ACTA GEOLOGICA HISPANICA, v. 34 (1999), nº 4, p. 323-328

Volcanic Stratigraphy of Hannah Point, Livingston Island, South Shetland Islands, Antarctica

Estratigrafia volcànica de la Punta Hannah, Illa de Livingston, Shetland del Sud, Antàrtida

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ABSTRACT

The Upper Cretaceous volcanic succession of Hannah Point is the best exposure of the Antarctic Peninsula Volcanic Group on Livingston Island. The aim of the present paper is to contribute to the characterisation of the stratigraphy and petrography of this little studied succession, and briefly discuss some aspects of the eruptive style of its volcanism. The succession is about 470 m thick and is here subdivided into five lithostratigraphic units (A to E from base to top). Unit A, approximately 120 m thick, is mainly composed of polymict clast-supported volcaniclastic breccias and also includes a dacitic lava layer. Interstratified in the breccias of this unit, there is a thin laminated devitrified layer which shows some degree of welding. Unit B, approximately 70 m thick, is almost entirely composed of volcaniclastic breccias, and includes a volcaniclastic conglomerate layer. Breccias in this unit can be subdivided into two distinct types; polymict clast-supported breccias, and monomict matrix-supported breccias rich in juvenile components and displaying incipient welding. Unit C, about 65 m thick, is mainly composed of basaltic lavas, which are interlayered with minor volcaniclastic breccias. Unit D, approximately 65 m thick, is lithologically similar to unit B, composed of an alternation of polymict clast-supported breccias and matrix-supported breccias, and includes a volcaniclastic conglomerate layer. Unit E, about 150 m thick, is mainly formed of thick andesitic lava layers. Minor basaltic dykes and a few normal faults cut the succession, and the contact between units A and B can be interpreted both as an unconformity or a fault. The matrix-supported breccias included in the succession of Hannah Point have high contents of juvenile components and incipient welding, which suggest that part of the succession is the result of pyroclastic fragmentation and emplacement from pyroclastic flows. In contrast, the polymict clast-supported breccias suggest reworking of previous deposits and deposition from cool mass flows. The lavas indicate effusive volcanic eruptions, and the absence of features indicative of subaqueous volcanism suggests that at least these portions of the succession were emplaced in a subaerial environment.

Keywords: South Shetland Islands. Livingston Island. Antarctic Peninsula Volcanic Group. Magmatic arc. Volcanic succession. Volcaniclastic rocks.

RESUM

La successió volcànica que aflora a la Punta Hannah constitueix el millor afloraments de roques volcàniques de l'Illa de Livingston (Illes Shetland del Sud, Antàrtida) (Fig. 1). Tot i això, aquesta successió ha estat poc estudiada fins l'actualitat. Prèviament a la nostra visita durant l'any 1992, la localitat de la Punta Hannah havia estat únicament visitada per Hobbs (1968), qui va publicar un tall esquemàtic i la descripció petrogràfica de diverses mostres. Dues datacions K-Ar, indiquen que la successió de la Punta Hannah té una edat de Cretaci superior (Smellie et al., 1996). La finalitat del present article és publicar un esquema geològic més complet de l'aflorament de la Punta Hannah que el presentat per Hobbs (1968), contribuir a la caracterització estratigràfica i petrològica de la successió, i interpretar alguns aspectes sobre l'estil eruptiu del vulcanisme d'aquesta localitat. La successió té uns 470 m de potència i la subdividim en cinc unitats litoestratigràfiques, d'acord amb l'abundància dels diferents tipus de roques i les relacions angulars entre els diferents paquets estratigràfics. La unitat A (Fig. 2), d'aproximadament 120 m de potència, és constituïda principalment per bretxes vulcanoclàstiques polimíctiques amb suport de grans, i inclou un nivell de laves dacítiques. Les bretxes d'aquesta unitat mostren la intercalació d'un nivell laminat de potència centimètrica amb textures de desvitrificació i un cert grau de soldament. La unitat B (Fig. 2), d'aproximadament 70 m de potència, és constituïda fonamentalment per bretxes vulcanoclàstiques i inclou un nivell de conglomerats vulcanoclàstics. Les bretxes d'aquesta unitat se subdivideixen en dos tipus ben diferenciats; bretxes monomíctiques amb suport de matriu amb abundància de components juvenils i que mostren soldament, i bretxes polimíctiques amb suport de grans. La unitat C (Fig. 2), d'aproximadament 65 m de potència, és formada principalment per laves basàltiques en les que s'intercalen nivells de bretxes vulcanoclàstiques. La unitat D, d'aproximadament 65 m de potència, és litològicament similar a la unitat B i inclou un nivell de conglomerats vulcanoclàstics. La unitat E, d'aproximadament 150 m de potència, és parcialment coberta, formada per nivells potents de laves andesítiques. Entre les unitats A i B hi ha diversos dics de composició basàltica que compliquen la interpretació del contacte entre els dos trams, que tant es pot tractar d'una falla com d'una discordança. La successió es troba afectada per dues famílies conjugades de falles normals amb una direcció ENE-WSW i amb salts verticals que no superen els 10 m. Les bretxes monomíctiques amb suport de matriu incloses en la successió volcànica de la Punta Hannah, tenen un alt contingut en components juvenils que indiquen una fragmentació piroclàstica, resultat d'erupcions explosives. La presència abundant de matriu, d'amígdales, de textures de desvitrificació i de textures indicadores de soldament suggereixen que aquests dipòsits podrien haver-se emplaçat a partir de fluxos piroclàstics. Contrastant amb això, les bretxes polimíctiques amb suport de grans, suggereixen un retreballament de dipòsits previs i deposició en fred a partir de fluxos en massa. La resta de la successió és formada per laves, que són el resultat d'erupcions predominantment efusives. L'absència de característiques típiques del vulcanisme subaquàtic suggereix que, com a mínim, la part de la successió corresponent a les laves es va emplaçar en condicions subaèries.

Paraules clau: Illes Shetland del Sud. Illa de Livingston. Grup Volcànic de la Península Antàrtica. Arc magmàtic. Successió volcànica. Roques vulcanoclàstiques.

INTRODUCTION

Livingston is the second largest of the South Shetland Islands, which are separated from the Antarctic Peninsula by the Bransfield Strait (Fig. 1). Hannah Point is located on the south-central coast of Livingston Island, midway between Byers Peninsula and Hurd Peninsula (Fig. 1). Surprisingly, in spite of its being the best exposed and most extensive volcanic outcrop on the island, Hannah Point has received little attention from stratigraphers and volcanologists. Prior to our visit, it had virtually only been visited by Hobbs (1968), who collected several samples and gave the first descriptions and a schematic section of the volcanic succession. In 1992, we undertook additional field work on Hannah Point, including systematic sampling and collection of additional stratigraphic and structural data. Part of our data, such as K-Ar radiometric ages and geochemical analyses, were published by Smellie et al. (1996) and Xiangshen et al. (1996), but detailed descriptions of the volcanic succession were omitted by them. The aim of the present contribution is to provide a detailed description of the stratigraphic succession of Hannah Point and discuss, as far as possible, the possible origin of the volcanic rocks and the eruptive style of volcanism.

GEOLOGICAL BACKGROUND

Several of the main geological units of the Antarctic Peninsula region (such as forearc basin, magmatic arc and extension-related volcanics) crop out on Livingston Island (see Pallàs, 1996 for a review).

The Miers Bluff Formation is probably early Triassic (Willan et al., 1994). It makes up most of Hurd Peninsu-

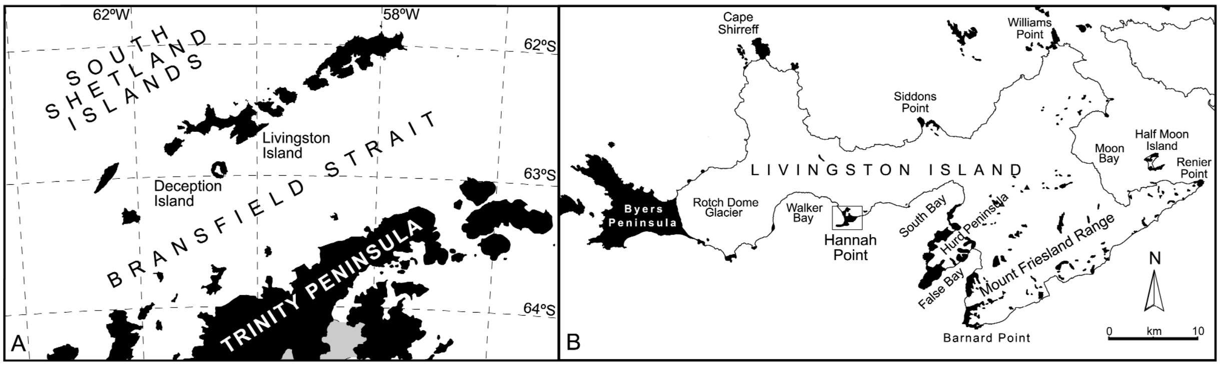

Figure 1.- Location of the area studied and place names referred to in text.

Figura 1.- Situació de l'àrea d'estudi i noms de les localitats citades al text.

la, is 3 km thick and the oldest unit in the South Shetland Islands. It consists of a NW-dipping, open-folded and mostly overturned turbiditic sequence (Dalziel, 1969; Pallàs et al., 1992; Doktor et al., 1994; Smellie et al., 1995) of equivocal and not well understood tectonic setting (Smellie et al., 1995; Tokarski et al., 1997).

The little deformed late Jurassic to early Cretaceous Byers Group crops out in Byers Peninsula and records deposition in a marine to continental forearc basin (Smellie et al., 1980, Crame et al., 1993). The amount of intercalated volcanic rocks increases upwards, indicating a gradual encroachment of the magmatic arc into the forearc basin (Hathway and Lomas, 1995).

The mesozoic to cenozoic magmatic arc is represented both by calcalkaline plutonic (Antarctic Peninsula Batholith, Leat et al., 1995) and volcanic rocks (Antarctic Peninsula Volcanic Group, Thomson, 1982). On Livingston Island, the Batholith is represented by late Cretaceous tonalite plutons, which cut through the Miers Bluff Formation in Hurd Peninsula (Kamenov, 1995), and Eocene tonalites which are thought to make up most of the Mount Friesland range (Smellie et al., 1995; 1996). Apart from Hannah Point, the Antarctic Peninsula Volcanic Group and its hypabyssal counterparts crop out in Cape Shirreff (see Pallàs et al., this volume), Siddons Point, Williams Point and the eastern-central part of the island (Smellie et al., 1995; 1996; Xiangsheng, Z. et al., 1996).

Quaternary lavas and volcaniclastic rocks of alkaline affinity crop out on the central areas of Livingston Island, north-west of the Mount Friesland range, and are interpreted as related to extension of the Bransfield Basin rift (Smellie et al., 1995; 1996).

PREVIOUS WORK ON HANNAH POINT

According to Hobbs (1968) the basal 43 m of the Hannah Point succession consists of massive andesites interbedded with green agglomerates, amygdaloidal lavas and tuffs. The following 110 m are composed of friable agglomerates, fissile ashes and amygdaloidal lavas, while the top 195 m are composed of massive andesite layers (much thicker than the basal ones) interbedded with amygdaloidal lavas.

The rocks of Hannah Point were considered by Smellie et al. (1984) to be part of the volcanic succession cropping out on Byers Peninsula and, in consequence, were tentatively assigned to the Lower Cretaceous. Later K-Ar analyses of two basaltic andesite samples corresponding to the mid and upper part of the succession, gave 87.9 ± 2.6 and 67.5 ± 2.5 My respectively, clearly indicating they are Upper Cretaceous in age (Smellie et al., 1996). The older date is fully compatible with the model of volcanic migration suggested by Pankhurst and Smellie (1983), which implies gradually younger volcanism eastwards along the South Shetland archipelago. As geochemical analyses suggest, these two samples may be cogenetic, but the wide gap between the two dates precludes a simple interpretation. Although the older sample is more intensely altered than the younger one, Smellie et al. (1996) considered that the latter might have been reheated and reset by later intrusion phases, which have not been found in the Hannah Point section.

On the basis of geochemical data (major elements and REE), Smellie et al. (1996) ruled out any cogenetic relationship between the volcanic rocks of Hannah Point and the volcanics included in the Byers Formation. These au-

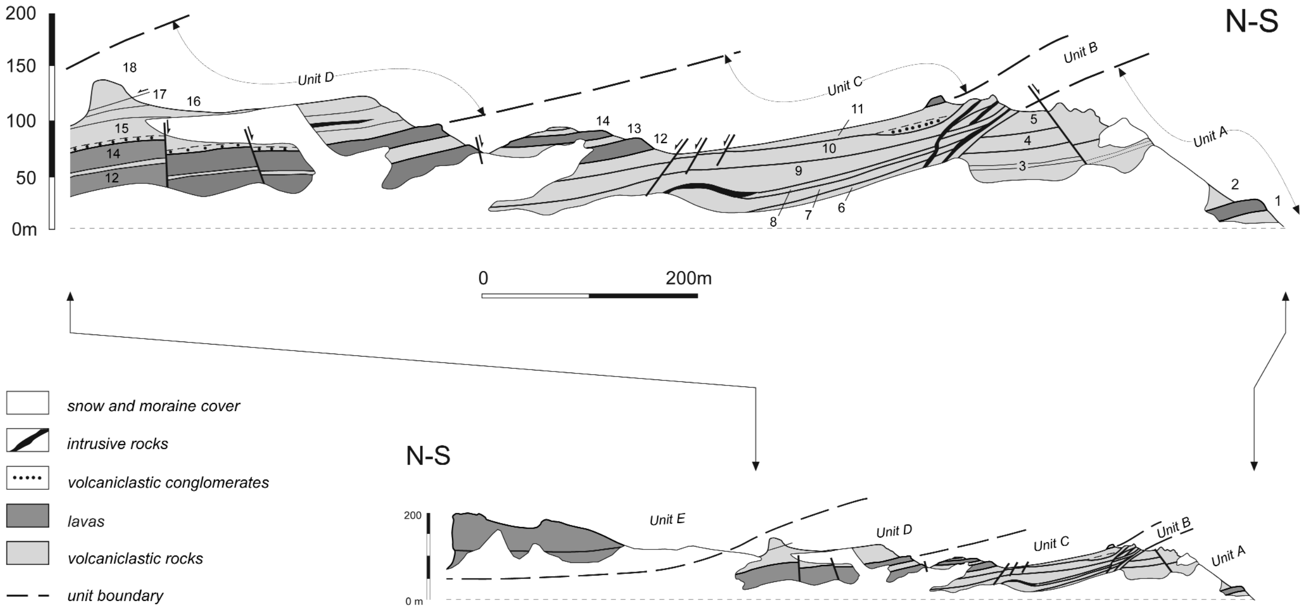

Figure 2.- Geological sketch of the volcanic succession cropping out at Hannah Point, as seen from Walker Bay. The simplified section at the bottom shows the whole succession, while the section at the top is an enlargement to show units A to D in greater detail. Numbers 1 to 18 refer to single layers.

Figura 2.- Esquema geològic de l'aflorament de la successió volcànica de la Punta Hannah, tal com s'observa des de la Badia de Walker. El tall simplificat inferior representa el conjunt de la successió, mentre que el tall superior és una ampliació per mostrar amb més detall les unitats A a D. Els nombres 1 a 18 corresponen a nivells individuals referits en el text.

thors suggested a possible cogenetic relationship with the dolerites cropping out at Siddons Point. Later isotopic analyses (Sr, Nd and Pb) and the study of La/Sm-La and Ce/Yb-Ce pairs indicate that the rocks of Hannah Point display crustal contamination and correspond to a different magma source from the rocks of Siddons Point, Byers Peninsula and Cape Shirreff (Xiangshen et al., 1996).

Despite detailed geochemical studies (Smellie et al., 1996 and Xiangshen et al., 1996) a comprehensive description of rock types and the stratigraphic succession has not yet been published. We provide here a description of the stratigraphy of Hannah Point to complement the work of Hobbs (1968).

DESCRIPTION OF THE VOLCANIC SUCCESSION

The volcanic succession of Hannah Point dips about 10 to 15 degrees to the NNW, and constitutes a continuous 1800m-long outcrop (Fig. 2). This succession is divided into 5 lithostratigraphic units (labelled A to E in Fig. 2), according to the predominance of rock types and to angular relationships between units. Except for the contact between units A and B, the rest of the contacts are concordant and parallel (Fig. 2).

Unit A (layers 1 to 5 in Fig. 2) is approximately 120 m thick, and comprises 90% volcaniclastic rocks and 10% lavas. The basal layer of the unit is 13 m thick, formed of coherent dacitic lavas showing porphyritic and hyalopilitic textures, with clinopyroxene and plagioclase microphenochrysts. Clinopyroxene microphenochrysts constitute 30% of the phenocrysts and are euhedral to subhedral. The matrix is formed of plagioclase laths (30%), granular clinopyroxene (30%), quartz (10%) and opaque minerals. Clinopyroxene is locally altered to amphibole, and plagioclase to chlorite and quartz.

The rest of the unit is constituted of polymict, clast-supported, volcaniclastic breccias. The clasts are granule (>50% of the volume) to pebble in size, and subangular to subrounded. Clast composition includes sandstones and volcanic rocks that show variable porphyritic, pilotaxitic or hyalopilitic textures. Other components are euhedral to subhedral plagioclase crystals altered to calcite. The matrix of the volcanic breccias is mud to sand in size, and displays rare glass shards.

The unit includes a thin (7 cm) laminated and highly devitrified layer (layer 3 in Fig. 2), and a non-laminated discontinuous dark layer composed of iron oxides and quartz. Lamination is characterized by the alternation of thin layers (up to 5 mm thick) of dark and brown color and different grain sizes. Dark layers are mainly composed of opaque material, while variation of grain sizes in brown layers is due to different degrees of granophyric and spherulitic devitrification. Some layers include plagioclase crystals and elongated, probably collapsed, amygdales filled with chlorite and quartz.

Unit B (layers 6 to 11 in Fig. 2) is about 70 m thick and composed of volcaniclastic breccias and a conglomerate layer. Beds of unit A are truncated to the lower boundary of unit B, while beds of unit B are parallel to this boundary (Fig. 2). This contact between units A and B can be interpreted either as an unconformity or a fault. The clasts of the breccias are 10 to 40% of the volume, up to pebble in size, mostly subangular to rounded. Some breccias are polymict and clast-supported, with clasts mainly of mafic volcanic rocks and minor sandstones. Mafic volcanic rocks display porphyritic texture of plagioclase and clinopyroxene phenocrysts embedded in a devitrified glassy groundmass. Polymict breccias also contain fragments of plagioclase crystals altered to calcite and chlorite. Other breccias are matrix-supported, containing juvenile and lithic clasts in a devitrified glassy matrix with chlorite amydgales. Juvenile fragments are banded and spherical pumices, sometimes highly oxidised, plagioclase phenocrysts and zeolitised glass shards. A weak degree of welding, characterised by incipient collapse of pumice fragments, is common in the matrix-supported breccias. Layer 11 is a volcaniclastic conglomerate that displays an erosional base with a lag deposit and grades upwards to volcanic sandstone.

Unit C (layers 12 to 14 in Fig. 2) is about 65 m thick and is mainly composed of lavas interlayered with thinner poorly consolidated volcaniclastic layers. Lava layers (12 and 14 in Fig. 2) thin towards the south (from approximately 20 to 10 m) and are basaltic andesites with pilotaxitic or trachytic texture. Phenocrysts are mainly plagioclase (up to 60% of the volume), altered to quartz, chlorite and calcite. The matrix includes plagioclase (40%) and clinopyroxene (20 %). Layer 14 displays columnar jointing and planar jointing at the top, and corresponds to the oldest lavas dated by Smellie et al., (1996).

Unit D (15 to 18 in Fig. 2) is a stratigraphic package about 65 m thick and lithologically similar to unit B. Like unit B, it is composed of alternating polymict clast-supported breccias and matrix-supported breccias. Layer 15 is located at the base of unit D and is a volcanic conglomerate 2.5 m thick, which grades upwards to volcanic breccias.

Unit E is approximately 150 m thick. Ice and snow cover only allowed sampling of its upper part, corresponding to an approximately 80 m-thick coherent andesitic lava layer that shows columnar jointing. It is aphanitic in texture, with plagioclase microphenocrysts partially altered to chlorite and, less commonly, clinopyroxene. The youngest sample dated by Smellie et al., (1996) was collected from this layer.

Intrusi ve rocks and structure

Several dykes and sills cut the volcanic succession, mainly at the lower part of unit B. They are constituted of coherent rocks of basaltic composition, with porphyritic and equigranular textures. Phenocrysts are plagioclase altered to chlorite and, less commonly, clinopyroxene. The matrix is formed of plagioclase microlites, opaque ore and pyroxene.

The Hannah Point succession is mainly undeformed. Only a few ENE-WSW-trending normal faults can be distinguished, which can be grouped into two (north- and south-dipping) conjugate sets and imply vertical slips of no more than 10 m. A gentle fold, probably associated to the intrusion of a sill, affects the basal layers of unit B (Fig. 2).

CONCLUSIONS

The stratigraphic succession of Hannah Point was divided into five lithostratigraphic units, according to rock types and contacts between units. Units C and E are characterized mainly by andesitic lavas while units A, B and D are characterized by volcaniclastic rocks.

The large amount of juvenile components (pumices, glass shards) observed in matrix-supported volcaniclastic breccias indicates a pyroclastic mode of fragmentation. The presence of matrix with amygdales, devitrification textures and incipient welding (collapse of pumices) suggest that these breccias were emplaced from pyroclastic flows, as the result of explosive volcanic activity.

Polymict clast-supported breccias with no evidence of welding and devitrification textures suggest syn-volcanic reworking of previous deposits, short transport, and final deposition from cool mass flows.

According to the predominance of lavas in units C and D, the eruptive style of this portion of the Hannah Point succession is mainly effusive, and explosive activity would have played a minor role. The absence of volcanic features characteristic of subaqueous volcanism, such as pillow lavas and hyaloclastic textures, suggests that at least this part of the succession was emplaced in a subaerial environment.

A comprehensive facies-oriented analysis is needed to characterize in greater detail the volcanic succession of Hannah Point and to reveal its significance in the context of the geodynamic evolution of the Antarctic Peninsula during Cretaceous times.

ACKNOWLEDGMENTS

This study is part of project ANT-1270/91, funded by the CICYT. Dr. Zeng was supported by CNSF (49172092), CAS (KJ85-08-03) and SACC (85-03-04) and R.P. and J.M.C. by Grup de Processos Geodinàmics Superficials, ref. 3130-UB-06 financed by 1999SGR-00065. The authors thank the crew of the Spanish Antarctic Station for support during the austral summer of 1992-93.

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