Sedimentary deposits and petrography of the basalts of the island of Tenerife of the Canary archipelago (Spain)

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Abstract. The article is devoted to the study of sedimentary deposits on the slopes of the Teide volcano and petrography of the volcanic rocks of the island of Tenerife of the Canary archipelago (Spain). A description of the sediments, which are presented on the island’s territory, and an analysis of the features of the material composition of rocks are given.

1. Introduction
The island of Tenerife is one of the largest islands of the Canary archipelago, belonging to Spain and located in the Atlantic Ocean. The area of the island is 2058 km². The height of its main volcano Teide is 3,718 m above sea level.

The name of the island comes from the words "tene" (mountain) and "ife" (white). It is the name, which was given to this island by the locals of the Guancho tribe, since in the winter the top of the Teide volcano is covered with snow. When the two words were combined, the letter 'r' was added and the modern name Tenerife was obtained [1]. The Teide volcano and the archipelago itself have a number of other features. This is the highest point in Spain. Taking into account the base of the volcano under the ocean, its height is about 6000 meters (Fig. 1).

Figure. 1. Exterior view of the Teide volcano today [photo by Gertner I F].
The geological history of this island and the archipelago, in general, is a unique subject of research for many scientists. For example, only in the history of mankind were recorded two eruptions of the Teide volcano itself. The tectonic position of the Canary Islands corresponds to the classical scheme of manifestation of intraplate magmatism in the conditions of the formation of the present-day ocean and is characterized by a wide range of igneous rocks, including tholeiitic and subalkaline basalts, tephrite, phonolites and xenoliths of ultramafites. In this paper, only some aspects of the geological structure of the Teide volcano and the features of the chemical and petrographic composition of the main varieties of rocks of a given geological object are considered.

2. Sedimentary deposits on the slopes of the Teide volcano.
Sedimentary deposits on the island are represented by weathering products of volcanics. One of the attractions of this resort is black sand, which is the result of the washout of basalt flows in the tidal zones. Directly in the Las Canajades caldera, the products of aeolian erosion are observed with the formation of bizarre forms of outcrops and eluvial-deluvial sediments. Partly they have features of lake sediments, in the springtime due to the melting of snow on the peak of Teide, the caldera is filled with water. During the construction of the trunk road on the western slope of the volcano, was discovered a zone of chemical weathering of volcanic deposits, called a "layered pie" (Fig. 2).

**Figure. 2.** Exposure along the road on the western slope of the Teide volcano, revealing products of chemical weathering of volcanic flows [Photo by Gertner I F].

Its structure is due to the almost horizontal deposition of layers, painted in dark gray and light colors with a greenish, bluish, yellowish or pinkish hue. The bizarre alternation of multi-colored layers allowed the builders to call this outcrop a "layered pie". The rocks in this outcrop are represented by fine-grained aleuro-clay material [2]. The different coloration of thin layers is due to variations in the
transformation conditions and the chemical composition of the products of volcanic eruptions, in particular, the enrichment of certain gases and the results of fumarolic activity. It should be noted that the width of this outcrop is only a few hundred meters and in the geomorphological terms is confined to the intermountain tract formed as a result of the “plowing” of the volcanic stream during the eruption of Teide in 1706 [3]. A similar type of exposure, but with a less spectacular variety of colors, is on the coast near the city of Garachico. Given that on this slope periodically forms a lake in the caldera of Las Canajes, it can be assumed that these rocks have a mixed origin, i.e. may be alluvial deposits of a locally occurring water stream. One of the arguments in favor of this point of view is another type of cemented boulder deposits, whose outcrops are observed literally 200 meters to the south in the same bay (Fig. 3).

![Figure. 3. Outcrops of cemented boulder-pebble deposits [photo by Gertner I F].](image)

This sedimentary complex is most likely formed due to the erosion of deluvium of the outcrops in the coastal zone, followed by cementation by clay material from the adjacent weathering zone. Probably, this was taking place against the background of a general uplift of the island. The strength of cementation of such deposits is not high, therefore in the most crowded places their outcrops are strengthened by a metal grid.

3. Petrographic description of the basalts of the island of Tenerife.

At the disposal of the author was a small number of samples that corresponded to the most widespread facies of eruptions of the island of Tenerife, namely, basalts. Among them, the following main varieties were identified, reflecting the different degree of crystallization and the likely formation conditions.

For the petrographic description of samples, the manual [4,5,6,7] was used as a definition of the optical constants of the minerals under study.

Olivine basalt - a dark-gray rock, cryptocrystalline, dense with numerous almonds and pronounced pores. In the pores fragments of organic remains are noted. Under the microscope, a porphyry structure and a disseminated homogeneous texture are established. The phenocrysts are represented by olivine and augite (with grain sizes in the average: 1-4 mm long, 0.5-1.5 mm wide). The bulk has a pilolate structure, consisting of microlites of olivine, plagioclase, augite, and magnetite. Mineral composition: olivine - 70%, augite - 5%, plagioclase - 15%, magnetite - 10%. Olivine is represented mainly in the form of phenocrysts. The phenocrysts have an elongated, isometric form of grains. At one nikole it is colorless with a high relief and slightly pronounced cleavage at an angle of 90°. In
crossed nicols has bright colors of interference: the birefringence index is \( \text{Ng-Np} = 0.34 \), the extinction angle \( c: \text{Ng} = 0 \). Olivine is also observed in the form of microliths. In this sample, there are grains in the form of "windows", where the olivine grain and the bulk of it, this indicates that rapid crystallization has occurred. Augite is represented in phenocrysts with angular, diamond-shaped, hexagonal grains with dimensions on average: along the length up to 2.5 mm and in width up to 1 mm. In crossed nicols, a slightly greenish color with a shade of gray is observed, the refractive index \( \text{Ng-Np} = 0.25 \) with an extinction angle \( c: \text{Ng} = 42 \). In one nikoile, it is colorless. The characteristic extinction is in the form of a figure of an hourglass, which allows us to call it augite. Plagioclase is \( \text{Ng} = 0.25 \) with an extinction angle \( c: \text{Ng} = 42 \). In one nikoile, it is colorless. The characteristic extinction has bright colors of interference: the birefringence index of \( \text{Ng-Np} = 0.007 \). Characterized by polysynthetic twins. To determine the number of plagioclase, more than five measurements of different grains were performed. As a result, andesine with the number 37 was determined. Magnetite is observed as a fine expressed rash, isotropic.

Similar to this breed are samples №2, №4 and №6, but there are small differences. In sample No. 2 the rock is dense with less pronounced porosity, and sample No. 4 in terms of density and porosity corresponds to sample № 2 and has two differences from sample No. 1. Here olivine has more rounded grains, and augite is green in color, in sample No. 6 large elongated grains of olivine are observed. In all samples, the amount of phenocrysts reaches 10%.

The basalt conglomerate is composed of pebbles of gray, dark gray and brown color, cemented with light gray cement. The structure is small-pebble. The size of the wreckage varies from 0.5mm to 2cm in the diameter. Pebbles are well-rounded (3rd class of roundness according to A.V. Khabakov). The texture is spotty due to the presence of darker fragments on the background of light-colored cement. Microscopically the rock has a light gray, brown color. The bulk is poorly crystallized with a hyalopilite structure. Pebbles are represented by basalt, phenocrysts of olivine and pyroxene are separately observed. Olivine has a rounded shape of grains, in one nikoile it is colorless with a pronounced relief and slightly pronounced cleavage. In crossed nicols has bright colors of interference, the refractive index \( \text{Ng-Np} = 0.036 \). We observe a direct extinction angle \( c: \text{Ng} = 0^\circ \). Augite is presented in the form of an angular, hexagonal shape. In one nikoile - colorless, brownish. In crossed nicols, the extinction angle \( c: \text{Ng} = 42^\circ \), the refractive index \( \text{Ng-Np} = 0.025 \). In pebbles, small porphyry grains of plagioclase are observed (with dimensions of up to 0.5 mm in width and up to 3 cm in length), as well as a small number of fine augite grains with a dimension of up to 1.5 cm in length and a width of up to 0.5 cm. Plagioclase in one nikoile is colorless, and in crossed nicols has a light gray color with a refractive index of \( \text{Ng-Np} = 0.009 \). Based on the results of several measurements, plagioclase was determined under number 39 - andesine.

The sintered tuff - a brown rock, which is composed of rounded fragments of volcanic glass with dimensions: up to 4 cm in length and up to a width of 1.5 cm, isotropic. Cement is iron-chlorite. In addition, there are grains of olivine and augite. A shell-shaped form with a brownish color in crossed nicols prisms and black in one, isotropic, represents volcanic glass. Olivine is presented in the form of small diamond-shaped, elongated grains with dimensions: length up to 3mm and width to 0.05mm. In one nikoile is colorless, and in crossed nicols has bright colors of interference, has a birefringence index \( \text{Ng-Np} = 0.037 \). Augite is observed in the form of elongated grains with dimensions on average: 1 mm in length and in width to 0.02 mm. In crossed nicols, the refractive index: \( \text{Ng-Np} = 0.025 \) and the extinction angle \( c: \text{Ng} = 42 \), and in one nikoile is colorless.

Olivine is a pyroxene porphyrite, which is characterized by a dark gray color. In the breed, there is a large number of phenocrysts, which are represented by olivine and pyroxene. Under the microscope, the structure of the main mass is intergranular; the texture is interspersed. The phenocrysts are represented by olivine and augite. Olivine is observed in the form of rounded and diamond-shaped grains with an average length of up to 8 mm and a width of up to 3 mm. In one Nikole it is colorless with a pronounced relief, in crossed nicols prisms has bright colors of interference with a birefringence index \( \text{Ng-Np} = 0.038 \) from yellow to blue-green color. The grains are large and heavily "cracked." Augite is represented in the form of elongated grains with dimensions, on average, in length up to 1 cm
and in width up to 0.5mm. In one nikel it is colorless, while gray-violet color with a zonal structure is observed in the crossed ones, the refractive index Ng-Np = 0.05, c: Ng = 42.

Gialobasalt - presumably the basic composition. The structure is hyalopilitic. The whole rock is composed of a glassy, isotropic mass. In the form of microlites and small phenocrysts, plagioclase and biotite grains are fixed, which makes it possible to compose this rock with basaltoids of increased alkalinity. Plagioclase is represented in the form of small, elongated grains (microlites) with polysynthetic twins. In the crossed nicols it has the light gray interference colors; the refractive index Ng-Np = 1.530. In one nikel it is colorless. The size of grains on average up to 2 cm in length and the width to 0.5 cm. Biotite is observed in the form of elongated leaves. In one nikel, it has brown colors interfere with pleochris, in crossed - yellowish. The birefringence index is Ng-Np = 0.050, the extinction angle is c: Ng = 0. Laminar motion is observed in this rock.

4. Features of the chemical composition of volcanics of the Canary Archipelago.
The igneous rocks of a given geological object have a wide range of compositions, reflecting variations from ultrabasic to medium magma derivatives. The main mass of the rocks corresponds to the series of increased alkalinity (Figure 4).

![Figure 4. Binary diagram of Na2O + K2O - SiO2.](image)

In this diagram (Fig. 4), it can be observed that the rocks correspond to families of ultrabasic, basic and medium breeds. Figurative points, located on the interval of SiO2 content of 40-45%, belong to ultrabasic rocks. The SiO2 content (45-53%) corresponds to the composition of the main rocks. The SiO2 content (53-61%) belongs to the middle rocks. According to the content of alkalis, all rocks vary from 3 to 15%, where the most alkaline are phonolites, and the least alkaline - subalkaline basalts and basanites. The ratio of iron and magnesium oxides allows them to be diagnosed as products of the tholeiitic series (Fig. 5).
However, it should be noted, that the products of high-alkaline magmas of K-Na specialization are characterized by increased iron content and, as a rule, correspond to derivatives of the thallium trend, whereas their varieties of increased potassium can correspond to calc-alkaline specialization.

According to the results of the analysis of the diagram "K2O / Na2O) -SiO2" (Figure 6), we see that most rocks belong to the potassium-sodium series, and only individual figurative points of tephrite fall into the region of sub-potassium and potassium derivatives proper. These deviations may be associated with late metasomatic changes in these rocks or with the process of interaction with groundwater enriched with potassium.
As a result of petrochemical analyzes, it can be concluded that the volcanic rocks of the Canary Archipelago and the Tenerife Islands in particular belong to the products of the alkaline and subalkaline K-Na series of specialization, which is a typical example of plume magmatism under oceanic crust conditions. Further more detailed geochemical and isotopic studies will make it possible to clarify the sources of matter of mantle substrates and their interaction with the oceanic crust.

5. Conclusions
The conducted researches allow to distinguish several stages of formation of the Canary Oceanic archipelago by the example of the island of Tenerife. In addition to the volcanic eruptions proper, which are responsible for the growth of the relief above the ocean level, the processes of weathering play an important role, creating the formation of a peculiar soil cover and unique flora and fauna. The analysis of the material composition of basaltoids and their probable differentiates, as the most representative species of the Tenerife rocks, makes it possible to compare them with the products of magmatic activity of increased alkalinity in the potassium-sodium specialization, which is typical for the manifestation of plumes on the structures of modern oceans.

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