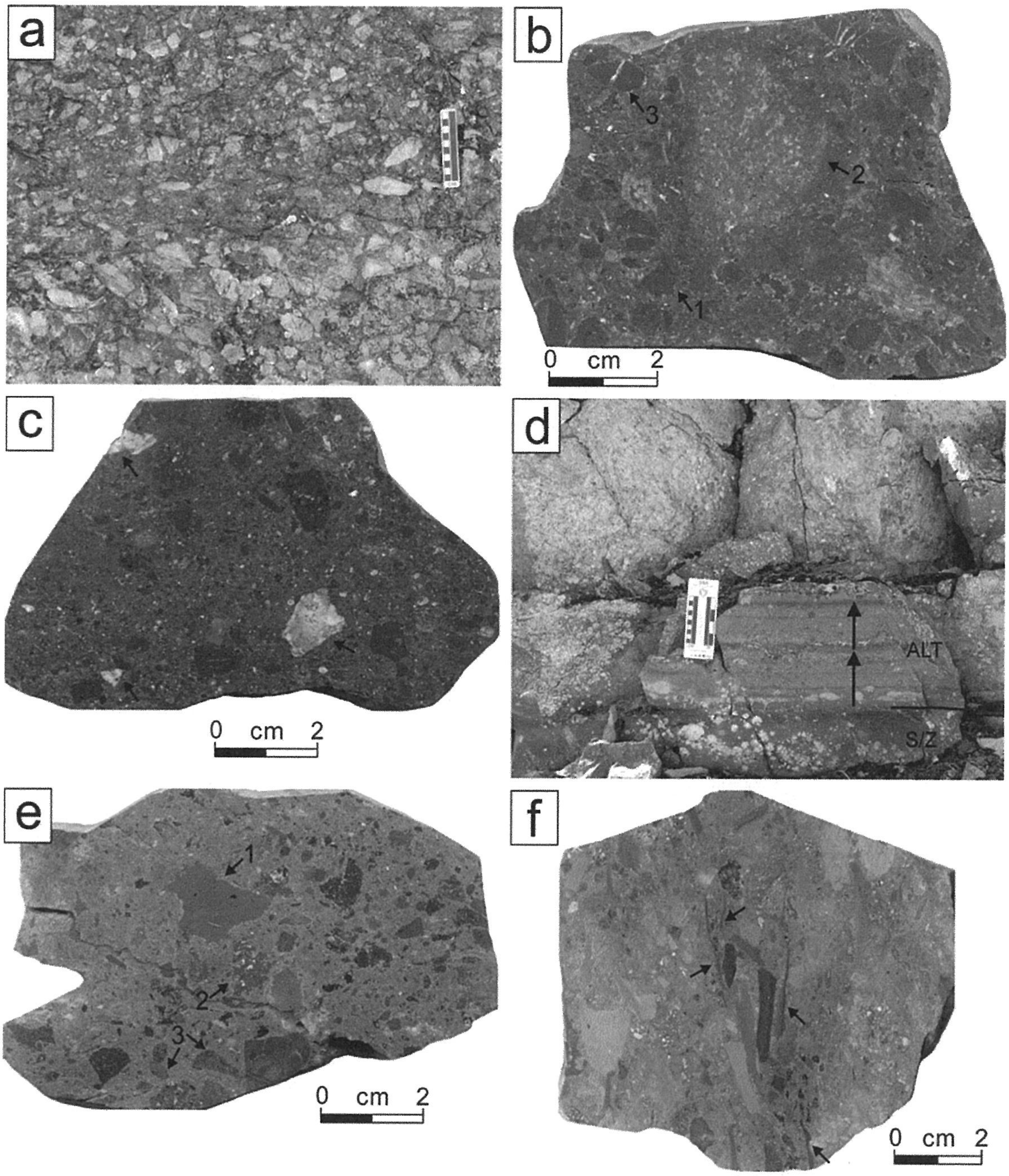

Fig. 5.7-5. Photographs of representative lithofacies of Facies Association II. **a** Basaltic tuff breccia (lithofacies BTB) with clast-supported angular blocks; outcrop near Oittan rock; *scale bar* 10 cm. **b** Slab of basaltic tuff breccia (lithofacies BTB), showing a predominance of dense, non-vesicular, angular blocky clasts occasionally with ragged margins (*arrow 1*); also present vesicular (amygdaloidal), globular shaped clasts with ragged margins (*arrow 2*). *In situ* fragmented clasts (*arrow 3*) separated by tiny quartz veins indicate degassing fracturing or thermal contraction just after deposition. **c** Slab of basaltic lapilli tuff (lithofacies BLT) consisting of dense blocky clasts with minor amounts of accidental lithics of quartz-vein fragments (*arrows*). **d** Andesitic lapilli tuff (lithofacies ALT) with inversely graded strata at the base; *arrows* indicate inverse grading. **e** Slab of andesitic lapilli tuff (lithofacies ALT), showing a predominance of non-vesicular, angular blocky clasts with sharp edges (*arrow 1*); occasional vesicular (amygdaloidal) clasts display highly rugged margins (*arrow 2*); subrounded lapilli (*arrow 3*) suggesting possible "milling" in the eruption centers. **f** Slab of welded andesitic lapilli tuff (lithofacies ALT) with elongate, greenish to dark gray glassy shards; isolated fault block in section 1

plastic flows. The abundance of vitric materials in the matrix, the occasional welded features and the rarity of accidental lithic particles collectively suggest that the deposits are pyroclastic in origin, emplaced most probably by dense pyroclastic flows, rather than being epiclastic or resedimented, as suggested by previous interpretations (Yoo et al. 2001). The predominance of angular blocky, dense clasts, and the large grain size (common boulder-grade clasts) suggest that the pyroclastic flows can be described more appropriately as block-and-ash flows (e.g., Siebe et al. 1993; Carrasco-Nunez 1999), which were generated probably by Vulcanian eruptions (Self et al. 1979; Clarke et al. 2002). The incorporation of globular and/or vesicular clasts as well as dense, angular blocky clasts of diverse lithology suggests an explosive crumbling of lava domes with thick solidified crusts possibly due to a detonation of an ascending magma as a result of interactions with groundwaters (Self et al. 1979; Druitt et al. 2002). The angular blocky clasts can be viewed as cognate lithic particles generated by the fragmentation of the dome crust or chilled margins of ascending magma, whereas the globular clasts were probably formed by disintegration of the hot and plastic interior of the domes or extruding magma. Further gas streaming after the initial explosion may have generated some vesicular juvenile clasts. The appreciable rounding of some blocky clasts with subdued corners and smooth margins can be accounted for by "milling" in the vent by repeated ejection and falling back into the openings.

The virtual lack of ashfall deposits and pedogenic alteration features in FA II suggest rapid accumulation of pyroclastic debris in a near-vent setting. The presence of a probable layer 1 deposit at the bases of some thick ignimbrite units also supports this inference because the runout distance of the most powerful pyroclastic surges hitherto documented only rarely exceeds a few tens of kilometres (e.g., Calder et al. 1999), The FA II deposits are therefore interpreted as slope aprons (volcaniclastic aprons or ring plains) (Palmer and Neal 1991; Siebe et al. 1993), extending from the summit crater of a large stratovolcano.

Facies Association III

FA III occurs as thin lenses or pockets intercalated with FA II deposits (Fig. 5.7-3). It consists mainly of sandstone/siltstone couplets (lithofacies S/Z), locally including resedimented conglomerates (lithofacies C). The sandstone/siltstone couplets are normally graded with a sandstone-dominant base and a mudstone-dominant top, and are commonly inter-stratified with diffuse boundaries (Fig. 5.7-6c). Siltstone layers are mostly homogeneous, red to brown in color and locally bioturbated (vertical burrows). Abundant plant fossils have been found in some

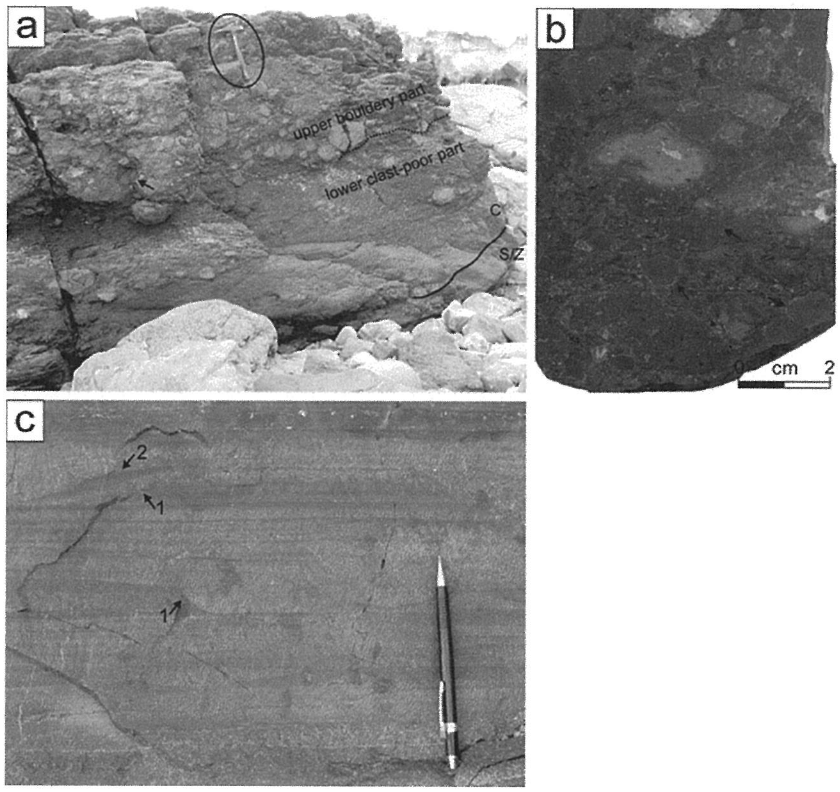

Fig. 5.7-6. Photographs of representative lithofacies of Facies Association III. **a** Reworked conglomerate (lithofacies C), showing an overall inverse grading from a clast-poor lower part to a bouldery, clast-rich upper part; intraclastic siltstone chunks (*arrows*; *hammer* for scale 32 cm). **b** Slab from the upper part of conglomerate in **a**. Note the rounded outlines of each clast, although some with angular corners; common and characteristic incorporation of intraclastic siltstone fragments (*arrows*). **c** Sandstone/siltstone couplets (lithofacies S/Z), showing a thinning- and fining-upward stacking pattern, with scour bases (*arrow 1*) and local incorporation of siltstone rip-up clasts (*arrow 2*; *pencil* for scale 14.6 cm)

layers (Fig. 5.7-3). Sandstone layers are generally thin-bedded with occasional local or broad scours at the base (Fig. 5.7-6c). They are either ungraded or normally graded with an upward increase in silt content. Cross-stratification is relatively rare. The couplets are commonly deformed and distorted with flame structures. Resedimented conglomerates are typically irregularly bedded with protruding clasts. Each unit is inverse-to-normally graded with largest clasts floating in the upper two-thirds. Clasts range in size from pebble to boulder grade; mostly rounded to subangular (Fig. 5.7-6a,b). They consist predominantly of dense basaltic fragments along with some red siltstone chunks. The matrix comprises extremely poorly sorted, red sandy siltstone.

The colour, texture, structure and bedding features of the sandstone/siltstone couplets collectively suggest a predominance of suspension settling from rapidly waning floods. Ephemeral shallow channels are indicated by the scours and rare cross-stratification of sandstone layers. The common deformation structures and the scarce pedogenic features suggest rapid sedimentation due to high flood frequency. The resedimented conglomerates are interpreted as debris flows, based on the prominent inverse grading, irregular bedding and the presence of protruding clasts. Intimate association of debris flow deposits within the flood deposits is indicative of relative proximity to the source area, i.e., hill slope. FA III is therefore interpreted as floodplains developed in low lands extending from the lower reaches of the volcaniclastic aprons of FA II. The floodplains must have developed during inter-eruptive periods by active hydrologic remobilization processes, i.e., precipitation and flash floods.

Discussion

This study recognizes a new unit of discrete massive basalts (FA I deposits) along the southern coast of Barton Peninsula (e.g., Narebski Point) as fossil vent fillings (plugs) of spatter/cinder cones, contrary to the previous interpretations viewing the basalts as late-stage intrusions. The intrusive origin was suggested, mainly based on the lower degree of alteration and the more evolved (sodic) composition of the basalt compared with those of the upper basalt succession (Birkenmajer 1998; Willan and Armstrong 2002). It should, however, be noted that there lies an intervening, 100–200 m thick, volcaniclastic succession (Sejong Formation) that contains abundant andesitic rocks (tuffs and flows) between the two basalt units. Direct comparison of chemistry of the massive basalts of FA I with that of the upper basalt succession is therefore meaningless or misleading, unless isotope or trace element evidence for derivation from a single parent magma is provided. Lower degree of alteration of the former can be accounted for by less hydrothermal alterations due to low permeability of the massive basalt and the distance from the hydrothermal source (Willan and Armstrong 2002). Furthermore, our new finding of the fringing basaltic agglomerates or agglutinates (lithofacies BAu or BAo) around the massive basalts (Fig. 5.7-3) strongly indicates active eruptions through an open vent. Together with this, the unconformable draping by the volcaniclastic deposits of FA II indicates that the basaltic rocks of FA I were formed at the earliest stage of Barton Peninsula volcanism, negating the former interpretation viewing them as latest-stage intrusions. Suffice it to say that the relative timing of stratigraphic units should be established primarily by the contact relations in the field rather than by other geological or geochemical criteria.

The unconformably overlying FA II deposits show marked differences in composition and lithofacies characteristics compared to the underlying FA I deposits. FA I is characterized by near-vent accumulations of basaltic ejecta (spatters and bombs), lacking appreciable matrix materials, whereas FA II is composed of laterally persistent beds, consisting dominantly of angular-blocky, dense (non- to poorly vesicular), basaltic to andesitic clasts set in a fine-grained ash matrix. These variations can be attributed to the changes in eruption styles from the precursory, localized fire-fountaining (Hawaiian) to Strombolian eruptions at small spatter/cinder cones to extensive Vulcanian eruptions, accompanied by explosive dome collapses at the summit vent of a larger volcanic edifice. The main area of the lava domes could be the inferred subsurface caldera structure to the northeast of Noel Hill (Fig. 5.7-2; Armstrong 1995), although dome extrusions could have also occurred at numerous satellite vents. The change in eruption styles and volcano types can be explained by an increase in explosiveness due to compositional differentiation (evolution) of the parental magma along with possible contribution of external water (e.g., groundwater). Table 5.7-2 summarizes the changes in volcanic phases in chronological order.

Although the present study concentrates on a small well-exposed area (Barton Peninsula), the results can give some insights into the stratigraphy and evolving history of the early-Tertiary volcanic succession of King George Island. Despite the huge efforts to establish a stratigraphy of the island over the last two decades (e.g., Birkenmajer 1983; Smellie et al. 1984), there are still poor correlations among the locally identified rock units (formations or groups). We suggest that better correlations can be achieved through grouping genetically related lithofacies, characterizing their responsible eruption styles and identifying fossil volcanic vents before undertaking geochemical correlations or chronostratigraphic classifications by sparse and equivocal radiometric ages. Our work is put forward to be an example to initiate such an

Table 5.7-2. Summary of volcanic phases of the Sejong Formation

Stage	FA	Eruption style	Volcano form	Sourve vent
Stage 2 (50–44 Ma[a])	FA II	Vulcanian: block-and-ash flows, minor scoria flows and ash flows in relation with dome extrusion and collapse	Stratovolcano	Inferred subsurface caldera structure to the northeast of Noel Hill or indefinable satellite vents
Stage 1 (50–44 Ma)	FA I	Fire fountaining and Strombolian: lava effusions and ballistic ejections	Spatter/cinder cones	Nambong coast, Narebskip Point, Winship Point, Three Stacks Point and Oittan Rock

[a] Hitherto obtained radiometric ages of the rocks of stages 1 and 2 are overlapped in the error ranges.

approach (see also Smellie et al. 1998) and we hope to inspire the workers in adjacent areas. Two points will be particularly helpful regarding regional correlations. One is to identify and isolate basaltic lava/agglutinate/agglomerate complexes and the other is to group block-and-ash flow deposits dominated by blocky, poorly vesiculated clasts. The descriptive details provided here should help in their recognition elsewhere. We have found that there are many volcaniclastic deposits similar to the FA II elsewhere in King George Island, e.g., Fildes Peninsula (our observations), Potter Peninsula (Barton 1965) and Admiralty Bay (Birkenmajer 1980). It is therefore tentatively suggested that Vulcanian eruptions accompanied by lava dome collapses may have played a major role in the formation of stratovolcanoes on King George Island in Eocene times. Given the extensiveness and completeness of the early-Tertiary volcanic sequences on King George Island in the northern Antarctic Peninsula region, establishing a more sophisticated stratigraphy and evolution history for the island can serve as a key to understanding its regional geological and tectonic evolution, particularly in relation to the formation of the South Shetland Islands arc.

Conclusions

Based on detailed lithofacies analysis and field mapping, the volcano-sedimentary evolution of the Sejong Formation is reconstructed. The first stage is marked by the basaltic lava/agglutinate/agglomerate complexes (FA I, Chottae member) that form discrete semi-circular patches in map view. They represent isolated, small-scale spatter/cinder cones due to fire fountaining (Hawaiian) to Strombolian eruptions. The second stage is represented by repetitive emplacement of basaltic to andesitic block-and-ash flows and attendant andesitic lava flows (FA II), which suggests onset of explosive and effusive eruptions (Vulcanian) of more evolved (intermediate) volcanic centres, probably associated with repeated extrusions and collapses of lava domes at a summit crater of a larger (strato-)volcano. Active hydrologic remobilization processes across the volcaniclastic aprons of FA II during and in the immediate aftermath of the eruptions resulted in the intercalated floodplain and mass-flow deposits of FA III. The overall characteristics of individual lithofacies and facies associations suggest a deposition of the entire Sejong Formation in a subaerial environment. The changes in eruption style from effusive Hawaiian to explosive Vulcanian types may reflect compositional evolution of arc magmas in association with an increasing contribution of groundwater to the magma.

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Appendix

Formal Stratigraphic Summary

- Name: Sejong Formation (after Lee et al. 2002).
- Type section: Nambong and Jiribong (sections 1 and 3 in Fig. 5.7-3).
- Thickness/extent: 100–200 m thick; traceable along southern peripheral coast of the Barton Peninsula (Fig. 5.7-2), also occurs in Weaver Peninsula.
- Stratigraphic position: lowest stratigraphic unit in Barton Peninsula, overlain by either basaltic-andesite lava succession or tuff/lava succession.
- Lithology: thick-bedded (>1 m), tabular, basaltic to andesitic tuff breccias and lapilli tuffs with thin lenses (1–5 m thick) of fluvial red sandstone/siltstone couplets and minor reworked debris-flow conglomerates and rare andesitic lava flows.
- Depositional environment: subaerial volcaniclastic aprons with floodplains and ephemeral channels during inter-eruptive periods.
- Age: Eocene (50–44 Ma).
- Regional correlation: Cardozo Cove Group in Admiralty Bay area (Birkenmajer 1998).

- Name: Chottae member (this study).
- Type sections: Nambong and Narebski Point (sections 1 and 2 in Fig. 5.7-3).
- Thickness/extent: about 30 m thick, discrete semicircular patches with approximate diameters of 400–600 m at Nambong coast, Narebski Point, Three Stacks Point, Winship Point and Oittan Rock (Fig. 5.7-2).
- Stratigraphic position: Basal unit of the Sejong Formation, either conformably or unconformably overlain by the Sejong Formation.
- Lithology: central massive/jointed basalt lavas and fringing basaltic lava flows, agglomerates and agglutinates with minor amounts of basaltic tuff breccias.
- Depositional environment: subaerial spatter/cinder cones.
- Age: Eocene (50–44 Ma).

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