NEW DATA ABOUT VOLCANO-SEDIMENTARY SUCCESSIONS ON BYERS PENINSULA AND HANNAH POINT, LIVINGSTON ISLAND, ANTARCTICA

Stefan Velev[1], Cristine Trevisan[2], Docho Dochev[3], Janko Gerdjikov[3], Kamen Bonev[4]

[1]National Center for Polar Studies, Sofia University "St. Kliment Ohridski"1504 Sofia; velev.stefan83@gmail.com
[2]Chilean Antarctic Institute (INACH), Punta Arenas; ctrevisan@inach.cl
[3]Sofia University "St Kliment Ohridski" 1504 Sofia, FGG, dochev@gea.uni-sofia.bg, janko@gea.uni-sofia.bg
[4]Bulgarian Antarctic Institute, Sofia; bonev.kamen@gmail.com

ABSTRACT. Livingston is the second largest of the South Shetland Islands, which are separated from the Antarctic Peninsula by the Bransfield Strait. Some ice-free areas, such as Byers Peninsula and Hannah Point provide a perfect opportunities for studying the outcropping rocks. The thick Upper Jurassic-Lower Cretaceous sedimentary sequences exposed on Byers Peninsula are dominated by mudstones, sandstones, and rare levels of conglomerates and breccias. Igneous rocks are presented by subvolcanic, hypabyssal shallow intrusions, effusive, explosive and volcaniclastic varieties. Several basaltic cryptodomes are intruded into unconsolidated sediment rocks. The penetration of the basalts into the wet sediments results in quench fragmentation and generation of in situ hyaloclastites (peperites). The rock sequences on Hannah Point are composed of different volcanic and volcanoclastic rocks with Upper Cretaceous age. Volcanic products include lava flows, pyroclastics, epiclastics, volcanic plugs and dykes. The magmatism on Livingston Island come to be younger from west to east: Lower Cretaceous at Byers Peninsula and Upper Cretaceous at the central part (Hannah Point). Along with this, the paleovolcanic setting changes from subaqueous at the most western part (Byers Peninsula) to subaerial at the central parts of the island (Hannah Point).

Keywords: Antarctica, Livingston Island, volcanic rocks, Lower-Upper Cretaceous

НОВИ ДАННИ ЗА ВУЛКАНОГЕННО-СЕДИМЕНТНИТЕ ПОСЛЕДОВАТЕЛНОСТИ ОТ П-В БАЙЕРС И НОС ХАНА, О-В ЛИВИНГСТЪН, АНТАРКТИКА

Стефан Велев[1], Кристин Тревисан[2], Дочо Дочев[3], Янко Герджиков[3], Камен Бонев[4]
[1]Национален Център за Полярни Изследвания, СУ „Св. Климент Охридски" 1504 София
[2]Чилийски Антарктически Институт, Пунта Аренас
[3]СУ „Св. Климент Охридски" ГГФ, 1504 София
[4]Български Антарктически Институт, София

РЕЗЮМЕ. Ливингстън е вторият по големина остров от архипелага на Южно Шетландските острови, които са отделени от Антарктическия полуостров посредством пролива Брансфийлд. Някои свободни от лед и сняг райони предоставят перфектни възможности за изследване на разкриващите се скали, именно такива са п-в Байерс и нос Хана. Горноюрско-долнокредните седиментни последователности на п-в Байерс са изградени от алевритово-глинести скали, пясъчници и редки нива от конгломерати и брекчи. Магмените скали са представени от субвулкански, хипоабисални плитки интрузии (щокове), ефузивни, експлозивни и вулканокластични разновидности. Няколко плитко заложени базалтови щока са внедрени във все още неконсолидираните седименти. Проникването на базалтовата магма сред влажните седименти води до тяхната фрагментация и бързо охлаждане, като това генерира хиалокластити (пеперити). Скалните последователности на нос Хана са съставени от различни вулкански и вулканокластични скали с горнокредна възраст. Вулканските продукти включват лавови потоци, пирокластити, епикластити, вулкански некове и дайки. Магматизмът на о-в Ливингстън се подмладява от запад на изток: Долна Креда на п-в Байерс и Горна Креда на нос Хана. Паралелно с това се променя и палеовулканската обстановка от субаквална в западните части на острова (п-в Байерс) до субаерална в централните части (нос Хана).

Ключови думи: Антарктика, о-в Ливингстън, вулкански скали, Долна-Горна Креда

Introduction

Livingston is the second largest of the South Shetland Islands, which are separated from the Antarctic Peninsula by the Bransfield Strait (Fig. 1). On the island there are some places with excellent exposures of volcano-sedimentary successions such as Byers Peninsula and Hannah Point.

The aim of this research is a field characteristic of the volcanic and volcano-sedimentary rocks from these localities and correlation between them.

The focus of present study is on a volcanic rock types. The main reason for this is lower knowledge about them.

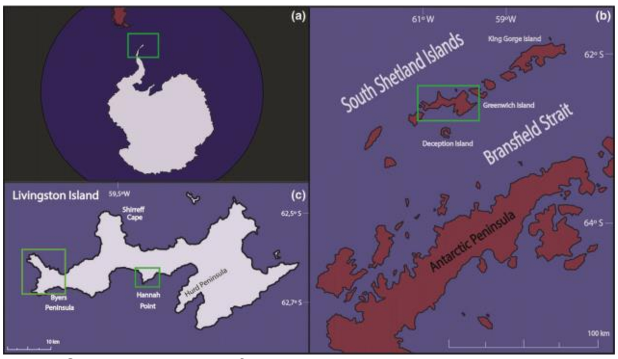

Fig.1. General location of studied areas. (a) Antarctic Peninsula. (b) Antarctic Peninsula and South Shetland Islands. (c) Livingston Island, in a green square Hannah Point and Byers Peninsula

Methods

For the purposes of the present investigation were carried out field works aiming a detailed characteristic of volcanic and volcaniclastic sequences and rock sampling. Fieldwork was carried out by a bulgarian geological expedition in 2017 and 2018.

Geological overview

The South Shetland Island arc is the most conspicuous geological feature present in the archipelago. It was formed as response to the subduction of the Pacific oceanic crust in a southeast direction under the continental crust of the Antarctic Peninsula. Its volcanic activity record ranges between 135 and 47 Ma (Smellie et al., 1984; Haase et al., 2012). The volcanic rocks mainly consist of lavas and associated volcaniclastic products (Smellie et al., 1984) of calc-alkaline to tholeitic affinities.

The late Jurassic to early Cretaceous Byers Group crops out on Byers Peninsula and records deposition in a marine to continental forearc basin (Smellie et al., 1980; Crame et al., 1993; Pimpirev et al., 1998). According to Crame et al. (1993) sedimentary and volcanic successions are grouped into 4 formations as follows: Anchorage Formation (Kimmeridgian–Tithonian), Devils Point Formation (Berriassian), President Beaches Formation (Berriasian) and Chester Cone Formation (Valanginian). Afterward Hathaway and Lomas (1998) revised the lithostratigraphical scheme of Crame et at. (1993) and proposed some new formal lithostratigraphic units: Anchorage Formation (Kimmeridgian–Tithonian), President Beaches Formation and Start Hill Formation (Berriasian), Chester Cone Formation (with Devils Point Member and Sealer Hill Member) (?Upper Berriasian to Valanginian) and Cerro Negro Formation (Aptian). On Byers Peninsula there are a lot of perfect examples of interaction between magma and wet unconsolidated sediments (Velev et al., 2018).

Hannah Point is part of the widespread occurrence of volcanic rocks from Livingston Island.

According to Hobbs (1968) the basal 43 m of the succession consist of andesites interbedded with agglomerates, amygdaloidal lavas and tuffs. The following 110 m are composed of friable agglomerates, ashes and lavas, while the top 195 m are composed of massive andesite layers interbedded with amygdaloidal lavas.

The rocks from Hannah Point were considered by Smellie et al. (1984) to be part of the volcanic succession cropping out on Byers Peninsula (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 Ma, indicating they are Upper Cretaceous in age (Smellie et al., 1996).

Pallas et al. (1999) recognized five members from base to top: (a) 120 of polymictic volcaniclastic breccias, (b) 70 m of volcaniclastic breccias, (c) 65 m of basaltic lavas, (d) 65 m of volcaniclastic breccias and (e) 150 m of andesitic lavas, suggesting that the rocks of this succession were emplaced as pyroclastic flows associated with explosive volcanic activity in a subaerial environment.

On the base of leaf imprints and fossil trunk Leppe et al. (2007) suggested a Late Cretaceous age. This was confirmed by Haase et al. (2012) based on 40Ar/39Ar whole rock data giving an age of 97.5 Ma.

Results and discussion

Byers Peninsula

On the Byers Peninsula igneous rocks are very widespread. The volcanic facies is represented by lava flows, sills, dykes, volcanic plugs and some hypabissal rocks with lower Cretaceous age (Fig. 2).

The lavas are characterized by well developed colonnade and entablature structures (Fig. 3). In most of the cases lava flows are stratified, separated each other by levels of lava breccias and volcaniclastic rocks.

Several volcanic plugs cropped out at Sealer Hill, Cerro Negro and Lair Point. Very characteristic for these structures is columnar jointing. They indicate different monogenetic volcanic centers.

Sill-like bodies have a much bigger distribution than dykes. Impressive structures of these type cropped out on Devils Point and Punta Campamento. Their thickness is up to about 45 m.

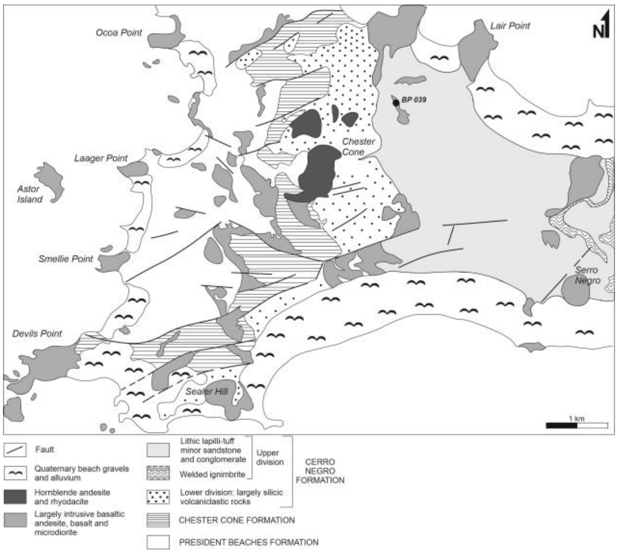

Fig. 2. Geological map of Byers Peninsula (after Hathway and Lomas, 1997)

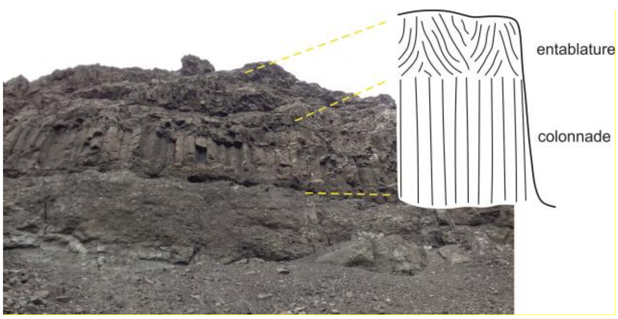

Fig. 3. Lava flow with colonnade and entablature

On Byers Peninsula there are a lot of evidences of interaction of magma and wet unconsolidated sediments.

The basaltic cryptodomes crop out in several places on the Byers Peninsula. They are intruded in unconsolidated sediment rocks (alternation of sandstones and siltstones). The cryptodomes have irregular fingershaped contacts (Fig. 4a). The penetration of the basalts in the wet unconsolidated sediments results in quench fragmentation and generation of in situ hyaloclastite. The low viscosity magma is influxed in the sediments and peperites (White et al., 2000) are formed due to temperature differences and the fluidization effect. In peperitic facies, sandstones or siltstones fill joints and fractures that define pseudo-pillows (Fig. 4b), lobe-like bodies (Fig. 4e), polyhedral joint blocks and closely packed fabric (Fig. 4c) or sediment, matrix-rich breccia (Fig. 4d), contains fragments and apophyses of basalts (dispersed fabric). Often the basalt fragments show jigsaw-fit texture and some of the direct contacts with the sediments have chilled margins. Along some contacts, peperite with dispersed fabric passes through a zone of closely packed peperite into coherent facies. Alternatively, closely packed peperite passes directly into coherent facies. Examples of peperite with more than one clast type (globular, blocky and platy), and involving sedimentary matrix are common (Doyle, 2000).

The thick Upper Jurassic-Lower Cretaceous sedimentary and volcano-sedimentary sequences exposed on the Byers Peninsula are dominated by mudstones, sandstones, and rare levels of conglomerates and breccias. The sedimentary sequences are well dated based on ammonites, belemnites, palynomorphs, and fossil flora. Igneous rocks are present by almost magmatic facies – subvolcanic, hypabyssal shallow intrusion, effusive, explosive and volcanoclastic. Several basaltic cryptodomes are intruded into unconsolidated sediment rocks. The penetration of the basalts into wet sediments results in quench fragmentation and generation of in situ hyaloclastite. These textures are evidence for subaqueous setting of volcanism in this part of Livingston Island.

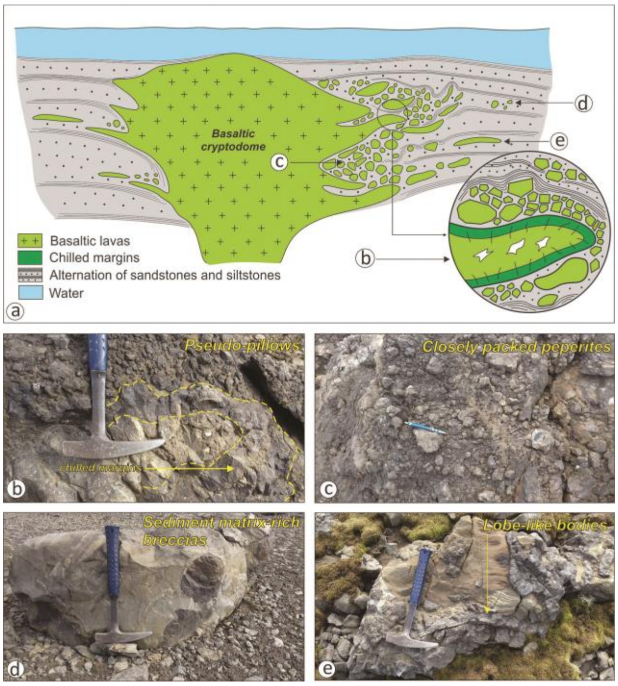

Fig. 4. Intrusions of cryptodomes in nonconsolidated sediments. (a) idealized scheme. (b) pseudo-pillows. (c) closely packed peperites. (d) sediment matrix-rich breccias. (e) lobe-like platy body

Hannah Point

The upper Cretaceous volcano-sedimentary succession on Hannah Point is composed of lava flows, dykes, volcanic plugs, pyroclastic and epiclastic rocks and rare, thin levels of sediments.

In the lower parts of the cross section there are two lava flows separated each other by autobrecciated levels (lava breccias) (Fig. 5).

Typical for the flows are colonnade and entablature structures.

Other two lava flows are established in the middle parts of the succession.

Volcaniclastic rocks are the most common on Hannah Point. These include pyroclastic and epiclastic varieties.

There are two types of pyroclastic rocks-agglomerate tuffs and ignimbrites.

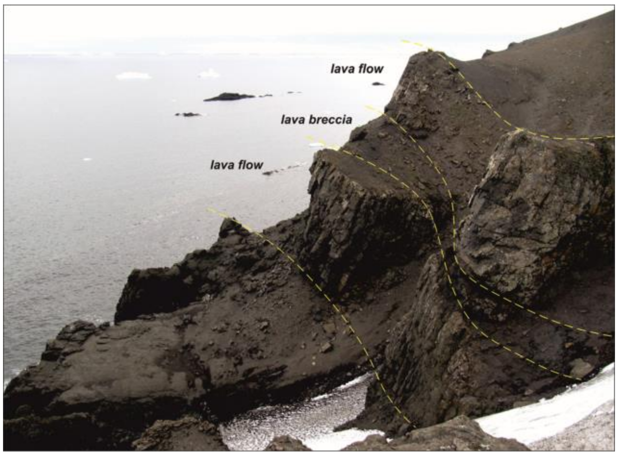

Fig. 5. Lava flows in the lower parts of the cross section on Hannah Point

One volcanic plug is intruded in volcano-sedimentary layers. It is located in the northern part of the cross section and represent typical remnant volcanic structure.

Perfectly developed is columnar jointing. In the lower and middle parts of the body columnar joints are vertical, which is an indication of the vertical movement of the lava. In the upper levels of the structure the lava begins to flow in different directions (Fig. 6).

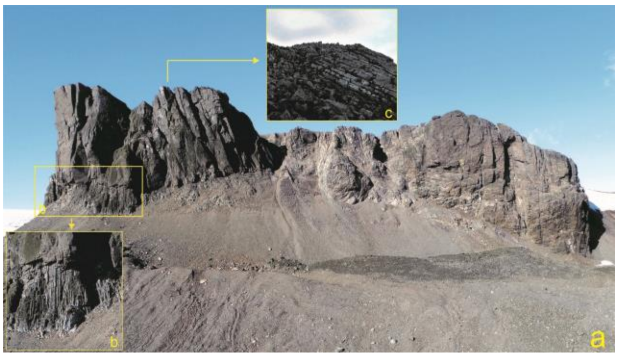

Fig. 6. (a) general view of volcanic plug. (b) vertical prismatic joints. (c) tilted prismatic joints

Two dikes are established with thickness ranging from 1 to 2.5 m (Fig. 7).

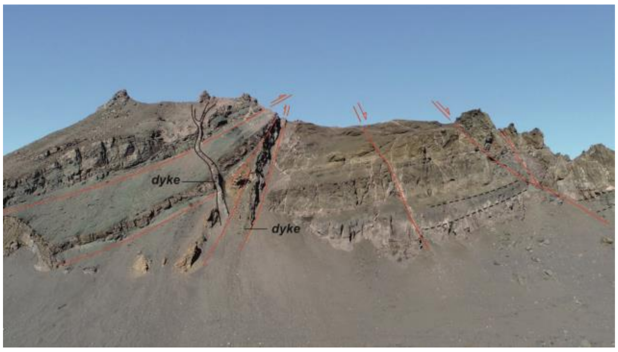

Fig. 7. Subvertical dyke bodies

The field works allowed to collect detailed data about the rocks from Hannah Point.

The studied area is dominated by volcanic and volcaniclastic rocks. Sediments are poorly represented.

All volcanic products (lava flows, pyroclastic and epiclastic rocks, volcanic plugs) are result of the activity of one subaerial volcanic center. The observed dikes are the the last magmatic phase.

The volcano-sedimentary succession can be considered as a monogenetic, stratified volcanic structure, formed by alternation of effusive, pyroclastic and epiclastic sequences.

Conclusions

The magmatism on Livingston Island come to be younger from west to east: Upper Jurassic to Lower Cretaceous at Byers Peninsula, Upper Cretaceous at the central part (Hannah Point) and Eocene at Hurd Peninsula and Barnard Point. Along with this, the paleovolcanic setting changes from subaqueous at the most western part (Byers Peninsula) to subaerial at the central parts of the island (Hannah Point).

The deposition conditions for the sediments on the island are various. At the western part of the Byers Peninsula the gently dipping ?Kimmeridgian-Berriasian sediments are deposited in deep-marine paleoenvironments, while in the central part of the peninsula ?Berriasian-Valanginian sediments are shallow marine. In the eastern part of the Byers Peninsula sedimentary rocks Valanginian – Aptian in aged are deposited in non-marine conditions. The sedimentary beds exposed in the central part of the island (Hannah Point) are non-marine too and much younger (Coniacian-Maastrichtian). At the eastern part of the Island (Hurd Peninsula) lower and middle part of the anchimetamprphosed sedimentary sequences of Miers Bluff Formation (Campanian-Maastrichtian) are also formed in deep-marine paleoenvironments, while upper parts of the formation (Maastrichtian-?Paleocene) demonstrated the final regressive stage with coarse sedimentation.

Acknowledgements. Sincere thanks to Prof. Christo Pimpirev for the opportunity to work on Livingston Island.

This work has been carried out in the framework of the National Program of Polar Research supported by Ministry of Education and Science of Bulgaria (Agreement No 80-10-242)

Thanks to everyone from the logistic team who secured our safe arrival and stay in Antarctica.

References

Crame, J. A., D. Pirrie, J. S. Crampton, A. M. Duane. 1993. Stratigraphy and regional significance of the Upper Jurassic–Lower Cretaceous Byers Group, Livingston Island, Antarctica. – J. Geol. Soc. London, 150, 1075–1087.

Doyle, M. G. 2000. Clast shape and textural associations in peperite as a guide to hydromagmatic interactions: Upper Permian basaltic and basaltic andesite examples from Kiama, Australia. – Australian J. of Earth Sci., 47, 167–177.

Haase, K. M., C. Beier, S. Fretzdorff, J. L. Smellie. Garbe-Schonberg. 2012. Magmatic evolution of the South Shetland Island, Antarctica, and implications for continental crust formation. Contrib. Mineral. Petrol. 163 (6), 1103-1119.

Hathaway B., S. A. Lomas(1998) The Upper Jurassic-Lower Cretaceous By-ers Group, South Shetland Islands, Antarctica: revised stratigraphy and regionalcorrelations, Cret. Res.,19, 43–67.

Hobbs, G.J., 1968. The geology of the South Shetland Islands. IV . The Geology of Livingston Island. British Antarctic Survey Scientific Reports, 47, 34 pp.

Leppe M., W. Michea, C. Muñoz, S. Palma-Heldt, and F. Fernandoy. 2007. Paleobotany of Livingston Island: The first report of a Cretaceous fossil flora from Hannah Point. U.S. Geological Survey and The National Academies; USGS OF-2007-1047, Short Research Paper 081; doi:10.3133/of2007-1047.srp081.

Pallàs. R., C. Soriano., X. Zheng, F. Sàbat, J.M. Casas. 1999. Volcanic stratigraphy of Hannah Point, Livingston Island, South Shetland Island, Antarctica. – Acta Geologica Hispanica, 34, 4, 323-328.

Pimpirev Ch., D. Vangelov (1998) Ancient subaqueous mouth bar type system, Byers Group, Livingston Island, Antarctica, Ann. Univ. Sofia "St. Kliment Ohridski", Fac. Geol. Geog., 90(1), 29–43.

Smellie, J.L., R.E.S Davies, and M.R.A Thomson. 1980. Geology of a Mesozoic intra-arc sequence on Byers Peninsula, Livingston Island, South Shetland Islands. British Antarctic Survey Bulletin, No. 50, 55-76

Smellie, J.L., R.J. Pankhurst, M.R. Thomson, R.E. Davies. 1984. The geology of the South Shetland Island: IV. Stratigraphy, geochemistry and evolution. Br. Antarct. Surv. 87 (85 pp.).

Smellie,J.L., R. Pallas, F. Sabat, X. Zheng. 1996. Age and correlation of volcanism in central Livingston Island,South Shetland Islands:K-Ar and geochemical constraints.J.S.Am. Earth Sci. 9, 265–272.

Velev, S., D. Dochev, and K. Bonev. 2018. Interaction of magma and wet unconsolidated sediments: case study from Byers Peninsula, Livingston Island, Antarctica. REVIEW OF THE BULGARIAN GEOLOGICAL SOCIETY, vol. 79, part 3, 2018, p. 63–64

White, J. D. L., J. McPhie, I. Skiling. 2000. Peperite: a usefull genetic term. – Bull. Volcanol., 62, 65–66.