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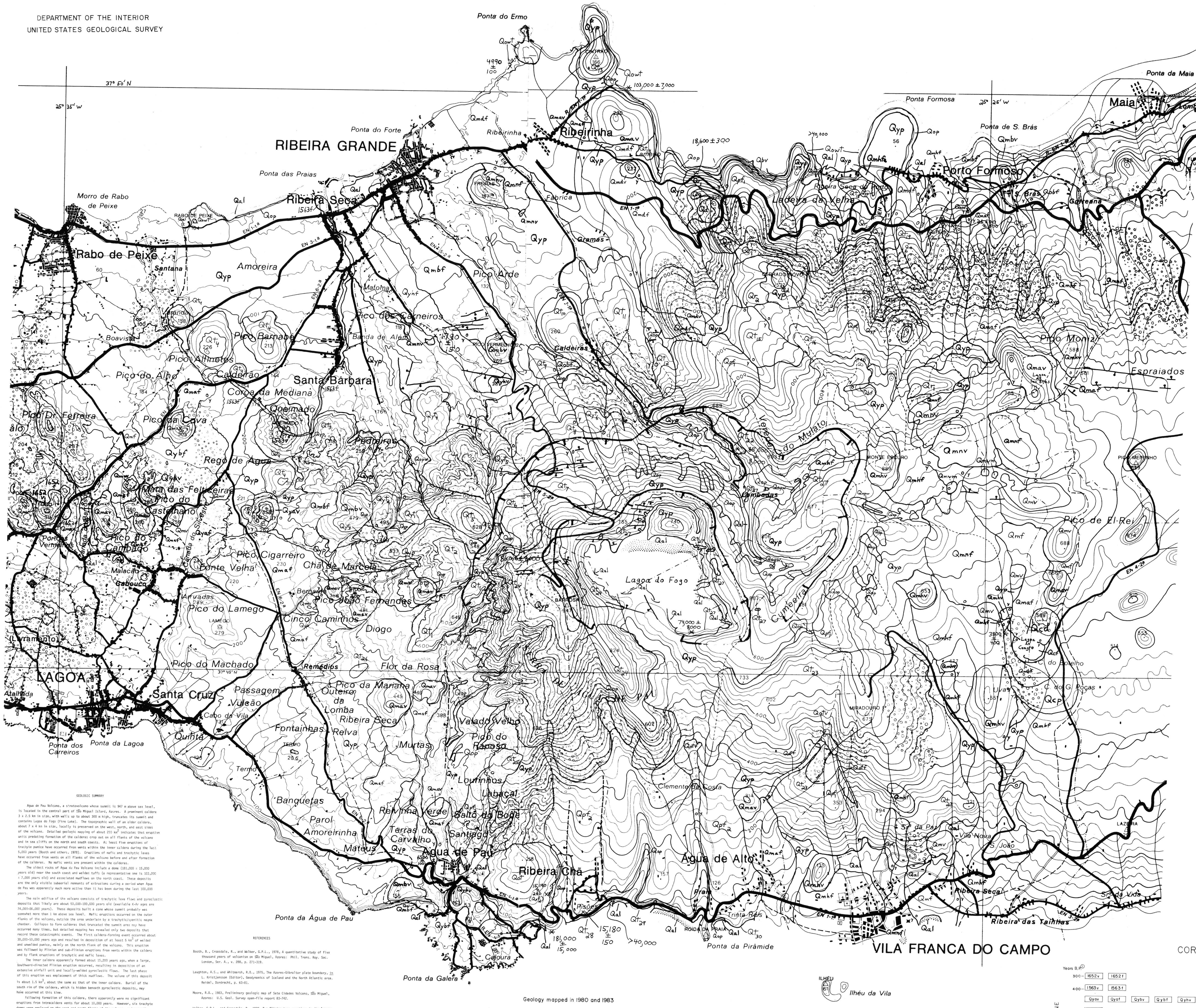

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PRELIMINARY GEOLOGIC MAP OF AGUA DE PAU VOLCANO, SÃO MIGUEL, AZORES

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GEOLOGIC SUMMARY

Agua de Pau Volcano, a stratovolcano whose summit is 947 m above sea level, is located in the central part of São Miguel Island, Azores. A prominent caldera 3 x 2.5 km in size, with walls up to about 300 m high, truncates its summit and contains Lagoa do Fogo (Fire Lake). The topographic wall of an older caldera, about 7 x 4 km in size, locally is preserved on the west, north, and east sides of the volcano. Detailed geologic mapping of about 250 km^2 indicates that eruptive units predating formation of the calderas crop out on all flanks of the volcano and in sea cliffs on the north and south coasts. At least five eruptions of trachyte pumice have occurred from vents within the inner caldera during the last 5,000 years (Booth and others, 1978). Eruptions of mafic and trachytic lavas have occurred from vents on all flanks of the volcano before and after formation of the calderas. No mafic vents are present within the calderas.

The oldest rocks of Agua de Pau Volcano include a dome (181,000 ± 15,000 years old) near the south coast and welded tuffs (a representative one is 103,000 ± 7,000 years old) and associated mudflows on the north coast. These deposits are the only visible subaerial remnants of extrusions during a period when Agua de Pau was apparently much more active than it has been during the last 100,000 years.

The main edifice of the volcano consists of trachytic lava flows and pyroclastic deposits that likely are about 50,000-100,000 years old (available K-Ar ages are 74,000-86,000 years). These deposits built a cone whose summit probably was somewhat more than 1 km above sea level. Mafic eruptions occurred on the outer flanks of the volcano, outside the area underlain by a trachytic/syenitic magma chamber. Collapse to form calderas that truncated the summit area may have occurred many times, but detailed mapping has revealed only two deposits that record these catastrophic events. The first caldera-forming event occurred about 30,000-50,000 years ago and resulted in deposition of at least 5 km^3 of welded and unwelded pumice, mainly on the north flank of the volcano. This eruption was followed by Plinian and sub-Plinian eruptions from vents within the caldera and by flank eruptions of trachytic and mafic lavas.

The inner caldera apparently formed about 15,200 years ago, when a large, southward-directed Plinian eruption occurred, resulting in deposition of an extensive airfall unit and locally-welded pyroclastic flows. The last phase of this eruption was emplacement of thick mudflows. The volume of this deposit is about 1.5 km^3, about the same as that of the inner caldera. Burial of the south rim of the caldera, which is hidden beneath pyroclastic deposits, may have occurred at this time.

Following formation of this caldera, there apparently were no significant eruptions from intracaldera vents for about 10,000 years. However, six trachyte domes were emplaced on the west and north flanks of the volcano, and sporadic mafic eruptions continued from vents outside the area underlain by the magma chamber.

The caldera became active again about 5,000 years ago, when the large Fogo A Plinian deposit and associated mudflows (Walker and Croasdale, 1970) were erupted. The Fogo A deposit rests directly on the 15,200-year-old caldera-forming unit on the south flank of the volcano.

Four more Plinian and sub-Plinian eruptions of trachyte pumice, the latest in A.D. 1563, have occurred from vents within the caldera since deposition of Fogo A (Booth and others, 1978). The maar of Lagoa do Congro and two associated trachyte domes formed about 3,800 years ago on the east flank of the volcano. Eruption of mafic lavas from flank vents, chiefly on the west side of the volcano, occurred throughout this period, most recently in A.D. 1652.

Several fumaroles (Zbyszewski and others, 1958, 1959) occur on the north flank of Agua de Pau Volcano. They apparently have been localized by shallow west- to northwest-trending faults whose traces are approximately parallel to the Azores fracture zone (Laughton and Whitmarsh, 1975) that lies north of São Miguel. Several fumaroles occur near intersections of these faults with the outer caldera boundary.

Xenoliths of syenite occur in mafic and trachytic lavas erupted throughout the subaerial sequence and are particularly abundant in the 15,200-year-old and Fogo A deposits. The xenoliths probably represent fragments of a pluton emplaced during formation of the ancestral (>100,000 years old) Agua de Pau Volcano. Xenoliths of gabbro and ultramafic rocks, including spinel lherzolite, occur in some mafic cones and flows.

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DESCRIPTION OF MAP UNITS

Qal — Alluvial, littoral, eolian, and lacustrine deposits, consisting chiefly of silt- to boulder-sized clasts of pumice and mafic and trachytic lava flows and domes. Approximately coeval with post-Fogo A (Walker and Croasdale, 1970) deposits. Not mapped where underlying units can be recognized.

1652v — Cone of Fogo 1[3], at the west edge of the map. Consists of alkali olivine basalt, transitional to hawaiite, with 3-6 percent olivine, 3-6 percent clinopyroxene, and 1-3 percent plagioclase phenocrysts. Cone formed during the A.D. 1652 eruption, the most recent on São Miguel.

1652f — Aa and pahoehoe flow from 1652v. Consists of alkali olivine basalt, transitional to hawaiite, with 3-5 percent olivine, 3-6 percent clinopyroxene, and 1-3 percent plagioclase phenocrysts.

1563v — A.D. 1563 spatter rampart on top of Queimado (west part of map). Consists of alkali olivine basalt with 1-3 percent olivine and less than 1 percent clinopyroxene phenocrysts. Scattered xenoliths of syenite are present. This eruption immediately followed a trachytic Plinian eruption in the Agua de Pau caldera.

1563f — Pahoehoe flow from 1563v. Consists of alkali olivine basalt with 1-3 percent olivine and less than 1 percent clinopyroxene phenocrysts. Scattered xenoliths of syenite are present.

Qyp — Widespread airfall pumice and mudflow deposits, chiefly from vents within Agua de Pau caldera; includes minor pumice from Sete Cidades Volcano, 30 km to the west-northwest (Booth and others, 1978; Moore, 1983). Isopachs of the five subunits from Agua de Pau Volcano are given in Booth and others (1978). Consist mainly of trachyte pumice with minor xenoliths of dense trachyte and mafic rocks. Unit is dominated by the Fogo A deposit (Walker and Croasdale, 1970), whose ^{14}C ages range from about 4,400-5,300 years old (M. Rubin, written commun., 1984). The youngest major contributor to Qyp was the A.D. 1563 Plinian eruption in Agua de Pau caldera (Walker and Croasdale, 1970). Locally includes basaltic pyroclastic deposits from adjacent vents (including a pre-Fogo A, 0.5-m-thick accretionary lapilli bed on the north coast near Ribeirinha), trachyte pumice (Qcp) from Lagoa do Congro, and minor alluvium. Qyp is thinnest (<1m) on the few units that postdate the Fogo A deposit. Qyp mantles all pre-existing and penecontemporaneous units and underlies the youngest Qal and mafic lavas erupted in A.D. 1563 and 1652; it is not mapped where underlying units can be recognized.

Qyav — Spatter and rootless flows that form a cone (358 m above sea level; west part of map) about 1 km south of Queimado. Consist of ankaramitic basalt with 10-15 percent olivine and 5-10 percent pyroxene phenocrysts.

Qyaf — Aa flow from Qyav. Consists of ankaramitic basalt with 10-15 percent olivine and 5-10 percent pyroxene phenocrysts.

Qybv — Spatter and cinders that form cone of Mata das Feiticeiras (west side of map) and a cone in the village of Agua de Pau (southwest edge of map). Mata das Feiticeiras consists of alkali olivine basalt with 3-6 percent olivine, less than 1 percent pyroxene, and less than 1 percent plagioclase phenocrysts. Cone in Agua de Pau is alkali olivine basalt with 2-4 percent olivine phenocrysts.

Qybf — Aa and pahoehoe flows from Qybv. Consist of alkali olivine basalt with phenocryst types and abundances similar to those of the source cones.

Qyhv — Vent deposits about 0.5 km south of Pico Vermelho (4 km southeast of Ribeira Grande). Consist of potassic hawaiite or mugearite with 2-4 percent plagioclase and less than 1 percent clinopyroxene phenocrysts.

Qyhf — Pahoehoe flow from Qyhv; forms lava delta in Ribeira Seca de Ribeira Grande. Consists of potassic hawaiite or mugearite with 2-4 percent plagioclase and less than 1 percent clinopyroxene phenocrysts. ^{14}C age is 1,790 ± 150 years (M. Rubin, written commun., 1984).

Qcf — Late dome and flows at Lagoa do Congro (east edge of map), representing the last phase of the Congro eruption. Consist of microcrystalline to glassy trachyte with 10-15 percent alkali feldspar and 1-2 percent biotite phenocrysts.

Qcp — Pyroclastic sheet at Lagoa do Congro. Consists of more than 40 trachyte pumice and ash beds with 10-20 percent alkali feldspar and 1-3 percent biotite phenocrysts. Deposit is mapped approximately within the 4 m isopach of Booth and others (1978). ^{14}C age of the basal pumice layer is 3,800 ± 400 years (M. Rubin, written commun., 1984).

Qcd — Dome on northeast wall of Lagoa do Congro crater, representing the first phase of the Congro eruption; dome was partly truncated during explosions that deposited Qcp. Consists of microcrystalline trachyte with 5-10 percent alkali feldspar and less than 1 percent biotite phenocrysts; rare xenoliths of basalt are present.

Qmnv — Cinder and spatter cones, consisting of microcrystalline to glassy basanitoid that generally is aphyric but may contain 1-2 percent plagioclase, less than 1 percent olivine, and less than 1 percent pyroxene phenocrysts.

Qmnf — Aa and pahoehoe flows erupted from vents Qmnv, consisting of microcrystalline to glassy basanitoid that generally is aphyric but may contain 1-2 percent plagioclase, less than 1 percent olivine, and less than 1 percent pyroxene phenocrysts.

Qmav — Cinder and spatter cones, consisting of microcrystalline to glassy ankaramite or ankaramitic basalt with 10-20 percent pyroxene, 10-20 percent olivine, and 0-2 percent plagioclase phenocrysts. Cone at Lagoa de San Bras (east side of map) is partly a maar. Vents of ankaramitic composition are concentrated in the west and southwest parts of the map. The ^{14}C age of Pico Joao Fernandes (west side of map) is 8,700 ± 200 years (M. Rubin, written commun., 1984).

Qmaf — Aa and pahoehoe flows erupted from vents Qmav, consisting of microcrystalline to glassy ankaramite or ankaramitic basalt with 10-20 percent pyroxene, 10-20 percent olivine, and 0-2 percent plagioclase phenocrysts. The ^{14}C age of a flow on the west side of the village of Agua de Pau is about 6,500 ± 100 years (M. Rubin, oral commun., 1982).

Qmbv — Widespread cinder and spatter cones, consisting of microcrystalline to glassy alkali olivine basalt with 1-8 percent olivine, 0-5 percent pyroxene, 0-5 percent plagioclase, and 1-3 percent biotite phenocrysts.

Qmbf — Aa and pahoehoe flows erupted from vents Qmbv, consisting of microcrystalline to glassy alkali olivine basalt with 1-8 percent olivine, 0-5 percent pyroxene, 0-5 percent plagioclase, and 1-3 percent biotite phenocrysts.

Qmhv — Cinder and spatter cones, consisting of microcrystalline to glassy potassic hawaiite and mugearite that generally is aphyric but may contain less than 1 percent total of olivine, pyroxene, plagioclase, amphibole, and biotite phenocrysts. Vents of hawaiitic composition are restricted to the east part of the map.

Qmhf — Aa and pahoehoe flows erupted from vents Qmhv, consisting of microcrystalline to glassy potassic hawaiite and mugearite that generally is aphyric but may contain less than 1 percent total of olivine, pyroxene, plagioclase, amphibole, and biotite phenocrysts.

Qmdv — Two cinder cones (north part of map), consisting of microcrystalline to glassy basalt that is hybrid and contains 5-10 percent corroded plagioclase and less than 1 percent each of pyroxene, olivine, and biotite phenocrysts. Quartz, sanidine, and microperthite xenocrysts and xenoliths of trachyte and syenite locally are common.

Qmdf — Aa and pahoehoe flows from Qmdv and on the west side of Porto Formoso. Consist of microcrystalline to glassy basalt that is hybrid and contains 5-10 percent corroded plagioclase and less than 1 percent each of pyroxene, olivine, and biotite phenocrysts. Quartz, sanidine, and microperthite xenocrysts and xenoliths of syenite and trachyte locally are common. The flow in Porto Formoso contains scattered small lherzolite xenoliths and abundant large (>1 m) xenoliths of partly-melted trachyte. ^{14}C age of the large flow east of Ribeira Grande is 4,990 ± 100 years (M. Rubin, written commun., 1984); it is interbedded with the Fogo A deposit (Walker and Croasdale, 1970).

Qmv / Qmvm — Cones of unknown but inferred mafic composition, generally so thickly mantled by Qyp that no rock can be found. Includes cones at the map boundary that were not examined closely. Qmvm includes three small craters (east part of map) that appear to be maars.

Qmf — Lava flows of unknown but inferred mafic composition, generally so thickly mantled by Qyp that no rock can be found. Includes flows at the map boundary that were not examined closely.

Qyt_3 — Two small cones and an associated flow, about 3 km south-southeast of Santa Barbara (west-central part of map). Consist of glassy trachyte and pumice that contains 2-4 percent alkali feldspar and less than 1 percent biotite phenocrysts.

Qyt_2 — Cone and associated flow, about 2 km southeast of Santa Barbara. Consist of microcrystalline to glassy trachyte with 15-20 percent alkali feldspar and less than 1 percent biotite phenocrysts.

Qyt_1 — Dome and associated flow, about 2.5 km southeast of Santa Barbara. Consist of microcrystalline trachyte with 12-18 percent alkali feldspar and 3-5 percent altered biotite phenocrysts.

Qyt_4 — Cone and associated dome, about 2 km east-southeast of Santa Barbara. Consist of microcrystalline to glassy trachyte with 5-10 percent alkali feldspar and less than 1 percent biotite phenocrysts.

Qyt_5 — Dome and associated flow, about 2.5 km northwest of Lagoa do Fogo. Consist of microcrystalline trachyte with 15-25 percent alkali feldspar and 1-2 percent biotite phenocrysts. Xenoliths of feldspathic basalt and hybrid trachyte (the latter containing phenocrysts of alkali feldspar, olivine, green clinopyroxene, and quartz and xenoliths of syenite) locally are abundant.

Qyt_6 — Dome and associated flow, about 2.5 km north-northwest of Lagoa do Fogo. Consist of microcrystalline trachyte with 5-10 percent alkali feldspar and 1-2 percent biotite phenocrysts.

Qpf_2 — Pyroclastic flow (locally welded), airfall pumice, and mudflow deposits; eruption of this unit was chiefly responsible for formation, by collapse, of the inner caldera. Consists mainly of trachyte pumice with 2-20 percent alkali feldspar and less than 1 percent biotite phenocrysts. The welded zone, locally as much as 3 m thick, crops out mainly on the south coastal sea cliff between Pisoes and Trinta Reis. At the latter locality, xenoliths of syenite comprise 10-20 percent of the rock. Elsewhere, the unit consists mainly of Plinian airfall pumice more than 5 m thick and overlying mudflows that commonly exceed 50 m in thickness. The exposed part of the deposit is restricted to the south flank of the volcano. Estimated subaerial volume (uncorrected for vesicularity) is about 1.5 km^3, about the same as that of the inner caldera; an unknown but probably significant volume fell at sea. The mudflows that characterized the later stages of the eruption may have been responsible for burial of the south caldera rim, although that area is covered by younger pyroclastic deposits. ^{14}C ages of the basal Plinian deposit and of the overlying welded tuff are 15,190 ± 280 and 15,180 ± 150 years, respectively (M. Rubin, written commun., 1984).

Qd — Domes about 3 km east-southeast of Ribeirinha and at Cerrado Novo (about 5 km southeast of Ribeirinha; north-central part of map). Cerrado Novo dome is buried by Qyp, but probably it is trachyte. Dome 3 km east-southeast of Ribeirinha consists of microcrystalline trachyte with 10-15 percent alkali feldspar and less than 1 percent biotite phenocrysts. Both domes are nested within partial pumice rings, Qr_1 and Qr_2, and represent the final phases of these local flank eruptions. Age correlation of the domes is tentative and based on similar geomorphic expression and relative lack of erosion.

Qr_2 — Inner partial pumice rings about 3 km east-southeast of Ribeirinha and at Cerrado Novo. Consist of trachyte pumice, locally welded to obsidian, with 10-15 percent alkali feldspar and less than 1 percent biotite phenocrysts.

Qr_1 — Outer partial pumice rings about 3 km east-southeast of Ribeirinha, at Cerrado Novo, and about 1 km northeast of Monte Escuro (northeast part of map). Also includes scattered exposures of pumice fall and pyroclastic flow deposits along highway 1-2.5 km southwest of Porto Formoso. Consist of bedded and unbedded trachyte pumice, locally welded to obsidian, with 10-15 percent alkali feldspar and less than 1 percent biotite phenocrysts. ^{14}C age of ring nearest Ribeirinha is 18,600 ± 300 years (M. Rubin, written commun., 1984).

Qonf — Four aa flows along highway about 0.8 km south of Porto Formoso (northeast part of map). Consist of microcrystalline basanitoid with 0-5 percent olivine, 2-4 percent pyroxene, and 0-2 percent plagioclase phenocrysts and scattered xenoliths of gabbro. ^{14}C age of youngest flow is 26,500 ± 500 years (M. Rubin, written commun., 1984).

Qobf — Aa flows near Caldeiras (north-central part of map) and near Porto Formoso (northeast part of map). Flow near Caldeiras is hybrid basalt with 8-12 percent plagioclase, 2-4 percent pyroxene, and less than 1 percent olivine phenocrysts. Flow near Porto Formoso is hybrid basalt with 3-6 percent plagioclase phenocrysts.

Qotv — Poorly-exposed vent deposits in canyon about 3 km north of Vila Franca do Campo. Consist of tristanite scoria with less than 1 percent plagioclase and less than 1 percent pyroxene phenocrysts.

Qotf — Aa flows near Porto Formoso, in a canyon extending from Clemente da Costa to Praia (south-central part of map), and about 2 km north of Vila Franca do Campo (latter flows were erupted from Qotv). Consist of tristanite that either is aphyric or contains 1-2 percent plagioclase and less than 1 percent pyroxene phenocrysts. Flow near Praia locally contains abundant late-stage biotite in vesicles.

Qop / Qopw — Trachyte pyroclastic deposits, chiefly pumice deposited during Plinian and sub-Plinian eruptions, mudflows, and pyroclastic flows; includes minor ash. Qopw indicates zones of welded tuff, 2-15 m thick, within Qop mainly east and southeast of Lombadas. Qop is exposed in deep canyons and in sea cliffs. Upper and lower age boundaries uncertain; some weathered pumice and ash mapped as Qop could be as young as Qpf_2 and other deposits could be almost as old as Qowt. ^{14}C ages of pumice deposits near Porto Formoso (northeast coast) and Pisoes (south coast) are older than 40,000 years (M. Rubin, written commun., 1984). Not mapped where underlying units can be recognized.

Qpf_1 — Pyroclastic flows (commonly welded) and airfall pumice; eruption of this unit was chiefly responsible for formation, by collapse, of the outer caldera. Consists of welded and unwelded trachyte pumice with 4-8 percent alkali feldspar, 1-3 percent plagioclase, and less than 1 percent biotite phenocrysts. The welded zone dominates the unit and locally exceeds 80 m in thickness. The exposed part of the deposit is concentrated on the north and southeast flanks of the volcano; any possible deposits on the east or west flanks would be deeply buried by younger materials. Estimated subaerial volume (uncorrected for vesicularity), based only on known exposures, is about 5 km^3, nearly the same as that of the outer caldera (5.6 km^3); an unknown but probably significant volume fell at sea. Age is uncertain; the deposit fills modern canyons where up to 50 m of downcutting subsequently has occurred. The deposit underlies Qr_1 3 km east of Ribeirinha, so it is older than 18,600 years. Qpf_1 does not appear to overlie the 26,500 ± 500-year-old basanitoid flow (part of Qonf), although that flow is outside the mapped areal extent of Qpf_1. Qpf_1 overlies several trachyte domes and flows (Qt); the youngest Qt that has been dated is a Qt_{27} flow that is 74,000 ± 8,000 years old (A.R. da Silva, written commun., 1982). Qop that underlies Qpf_1 at Porto Formoso has been dated at >40,000 years (M. Rubin, written commun., 1984). Estimated age of Qpf_1 is 30,000-50,000 years.

Qbv — Basaltic vent deposits near Ladeira da Velha (north coast) and at a 632-m-high cone 2.5 km south-southwest of Porto Formoso. Latter cone consists of alkali olivine basalt with 4-8 percent olivine, 2-4 percent plagioclase, and 1-2 percent pyroxene phenocrysts; cone is overlain by Qpf_1. Exposure near Ladeira da Velha includes spatter, rootless flows, dikes, and short flows that range in composition from ankaramite to hawaiite but are mostly alkali olivine basalt.

Qbf — Aa flows, from the 632-m-high cone 2.5 km south-southwest of Porto Formoso and in a small canyon 1 km north-northwest of Monte Escuro. Flow from 632-m-high cone is alkali olivine basalt with 4-8 percent olivine, 2-4 percent plagioclase, and 1-2 percent pyroxene phenocrysts. Flow near Monte Escuro is poorly exposed and consists of hybrid basalt with 2-4 percent olivine and 1-3 percent plagioclase phenocrysts.

Qt_2 — Flow on west flank of Agua de Pau Volcano. Consists of microcrystalline trachyte with 15-25 percent alkali feldspar and 1-3 percent biotite phenocrysts.

Qt_1 — Flow on west flank of Agua de Pau Volcano; underlies Qt_2. Consists of microcrystalline, locally glassy trachyte with 3-6 percent alkali feldspar and 1-2 percent biotite phenocrysts.

Qt_{22} — Dome along road about 0.8 km north of Lombadas (near center of map). Consists of microcrystalline trachyte with 8-12 percent alkali feldspar and less than 1 percent biotite phenocrysts. K-Ar age is 85,000 ± 8,000 years (A.R. da Silva, written commun., 1982).

Qt_{24} — Flow and dome that underlie the southwest summit of Agua de Pau Volcano. Consist of microcrystalline trachyte with 8-12 percent alkali feldspar and less than 1 percent biotite phenocrysts; groundmass sphene is abundant. K-Ar age is 86,000 ± 8,000 years (A.R. da Silva, written commun., 1982).

Qt_7 — Flow along road on northwest flank of Agua de Pau Volcano. Consists of microcrystalline trachyte with 10-15 percent alkali feldspar and less than 1 percent biotite phenocrysts. Xenoliths of feldspathic basalt locally are abundant.

Qt_8 — Flow on northwest flank of Agua de Pau Volcano; underlies Qt_7. Consists of microcrystalline trachyte with 5-10 percent alkali feldspar and less than 1 percent biotite phenocrysts.

Qt_{10} — Large flow mainly in canyon extending from Lombadas to Caldeiras (north flank of the volcano); stratigraphically and topographically appears to be one of the oldest units on the volcanic edifice. Consists of microcrystalline trachyte with 10-15 percent alkali feldspar and 1-2 percent clinopyroxene phenocrysts.

Qt_3 — Domes and flows at Pedreiras (west central part of map). Consist of microcrystalline trachyte with 10-20 percent alkali feldspar and 1-3 percent biotite phenocrysts.

Qt_4 — Six domes (including Varanda, Pico Alfinetes, Pico Barnabe, and Queimado) in the west part of map. Consist of microcrystalline trachyte with 4-12 percent alkali feldspar phenocrysts and locally common xenoliths of dark trachyte.

Qt_{11} — Flow on north flank of Agua de Pau Volcano. Consists of microcrystalline to glassy trachyte with 3-6 percent alkali feldspar and less than 1 percent biotite phenocrysts.

Qt_{12} — Flow on north flank of Agua de Pau Volcano. Consists of microcrystalline trachyte with less than 1 percent alkali feldspar and less than 1 percent biotite phenocrysts.

Qt_{15} — Flow on north flank of Agua de Pau Volcano. Consists of microcrystalline to glassy trachyte with 5-10 percent alkali feldspar phenocrysts and common xenoliths of reddish basalt.

Qt_{16} — Flow on northeast flank of Agua de Pau Volcano. Consists of microcrystalline trachyte with 4-8 percent alkali feldspar and 1-2 percent biotite phenocrysts.

Qt_{28} — Flow on south coastal sea cliff. Consists of microcrystalline trachyte with 5-10 percent alkali feldspar, less than 1 percent olivine, less than 1 percent pyroxene, and less than 1 percent biotite phenocrysts. ^{14}C age is >40,000 years (M. Rubin, written commun., 1982).

Qt_{29} — Flow on south coastal sea cliff, lower in section than Qt_{28}. Consists of microcrystalline trachyte with 5-10 percent alkali feldspar, less than 1 percent olivine, less than 1 percent pyroxene, and less than 1 percent biotite phenocrysts.

Qt_5 — Flow on west flank of Agua de Pau Volcano. Consists of microcrystalline to glassy trachyte with 8-20 percent alkali feldspar and 3-6 percent biotite phenocrysts.

Qt_6 — Flow on west flank of Agua de Pau Volcano. Consists of aphyric microcrystalline trachyte with scattered xenoliths of basalt that contains common xenoliths of syenite. Interbedded with Qop.

Qt_9 — Dome between Pico Vermelho and village of Caldeiras (north part of map). Consists of microcrystalline trachyte with 2-4 percent alkali feldspar phenocrysts. Overlain by a Qobf flow.

Qt_{13} — Dome and associated pumice-rich carapace of Cintrão (north edge of map). Carapace consists of trachyte pumice with 4-8 percent alkali feldspar phenocrysts. Overlying Qyp includes basaltic accretionary lapilli from an unidentified offshore eruption.

Qt_{14} — Dome and associated flow at Lameiro (north edge of map). Consists of microcrystalline to glassy trachyte with 5-10 percent alkali feldspar, less than 1 percent clinopyroxene, and less than 1 percent biotite phenocrysts.

Qt_{17} — Flow about 2 km west-southwest of Porto Formoso. Consists of microcrystalline trachyte with 10-15 percent alkali feldspar and less than 1 percent biotite phenocrysts.

Qt_{18} — Flow in Ribeira Seca do Porto (1.5 km west of Porto Formoso). Consists of microcrystalline trachyte with 10-15 percent alkali feldspar and less than 1 percent olivine phenocrysts.

Qt_{19} — Flow about 1 km south of Porto Formoso. Consists of microcrystalline trachyte with 10-15 percent alkali feldspar and 1-2 percent biotite phenocrysts.

Qt_{20} — Flow about 1 km southeast of Porto Formoso. Consists of microcrystalline trachyte with 10-15 percent alkali feldspar and less than 1 percent biotite phenocrysts.

Qt_{21} — Flow about 3 km southeast of Porto Formoso. Consists of microcrystalline trachyte with 10-15 percent alkali feldspar phenocrysts.

Qt_{23} — Large flow on southeast flank of Agua de Pau Volcano. Consists of microcrystalline trachyte with 5-12 percent alkali feldspar and less than 1 percent biotite phenocrysts.

Qt_{25} — Crystal-rich flow about 1.5 km north-northeast of the village of Agua de Pau. Consists of microcrystalline trachyte with 25-40 percent alkali feldspar phenocrysts.

Qt_{26} — Dome about 1 km east of Remedios (southwest edge of map). Consists of microcrystalline trachyte with 8-12 percent alkali feldspar and 1-2 percent biotite phenocrysts.

Qt_{30} — Flow at base of section at Trinta Reis (south coast). Consists of microcrystalline trachyte with 15-20 percent alkali feldspar and 1-3 percent pyroxene phenocrysts.

Qt_{27} — Scattered domes and flows within outer and inner calderas of Agua de Pau Volcano (grouping of these rocks within this one unit does not imply coevality). Lithology is fairly homogeneous and consists of microcrystalline to glassy trachyte with 5-12 percent alkali feldspar and less than 1 percent biotite phenocrysts. Domes and flows within the inner caldera are mantled by Qyp (mainly pumice from the A.D. 1563 eruption), and domes and flows in the Lombadas area are interbedded with Qop. K-Ar age of one flow is 74,000 ± 8,000 years (A.R. da Silva, written commun., 1982).

Qowt — Welded pyroclastic deposits and associated mudflows on the north coast. Best access is at Porto de Santa Iria, near Ribeirinha, where a 160-m-thick section, including at least nine cooling units, dips 22° south. Relationship of these deposits to the modern Agua de Pau Volcano is uncertain; possibly they are outflow sheets from an ancestral Agua de Pau Volcano that was deeply eroded prior to development of the present edifice. Any caldera that may have formed during this time has been buried by younger deposits. High-standing erosional remnant near Rabo de Peixe consists of landward-dipping, coarse pyroclastic breccias whose matrix is trachytic and whose clasts are dominated by feldspathic basalt but also include minor trachyte. Thick finer-grained beds locally are columnar-jointed and may be welded (matrix is strongly altered); the deposit is interpreted as the proximal facies from a vent that mostly has been eroded away by the ocean. K-Ar age of one of the welded pyroclastic deposits near Santa Iria is 103,000 ± 7,000 years (A.R. da Silva, written commun., 1982).

Qot — Dome between villages of Agua de Pau and Ribeira Cha. Consists of microcrystalline trachyte with 8-12 percent alkali feldspar and less than 1 percent biotite phenocrysts. Appears to be a flank vent on the ancestral Agua de Pau Volcano, whose other remnants are not exposed in this area. K-Ar age is 181,000 ± 15,000 years (A.R. da Silva, written commun., 1982).

GEOLOGIC MAP SYMBOLS

- Contact, approximately located
- Inner and outer caldera boundaries, approximately located
- Geologic map boundary
- Normal fault, ball on downthrown side; dashed where inferred. Locally overlain by Qyp
- Reverse fault, teeth in upper plate
- o/y — Relatively older and younger units, at location where relationship is demonstrable
- X — Location of dated charcoal sample (M. Rubin, written commun., 1984)
- ✱ — Location of sample dated by K-Ar technique (A.R. da Silva, written commun., 1982)

Trachyte domes and flows (Qt) are numbered in an approximately clockwise sequence beginning on the west flank of the volcano. No age sequence is implied by the numbering scheme.

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CORRELATION OF MAP UNITS

QUATERNARY

Years B.P.[1]

HOLOCENE
- 300 — 1652v, 1652f
- 400 — 1563v, 1563f
- Qyav, Qyaf, Qybv, Qybf, Qyhv, Qyhf; Qyp; Qal
- 3800 — Qcf, Qcp, Qcd
- 4400-5300 — Fogo A[2]
- Qmnv, Qmnf, Qmav, Qmaf, Qmbv, Qmbf, Qmhv, Qmhf, Qmdv, Qmdf, Qmv/Qmvm, Qmf

HOLOCENE OR PLEISTOCENE
- Qyt_3, Qyt_2, Qyt_1, Qyt_4, Qyt_5, Qyt_6 — Post-caldera units[3] ↑

PLEISTOCENE
- 15,200 — Qpf_2 — Caldera-forming units (inner caldera)
- 18,600 — Qd, Qr_2, Qr_1
- 26,500 — Qonf, Qobf, Qotv, Qotf
- Qpf_1 — Caldera-forming units (outer caldera) ↓
- Pre-caldera units[3]
- 74,000-86,000 — Qbv, Qbf, Qt_2/Qt_1, Qt_{22}, Qt_{24}, Qt_7/Qt_8/Qt_{10}, Qt_3/Qt_4, Qt_{11}/Qt_{12}, Qt_{15}/Qt_{16}, Qt_{28}/Qt_{29}, Qt_5, Qt_6, Qt_9, Qt_{13}, Qt_{14}, Qt_{17}, Qt_{18}, Qt_{19}, Qt_{20}, Qt_{21}, Qt_{23}, Qt_{25}, Qt_{26}, Qt_{30}, Qt_{27}; Qop, Qopw
- 103,000 — Qowt
- 181,000 — Qot

1 Ages <500 years are based on historical accounts, summarized in Booth and others (1978). Ages are means; vertical scale is non-linear. Ages from >400->40,000 years are from M.Rubin, written communication, 1984 (^{14}C ages). Ages >74,000 years are from A.R. da Silva, written communication, 1982 (K-Ar ages).

2 Ages of the Fogo A deposit (Walker and Croasdale, 1970) range from about 4400-5300 years (M. Rubin, written communication, 1984).

3 Equivalent horizontal position on line does not imply absolute age correlation, only the stratigraphic position relative to higher and lower boxes. Vertical position indicates stratigraphic sequence.

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