VOLCANO-STRATIGRAPHICAL DESCRIPTION OF THE SUBMARINE COMPLEX

Submarine Volcanic Group

Six formations have been distinguished in this lithostratigraphic group, which are described from bottom to top. Terminology is based on McPhie et al. (1993).

Barranco del Tarajalito Formation

This unit contains volcanogenic facies associations, of either ultra-alkaline (nephelinites, nepheline phonolites, pyroxenites, kaersutitites, melteigites-ijolites, and nepheline syenites) or strongly alkaline rocks (basalts/basanites and phonolites, pyroxenites and amphibole-bearing pyroxenites) interpreted to originate from separate vents. Volcanogenic deposits are defined here in the sense of McPhie et al. (1993): volcaniclastic deposits resulting from surface processes operating on pre-existing volcanic rocks. Primary volcanic facies comprise pillow lavas and scoria pillow breccias with subordinate massive lavas. Some pillow breccias and pillow fragment breccias are also found associated with them. Enclaves of plutonic ultra-alkaline rocks (pyroxenites, ijolites, melteigites, glimmerites) are common. Volcanogenic facies appear interbedded with primary volcanic facies and consist mainly of volcanic polymictic breccias with some volcanic sandstones and siltstones. Most breccias are massive, matrix-supported, although normal and inverse graded beds occur locally. Inside these breccias, sedimentary rock fragments (chert, siltstone) from the Mesozoic sedimentary series and basic or salic fragments of volcanic and plutonic rocks (nephelinites, pyroxene basalts/basanites, nepheline phonolites, ijolites, nepheline syenites, pyroxenites) are common. Sandstone and siltstone levels are constituted by basaltic/basanitic and nephelinitic partially recrystallized glassy shards, which show their original morphologies. Parallel-lamination, ripple cross-lamination, wavy and lenticular bedding are frequent in these levels. The most common clast type is blocky shards with low vesicularity and limited by curviplanar surfaces. There are also subordinate flat shards (platy shard type). In the most fine-grained levels, trace fossils and fragments of planktonic foraminifers have been found.

La Herradura Formation

It is characterized by pyroxene- or amphibole/pyroxene-bearing basalts/basanites with subordinate phonolites and volcanic sandstones. Basaltic/basanitic rocks occur as pillow lavas, scoria pillow breccias, pillow breccias, pillow-fragment breccias and resedimented pillow-fragment breccias. Inter-pillow material often contains hyaloclastic shards, fragments of pyroxene and amphibole crystals and fragments of planktonic foraminifers. The vesicularity index of pillow lavas is larger than 50%, indicating low water depths during their emission if caused by water exsolution (Jones, 1969). The orientation of breccia bedding commonly changes in short distances without relation to the general orientation of the sequence. This suggests that these deposits form part of the slopes of small overlapping volcanic cones. Phonolitic domes and flows also occur associated with autoclastic breccias and resedimented autoclastic breccias of the same composition. In some breccias, phonolite fragments are accompanied by basaltic/basanitic clasts.

Los Negros Formation

Volcanic breccias and sandstones mostly represent the volcanogenic facies. Breccias contain clasts of pyroxene-amphibole basanite/basalts, phonolites and less abundant pyroxenites and kaersutitites. Sandstones contain glassy or hyaloporphyric angular shards of low vesicularity, limited by flat surfaces. The occurrence of many crystal fragments of pyroxene, amphibole and apatite is common. Some levels of microbreccias show large amounts of hyaline benthonic foraminifers (Nummulitids and Rotaliids), planktonic foraminifers, marine gastropods, bivalves and echinoderms.

La Gatera Formation

In this unit, basaltic/basanitic are dominant and comprise pillow-lavas, pillow breccias and pillow-fragment breccias. Breccia matrix is often hyaloclastitic and contains remnants of planktonic foraminifers.

Toscano Formation

Volcanogenic facies associations are again dominant and mainly represented by volcanic sandstones and siltstones with some layers of subordinated volcanic breccias. Clasts are usually basaltic/basanitic in composition although some subrounded phonolite fragments can also occur. Angular and polyhedral fragments with curvilinear surfaces are dominant in fine-grained layers. Fragments of pyroxene, amphibole, apatite and biotite crystals are common. Parallel- and ripple cross-lamination and wavy and lenticular bedding are frequent in these levels. Locally, hummocky cross bedding can occur. The silty levels show abundant bioturbation (horizontal and vertical burrows).

El Valle Formation

Three lithofacies associations are represented in this unit. These include a primary volcanic facies, a resedimented volcaniclastic facies and a sedimentary volcanogenic facies. Primary volcaniclastic and resedimented volcaniclastic facies comprise pillow lavas, pillow breccias and pillow-fragment breccias that were resedimented to different degrees. Basaltic/basanitic scoria pillow breccias also occur. In some levels, coral specimens of the Order Scleractinia appear encrusted in the outer surfaces of pillows or as a part of pillow-fragment breccias. Sedimentary volcanogenic facies associations consist of volcanic breccias, sandstones and siltstones. In the basal part of this formation, some breccia layers contain metric, stratified rock blocks that seem to come from the sandstones and siltstones of the Toscano Formation. These layers are mainly constituted by basaltic/basanitic clasts but phonolitic clasts are also common.

Transitional Volcanic Group

Five units grouped into four different formations have been distinguished in this lithostratigraphic group, which are described from bottom to top.

Caleta del Barco Formation

Two different facies associations appear in this unit. Association G1 is mainly represented by trachytic breccias, including coarse-grained pyroclastic tuffs and lapilli tuffs. Clasts have different compositions, from strongly flow-foliated trachyte pumice fragments to rounded clasts of syenites, phonolites, sedimentary rocks (sandstones, siltstones, and cherts), phlogopite/amphibole-bearing basanites and basic plutonic rocks (phlogopitites, kaersutitites, and gabbros). The matrix of these breccias is always trachytic. Some layers are reversely graded. Association G2 comprises massive trachytic rocks with textures indicative of lava flows. Sometimes, they host syenite xenoliths, probably co-genetic.

Piedra de Fuera Formation

Several facies associations appear in this unit, including pillow lavas, pillow-fragment breccias, scoria pillow breccias, and phlogopite-amphibole dikes (camptonites) cutting the different units of the Submarine and Transitional Volcanic Groups. Interlayered pillow lavas and hyaloclasticic breccias are locally arranged as bands or “foresets” with high primary dip.

Janey Formation

In this formation, polymictic matrix-supported conglomerates are interlayered with volcanic sandstones. Conglomerates show normal or reverse graded bedding and parallel or cross lamination. Rock fragments have a varied composition (volcanic clasts, quartzsandstones, chert, sandstones, siltstones, pyroxenites, kaersutitites and syenites) and they are rounded, sometimes imbricate, and show a high sphericity index. Sandstones show normal grading and low-angle, planar cross-lamination.

Barranco de la Fuente Blanca Formation

This is a complex alternation of calcirudites, calcarenites, calcilutites and polymictic conglomerates with large variations in the proportions of bioclastic and volcaniclastic material. Robertson and Stillman (1979) previously described these layers. Clasts of igneous origin include plutonic rock fragments (syenites and gabbros), some of them highly rounded, and volcanic rocks (basalts and trachytes). Pyroxene, phlogopite, apatite and oxide mineral fragments are also common. Fragments of corals, echinoderms, bivalves, bryozoos, and benthonic (*Assilina*, Nummulitids and Rotaliids) and planktonic foraminifers are common. In some layers, there are fine-grained sedimentary fragments (lutites, cherts).

PETROGRAPHIC DESCRIPTION

The nephelinite and phonolitic nephelinites are slightly altered, vesicular, microporphyritic rocks containing predominantly phenocrysts of nepheline, clinopyroxene, Fe-Ti oxide, sanidine, melanite, biotite, titanite and rare apatite and perovskite. The fine-grained to cryptocristalline groundmass typically contains abundant clinopyroxene and nepheline, less common Fe-Ti oxide and sanidine, as well as accessory apatite. They contain also xenocrysts of amphibole, biotite and pyroxene. The basanites are slightly altered, vesicular, porphyritic rocks, with predominant pyroxene and less common kaersutite and phlogopite. These basanites show a fine-grained to cryptocrystalline and partly glassy groundmas of clinopyroxene, plagioclase, phlogopite, amphibole, and less common Fe-Ti oxides and accesssory apatite. They contain xenocrysts of amphibole, biotite, titanite and pyroxene. The phonolites and trachytes are microporphyritic rocks with sanidine, biotite, titanite or nepheline as phenocrysts and a fine grained to cryptocrystalline and partly glassy groundmass of sanidine, nepheline, Fe-Ti oxide and accessory apatite. The camptonites are slightly altered, vesicular, porphyritic rocks, with predominant pyroxene, kaersutite and phlogopite, and with a fine-grained to cryptocrystalline and partly glassy groundmass of clinopyroxene, plagioclase, less common Fe-Ti oxides and accessory apatite. The piroxenites, kaersutitites, ijolites, melteigites and nephelinitic syenites are coarse-grained plutonic fragments and xenolithes consisting of interlocking crystals of nepheline, clinopyroxene, sanidine, kaersutite, phlogopite, titanite, melanite, zircon, perovskite, piroclore, Fe-Ti oxide and apatite in very variable proportions. The syenites of the strongly alkaline series are coarse-grained plutonic fragment and xenolithes consisting of interlocking crystals of clinopyroxene, sanidine, kaersutite, phlogopite, titanite, Fe-Ti oxide and apatite in very variable proportions.

ABSOLUTE DATING METHODS

K-Ar dating

Measurement of K-Ar ages was performed in the Institute of Nuclear Research of the Hungarian Academy of Sciences (ATOMKI), Debrecen, using a mass spectrometer and an Ar line constructed in the institute. Potassium was determined by flame photometry with Li internal standard and Na buffer. Details of methods have been described by Balogh (1985) and have been summarized by Balogh et al. (1999). The interlaboratory standards Asia 1/65, HD-B1, LP-6 and GL-O as well as atmospheric Ar were used for controlling and calibration of the analyses. Details of the instruments, the applied methods and results of calibration have been described elsewhere (Odin et al., 1982; Balogh, 1985). K-Ar ages were calculated using the constants proposed by Steiger and Jäger (1977).

Ar-Ar dating

404.7 mg of CPV-2 phlogopite has been irradiated for 3 hours in the 229/3 position (out of the centre of the core) of the nuclear reactor of the Central Institute of Physics, Budapest, along with interlaboratoty standards biotite LP-6. In order to homogenize the radial change of the neutron flux, the sample was rotated during irradiation by the cooling water (Balogh and Simonits, 1998). Irradiation parameter was $J = 1.168x10^{-3}$ at the place of phlogopite CPV-2. Samples were trapped in Al foil and placed in a cylindrical container made of 0.5 mm thick Cd. The Cd container was sealed hermetically in an Al canister. Ar extraction was performed in a resistance heated molybdenum furnace. Temperature was controlled with a Pt-PtRd thermocouple. The furnace was connected to the Ar purification line used for K-Ar dating. Samples were heated for 50 min at each temperature step. Procedural system blanks (atmospheric composition) were measured before degassing at each temperature step (from 10^{-9} increasing to 10^{-8} cm^3 Ar at 1400ºC).

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