DEPARTMENT OF THE INTERIOR
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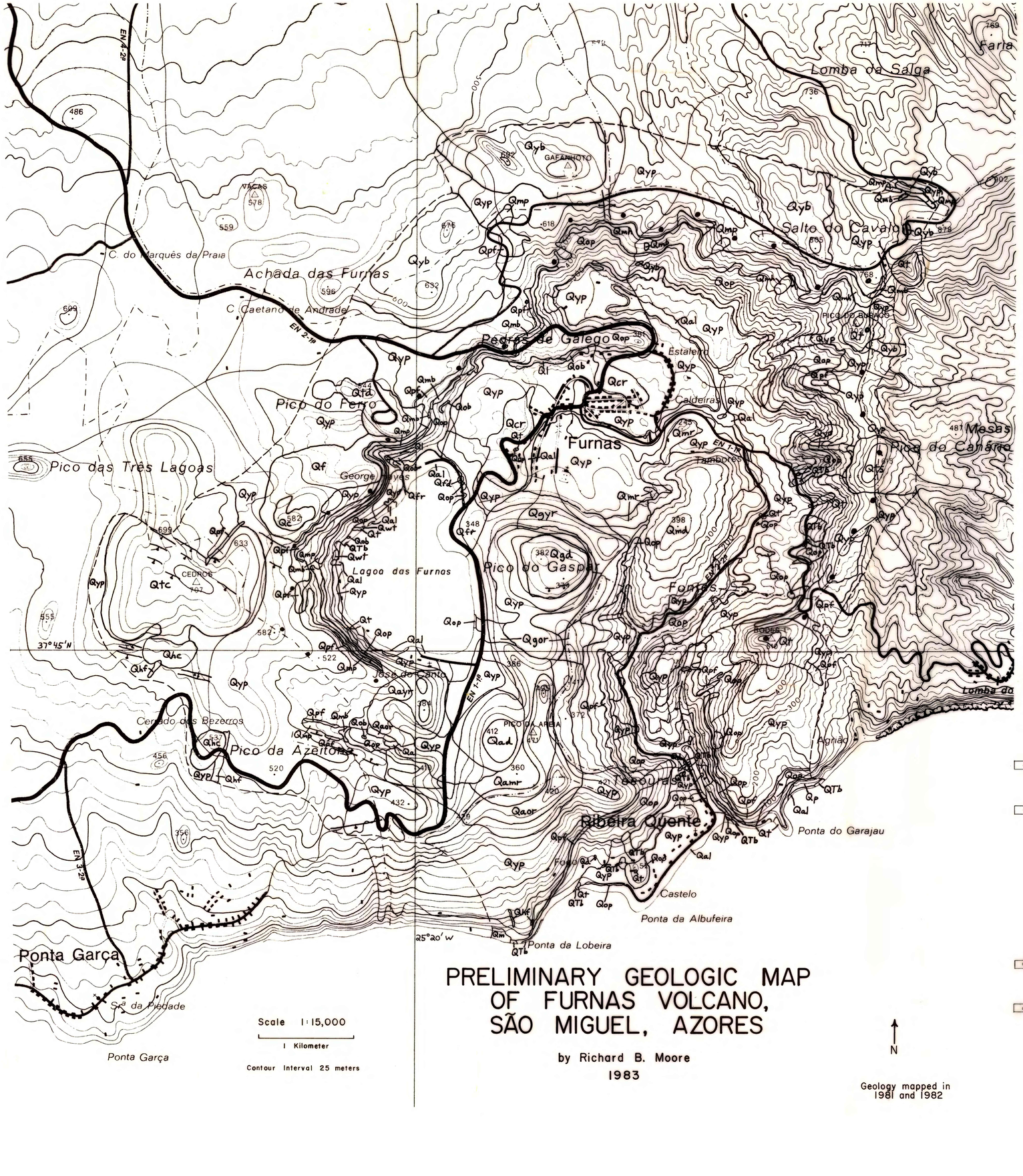


PRELIMINARY GEOLOGIC MAP OF FURNAS VOLCANO, SÃO MIGUEL, AZORES

by Richard B. Moore

1983

Scale 1:15,000

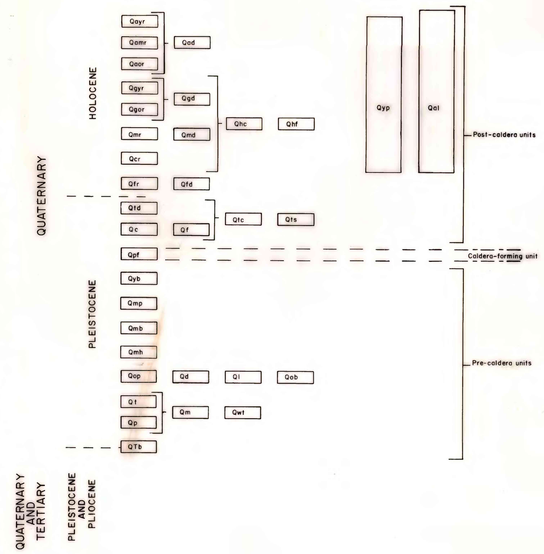
1 Kilometer

Contour Interval 25 meters

N

Geology mapped in 1981 and 1982

CORRELATION OF MAP UNITS



Qc — Two cinder and spatter cones, including Pico da Azeitona, on the southwest edge of the map. Consist of aphyric basalite. Overlie Qtc; interbedded with pre-A.D. 1640 part of Qyp.

Qhf — Aphyric basalite as flows from Qhc and from a buried vent on the south flank of the volcano. Interbedded with pre-A.D. 1640 part of Qyp.

Qpf — Pyroclastic flows, commonly welded; includes minor Plinian and sub-Plinian pumice deposits, ash, and mudflows. Consists mainly of welded and nonwelded trachyte pumice with 5-10 percent alkali feldspar and 1-2 percent biotite phenocrysts. Xenoliths of obsidian, trachyte, syenite, and basalt are present. Thickness commonly is 25-50 m but ranges from about 1 to 60 m. Thickness of the welded zone ranges from less than 1 m to about 25 m. The eruption was directed mainly south and east, but the deposit also is recognizable 10 km north of the village of Furnas. Volume is about 7 km^3, roughly the same as that of the caldera; ejection of Qpf was the main cause of caldera formation. Qpf occurs at or just below the western caldera rim; it fills canyons on the south flank of Furnas Volcano, near Ribeira Quente, and in the older Povoação caldera that adjoins Furnas Volcano to the east.

Qyb — Basalt cinder and spatter cones and small aa flows; includes one dike that intrudes Qyp on the north caldera wall. Qyb flow at Pico do Buraco erupted from the flank of the trachyte dome, Qt. Consist of alkali olivine basalt with 5-15 percent pyroxene, less than 1 to 15 percent olivine, and less than 1 to 20 percent plagioclase phenocrysts. Xenoliths of pyroxenite and wehrlite are present. Distribution restricted to the north side of the volcano. Thickly mantled by Qyp.

Qmp — Trachyte pyroclastic deposits, chiefly mudflows and pumice deposited by Plinian and sub-Plinian eruptions; includes ash and bentonitic pyroclastic flow deposits. Discontinuously exposed on west and north parts of the volcano. Xenoliths of obsidian, trachyte, and basalt are present.

Qmb — As flows of alkali olivine basalt and hawaiite; includes one small trachyte flow in the caldera wall on the east side of Pico do Ferro. Eruptions restricted to the west and north caldera wall; source vents generally are west and north of the mapped area. Small body of Qmb surrounded by Qyb on north caldera wall is hawaiite scoria that overlies Qmb. Basalt flows contain less than 1 to 2 percent olivine, less than 1 to 2 percent pyroxene, and 0-3 percent plagioclase phenocrysts. Hawaiite flows are aphyric. Trachyte flow contains 5-10 percent alkali feldspar phenocrysts. Scattered xenoliths of pyroxenite and wehrlite occur in most basalt flows.

Qmh — As flow on north caldera wall. Consists of hawaiite with less than 1 percent feldspar phenocrysts. Source vent buried beneath younger pyroclastic materials north of the mapped area. Locally overlain by Qmb.

Qap — Trachyte pyroclastic deposits, chiefly mudflows and pumice deposited by Plinian and sub-Plinian eruptions; includes minor ash, pyroclastic flow, and blast deposits. On west caldera wall unit is mainly Plinian pumice, interbedded with Ql and Qmb; on north caldera wall and in the canyon between Furnas and Ribeira Quente unit consists mainly of mudflows; in section northeast of Ponta da Lobeira unit includes mudflows, Plinian bpds, pyroclastic flows, blast deposits, and ash. Xenoliths of basalt, trachyte, and obsidian are present. Charcoal from a pyroclastic flow about 30 m above the base of the coastal section has a ^{14}C age of about 33,000 years (M. Rubin, oral commun., 1983).

Qd — Two dikes near Ribeira Quente. Intrude Qyp and are overlain by some Qap. Consist of microcrystalline trachyte with 1-3 percent feldspar and 1-3 percent biotite phenocrysts.

Ql — Lacustrine sediments; interbedded with Qap and Qmb on west caldera wall. Consist mainly of well-stratified, fine-grained, locally carbonaceous trachyte ash deposited in lakes that formed during the deposition of Qap.

Qmb — Basalt and basalite as and pahoehoe flows, interbedded with Qap and Ql on west caldera wall; includes one basalt dike and one small trachyte flow. Flows commonly exhibit pillow structures. Alkali olivine basalt contains 1-4 percent pyroxene, less than 1 percent olivine, and less than 1 percent plagioclase phenocrysts. Hawaiite is aphyric. Trachyte contains 2-4 percent alkali feldspar and less than 1 percent biotite phenocrysts.

Qt — Trachyte domes and flows. Lithology generally is uniform, consisting of 5-15 percent alkali feldspar and less than 1 to 3 percent biotite phenocrysts in a microcrystalline groundmass. Flow that underlies Ponta do Garajau apparently is hybrid and consists of microcrystalline trachyte with 1-3 percent alkali feldspar, 1-3 percent biotite, less than 1 percent olivine, less than 1 percent pyroxene, and less than 1 percent amphibole phenocrysts; scattered xenoliths of syenite, wehrlite, and olivine-phyric basalt are present.

Qp — Trachyte pyroclastic deposits underlying flow (Qt) that forms Ponta do Garajau. Basal 15 m is a blast deposit; upper 20 m is a mudflow. Source is either Furnas or Povoaçao Volcano, about 4 km to the east.

Qb — Mudflow of Ponta da Lobeira; includes thin (<1 m) plagioclase-phyric basalt dikes. Mudflow is chiefly trachyte with 10-15 percent alkali feldspar and less than 1 percent biotite phenocrysts; fragments of basalt are abundant. Lithification and alteration have obliterated most original structures, but, locally, slight stratification is present (dips are 5-10° west).

Qvt — Poorly exposed welded tuff at base of caldera wall on west side of Lagoa das Furnas. Consists chiefly of welded trachyte pumice with 5-10 percent alkali feldspar and less than 1 percent biotite phenocrysts. Source may have been Povoaçao Volcano, about 9 km to the east.

Qfb — As flows correlated with the Nordeste volcanic complex of Fernandez (1980). In the map area includes alkali olivine basalts, hawaiites, and mugearites; may include andesmite, since clasts of this lithology occur in some basal mudflows of Qpp at the base of the caldera wall on the west side of Lagoa das Furnas. Basalts contain 1-2 percent pyroxene, less than 1 to 5 percent altered olivine, and 0-5 percent plagioclase phenocrysts. Hawaiites and mugearites generally are aphyric or contain less than 1 percent biotite phenocrysts. K-Ar ages of the Nordeste complex east of the map area are about 1-4 m.y. (Abdel-Monen and others, 1975).

GEOLOGIC SUMMARY

Furnas Volcano, a stratovolcano with a maximum elevation of about 800 m above sea level, is located in the east central part of São Miguel, Azores. A caldera about 6 km in diameter, with walls up to 0.5 km high, truncates its summit. Detailed geologic mapping of about 75 km^2 indicates that eruptive units that predate formation of the caldera crop out chiefly in the caldera walls and in sea cliffs on the south coast. Post-caldera units are partial pumice rings and associated trachyte domes distributed across the caldera floor. Pre- and post-caldera cones of basalt and hawaiite occur outside the caldera boundary, chiefly on its north and west sides.

The Quaternary Furnas Volcano overlies the 1-4 m.y. Nordeste volcanic complex (Fernandez, 1980), exposed near Ribeira Quente on the south coast of São Miguel and at the bases of the caldera walls. Xenoliths of Nordeste basalt are locally common in later Plinian fall deposits.

The oldest rocks of Furnas Volcano probably are upper Pleistocene and include trachyte domes and flows exposed at the bases of the caldera walls and in sea cliffs near Ribeira Quente.

Trachyte pyroclastic deposits, chiefly mudflows and pumice deposited during Plinian and sub-Plinian eruptions, overlie the early domes and flows. Charcoal from 30 m above the base of this early pyroclastic unit has a ^{14}C age of about 33,000 years. Fine-grained ash accumulated in lakes that formed during this time. Basalt, basalite, and trachyte flows from vents west and north of Furnas entered some of these lakes and formed pillow lavas. Cones and flows of pyroxene-rich basalt overlie the trachyte pyroclastic units on the north flank of the volcano.

About 10,000-15,000 years ago, the modern caldera formed after ejection of at least 7 km^3 of trachyte pumice. This eruption produced pyroclastic flows that were directed primarily south and east; the deposit also is recognizable 10 km north of Furnas. The pyroclastic flows, commonly welded, fill canyons on the south flank of Furnas Volcano and in the older adjoining Povoaçao caldera.

Trachyte domes and scoria cones that immediately postdate formation of the caldera were erupted from radial and concentric fractures, chiefly west of Lagoa das Furnas, that likely formed during caldera collapse.

At least eleven Plinian and sub-Plinian eruptions of trachyte pumice, in four cases associated with emplacement of domes, have occurred from vents within the caldera during Holocene time. The largest of these eruptions produced the Furnas C deposit, dated at about 2900 years old (Booth and others, 1978). At least three eruptions of hawaiite occurred at vents west and south of the caldera during the same period. The most recent eruption of trachyte pumice occurred in A.D. 1640 and buried the south rim of the caldera.

Many fumaroles occur within the caldera and around its margins (Zbyszewski and others, 1958). Most of the fumaroles appear to be related to concentric caldera faults or to fractures that are radial to post-Furnas C domes.

DESCRIPTION OF MAP UNITS

Qal — Alluvial, lacustrine, and littoral deposits, consisting chiefly of silt- to boulder-sized clasts of mafic and trachytic lava flows, obsidian, welded tuff, syenite, and pumice. Approximately coeval with Fogo A (about 4600 years old; Walker and Croasdaile, 1970) and younger airfall pumice deposits (Qpy). Not distinguished where underlying units can be recognized.

Qpy — Widespread airfall pumice deposits, chiefly from vents within Furnas caldera; locally includes pumice from the Agua de Pau Volcano (Walker and Croasdaile, 1970; Booth and others, 1978), 15 km west of the village of Furnas. Isopachs of the deposits from Furnas Volcano are given in Booth and others (1978). Qpy north of the village of Furnas is dominated by the Furnas C deposit, dated at about 2900 years (Shotton and Williams, 1971); this deposit includes airfall pumice, mudflows, and carbonaceous lacustrine sediments. North and east of the village, Qpy also includes small unmapped mudflows of the underlying unit, Qpp. Qpy on the east side of Lagoa das Furnas is dominated by pumice ejected during emplacement of the Pico do Gaspar trachyte dome (Qgd). Qpy on the east side of the caldera is dominated by pumice ejected during emplacement of two trachyte domes (Qmd) between Tamboresta and Fontes (Pico das Mercondas of Zbyszewski, 1958, and Booth and others, 1978). Qpy on the south side of Furnas Volcano is dominated by pumice and mudflows of the A.D. 1640 eruption; the basal 1640 deposit between Pico da Azeitona and Ribeira Quente is a pyroclastic flow with abundant fragments of charcoal. Qpy west of Lagoa das Furnas includes deposits from the above sources as well as from the Agua de Pau Volcano. Extensive human modification of the surface complicates identification of the separate deposits between their source vents. Qpy nanties all pre-existing and penecontemporaneous units, except the youngest Qvt; it is not distinguished where underlying units can be recognized. Consists mainly of trachyte pumice with minor xenoliths of dense trachyte, obsidian, and basaltic rocks.

Qpyr — Youngest partial pumice ring of the A.D.1640 eruption, nested within part of Qpyr and Qpcr. Consists chiefly of trachyte pumice deposited during Plinian and sub-Plinian eruptions associated with emplacement of the Pico da Areia trachyte dome (Qpd). Locally includes surge deposits and lenticular pyroclastic flows. Scattered xenoliths of obsidian, trachyte, and basalt are present. Coeval with part of Qpy.

Qpcr — Middle partial pumice ring of the A.D. 1640 eruption, nested within part of Qpcr. Similar to Qpyr and Qpcr in origin and composition; locally includes relatively fine-grained, lithic-rich beds that may have resulted from explosive disintegration of part of Qpd. Locally altered by slightly younger fumaroles. Coeval with part of Qpy.

Qocr — Oldest partial pumice ring of the A.D. 1640 eruption. Similar to Qpyr and Qpcr in origin and composition. To the east and south, unit grades into mudflow, pyroclastic flows, and Plinian and sub-Plinian deposits of Qyp.

Qpd — Dome of Pico da Areia (Cova da Burra of Zbyszewski and others, 1958, and Booth and others, 1978), erupted in A.D. 1640. Consists of greyish-white microcrystalline trachyte with 1-3 percent alkali feldspar phenocrysts. Mantled by Qyp.

Qgyr — Younger trachyte pumice ring of Pico do Gaspar, which it nearly encircles; nested within part of Qpcr. Consists chiefly of coarse pumice resulting from Plinian and sub-Plinian eruptions associated with emplacement of the Pico do Gaspar trachyte dome (Qgd). Locally includes lenticular pyroclastic flow deposits. Large pumice fragments commonly partly welded to black glass. Scattered xenoliths of obsidian, trachyte, and basalt are present. Coeval with part of Qyp.

Qgor — Older partial pumice ring of Pico do Gaspar. Similar to Qgyr in origin and composition. Thickly mantled by younger pumice of Qgyr and the A.D. 1640 eruptions. Coeval with part of Qyp.

Qgd — Dome of Pico do Gaspar. Consists of grey to brown microcrystalline trachyte with 3-6 percent alkali feldspar and less than 1 percent biotite phenocrysts. Thickly mantled by Qyp.

Qmr — Partial trachyte pumice ring on the north and west sides of Qad. Generally poorly exposed due to burial by Qyp; where truncated by roads consists of pumice deposited during Plinian and sub-Plinian eruptions associated with the emplacement of Qad. Locally includes lenticular pyroclastic flow deposits. Xenoliths of obsidian, trachyte, and basalt are present. Coeval with part of Qyp.

Qmd — Two large domes (Pico das Mercondas of Zbyszewski and others, 1958, and Booth and others, 1978) between Tambores and Fontes. Consist of microcrystalline trachyte with 8-12 percent alkali feldspar and less than 1 percent biotite phenocrysts. Thickly mantled by Qyp.

Qcr — Partial trachyte pumice ring of the Furnas C eruption (Booth and others, 1978), exposed north and west of the village of Furnas. Consists mainly of pumice and ash deposited during Plinian and sub-Plinian eruptions; lenticular pyroclastic flow deposits are rare. Xenoliths of obsidian, trachyte, and basalt occur rarely. Partly overlain by Qyp, here consisting mainly of mudflows that occurred toward the end of the Furnas C eruption. ^{14}C age is about 2900 years (Shotton and Williams, 1971).

Qfr — Partial trachyte pumice ring on the northeast and northwest sides of Lagoa das Furnas. Poorly exposed; where visible consists of pumice deposited during Plinian and sub-Plinian eruptions, ash, blast deposits, and minor mudflows. Angular xenoliths of obsidian, trachyte, and basalt are common in the blast deposits and scattered in the Plinian and sub-Plinian beds. Likely source was the roughly circular crater that forms the northern part of Lagoa das Furnas.

Qfd — Small dome exposed in a roadcut on the northeast side of Lagoa das Furnas. Consists of altered reddish-to greenish-grey microcrystalline trachyte with 10-15 percent alkali feldspar phenocrysts. Probably emplaced during the eruption that formed Qfr.

Qtd — Domes of Pico de Ferro. Seven juxtaposed domes that consist of microcrystalline to glassy trachyte with 8-12 percent alkali feldspar and less than 1 percent biotite phenocrysts. Domes erupted along an arcuate fissure that trends from NS0W to west; the fissure is approximately radial to the caldera and likely formed at about the same time that the caldera collapsed. Qtd, Qc, Qf, Qtc, and Qts are considered to be only slightly younger than Qpf, the caldera forming unit; the apparent truncation of the eastern end of Qtd at the caldera rim suggests either that caldera collapse was not yet complete at the same time that Qtd erupted or that part of the easternmost dome cascaded into the caldera during its eruption. ^{14}C age is 10,000-15,000 years (M. Rubin, oral commun., 1983). Thickly mantled by Qyp.

Qc — Cone west of Lagoa das Furnas, between Cedros and Pico do Ferro. Consists of vesicular microcrystalline to glassy trachyte scoria with 1-3 percent alkali feldspar and less than 1 percent biotite phenocrysts. Thickly mantled by Qyp.

Qf — As flow from Qc. Consists of microcrystalline trachyte with 1-3 percent alkali feldspar and less than 1 percent biotite phenocrysts. Thickly mantled by Qyp.

Qtc — Cones and flows of the Cedros area, about 1.5 km west of Lagoa das Furnas. Five or more scoria cones formed along fractures that are concentric to the caldera and that probably developed as a consequence of caldera collapse. The related flows, that rafted coneal scoria, extend short distances from the cones. Cones and flows consist of vesicular microcrystalline to glassy trachyte with 3-5 percent alkali feldspar and 1-2 percent biotite phenocrysts. Unit overlies Qpf in a deep canyon on the northwest side of Cedros. Thickly mantled by Qyp.

Qts — Cone of Pico do Canario, on the east rim of the caldera. Consists mainly of coarse trachyte pumice, locally partly welded to black glass, with 3-5 percent biotite and 1-2 percent alkali feldspar phenocrysts. Mantled by Qyp.

GEOLOGIC MAP SYMBOLS

- Contact, approximately located
- Normal fault, hell on downthrown side
- Map boundary
- Caldera boundary, approximately located

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.