

RADIOCARBON DATES FOR LAVA FLOWS AND PYROCLASTIC DEPOSITS ON SÃO MIGUEL, AZORES

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INTRODUCTION

We report 63 new radiocarbon analyses of samples from São Miguel, the largest (ca 62 × 13km) and most populous (ca 150,000 inhabitants) island in the Azores archipelago (Fig 1). The samples are mainly carbonized tree roots and other plant material collected from beneath 20 mafic lava flows and spatter deposits and from within and beneath 42 trachytic pyroclastic flow, pyroclastic surge, mudflow, pumice-fall, and lacustrine deposits and lava flows. One calcite date is reported. The samples were collected during geologic mapping of the entire island (Moore, in press A; sample locations are shown on this map). Nine 1:25,000-scale topographic maps, published in 1983 by the Portuguese Army Cartographic Service, cover the island; samples and locations described below refer to these named sheets.

Six volcanic zones comprise São Miguel (Fig 2; Moore, in press B). From west to east, the zones are: 1) the trachyte stratovolcano of Sete Cidades; 2) a field of alkali basalt cinder cones and lava flows, with minor trachyte; 3) the trachyte stratovolcano of Agua de Pau; 4) a field of alkali basalt cinder cones and lava flows, with minor trachyte and tristanite; 5) the trachyte stratovolcano of Furnas and 6) the Nordeste shield volcano, which is mainly alkali basalt with minor trachyte. Rocks in Zones 1-5 are Quaternary in age, and rocks of the Nordeste shield volcano are Pleistocene and Pliocene in age (Moore, in press B). Charcoal was collected in volcanic Zones 1-5.

These dates establish ages for 48 previously undated lava flows and pyroclastic deposits, and revise three ages reported by Shotton, Blundell and Williams (1968, 1969) and Shotton and Williams (1971). The new dates provide limits on the ages of other units that lie above or below the dated units. These data are critical to deciphering the Holocene and late Pleistocene eruptive history of São Miguel and evaluating its potential volcanic hazards.

Average dormant intervals (Moore, in press B) during the past 3000 years are about 400 years for Sete Cidades volcano, 145 years for volcanic Zone 2, 1150 years for Agua de Pau volcano and 320 years for Furnas volcano. No known eruptions have occurred in volcanic Zone 4 during the past 3000 years.

Charcoal samples were analyzed at the Radiocarbon Laboratory of the US Geological Survey in Reston, Virginia. Pretreatment consisted of removal of modern rootlets and successive boiling in HCl, NaOH and HCl. Rinsing in distilled water followed each stage. The samples were converted to acetylene gas and their ¹⁴C activity was measured in three different proportional gas counters. The error quoted includes the standard 1 sigma counting error plus known laboratory uncertainties. Ages are reported in years BP (1950) and were not corrected to a calendar date by tree-ring calibrations. All comments below are by RB Moore.

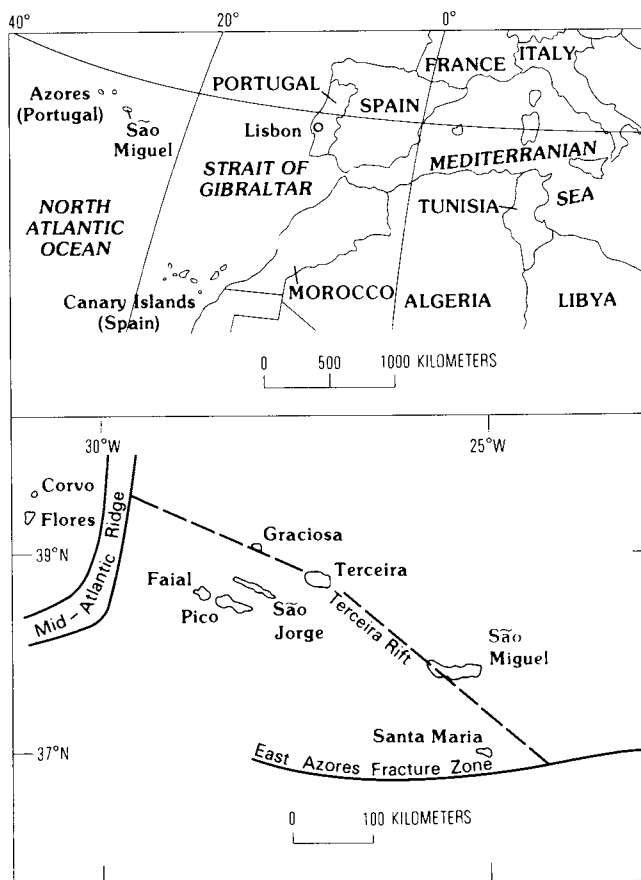


Fig 1. Index map of the Azores, after Moore (in press B)

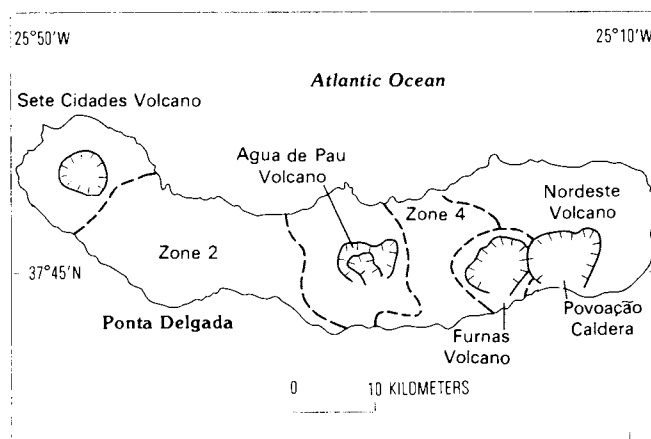


Fig 2. Index map of São Miguel, showing its six volcanic zones, after Moore (in press B)

W-5186. AD 1630 trachyte pumice deposit, Furnas volcano (Zone 5) 260 ± 70

Charcoal fragments in mudflow deposit associated with most recent eruption of Furnas volcano (Weston 1964). Sample from roadcut on northeastern side of village of Furnas; altitude 250m; Povoação sheet (37°47.02'N, 25°18.58'W). Coll 1981 by RB Moore.

Comment: within analytical uncertainty, date agrees with known age of 320 BP.

W-5264. AD 1630 trachyte pumice deposit, Furnas volcano (Zone 5) 295 ± 40

Large charcoal fragments in pyroclastic flow deposit associated with AD 1630 Plinian fall deposits of Furnas volcano. Sample from roadcut 1.7km south of Lagoa das Furnas; altitude 415m; Vila Franca do Campo sheet (37°44.48'N, 25°20.59'W). Coll 1982 by RB Moore.

Comment: date agrees with known age of 320 BP.

W-5430. Sete L trachyte pumice deposit, Sete Cidades volcano (Zone 1) 500 ± 100

Charcoal fragments in lens at base of mudflow deposit interbedded with Sete L (terminology of Booth, Croasdale & Walker 1978) trachyte pumice deposit. Sample from northern side of new roadcut 200m west of village of Sete Cidades; altitude 270m; Candelaria sheet (37°51.73'N, 25°48.20'W). Coll 1983 by RB Moore and M Rubin.

Comment: date agrees with written records indicating that eruption of Sete Cidades was occurring at time of Portuguese discovery and initial settlement of the Azores ca AD 1444 (van Padang *et al* 1967). Shotton and Williams (1971) reported age of 663 ± 105 BP for Sete L.

W-6175. Furnas G trachyte pumice deposit, Furnas volcano (Zone 5) 780 ± 120

Charcoal fragments in trachyte pyroclastic flow deposit that is fourth highest unit in late Holocene pyroclastic sequence erupted from Furnas volcano. Sample from new roadcut on northern flank of Pico do Canario, on eastern rim of Furnas caldera; altitude 660m; Povoação sheet (37°46.65'N, 25°16.79'W). Coll 1989 by RB Moore.

Comment: date establishes age of Furnas G deposit of Booth *et al* (1978).

W-5158. Pico das Camarinhas basanitoid cone, Sete Cidades volcano (Zone 1) 840 ± 60

Charcoal fragments at top of soil beneath scoria (basanitoid transitional to ankaramite) on eastern edge of Pico das Camarinhas cone. Scoria overlies trachyte dome and underlies Sete L deposit (Booth, Croasdale & Walker 1978). Aa flow from cone formed Ponta da Ferraria lava delta, westernmost point on São Miguel. Sample from roadcut; altitude 160m; Candelaria sheet (37°51.50'N, 25°50.89'W). Coll 1981 by RB Moore.

Comment: dates youngest subaerial mafic eruption on Sete Cidades volcano.

W-5262. Basanitoid flow, Zone 2 980 ± 90

Charcoal fragments at top of soil beneath extensive basanitoid aa flow erupted from young spatter rampart (W-5161) southeast of Sete Cidades caldera. Flow entered ocean and built small lava deltas at three points west of village of Feteiras. Sample from roadcut in village of Biscoito; altitude 125m; Candelaria sheet (37°48.59'N, 25°48.08'W). Coll 1982 by RB Moore and AMR da Silva.

Comment: W-5262 and -5161 agree well and establish age of this eruption at ca 1000 BP.

W-6131. Mata das Feiticeiras basanitoid flow, Zone 2 **1010 ± 120**

Charcoal fragments at top of soil beneath thin edge of extensive basanitoid aa flow from Mata das Feiticeiras spatter cone, in eastern part of Zone 2. Flow reached ocean and built large lava delta east of village of Rabo de Peixe. Sample from quarry on southwestern side of Pico da Cova; altitude 170m; Ponta Delgada sheet (37°47.22'N, 25°34.00'W). Coll 1988 by RB Moore.

Comment: dates young prehistoric eruption.

W-5161. Basanitoid spatter, Zone 2 **1020 ± 60**

Charcoal fragments at top of soil beneath basanitoid spatter that underlies Sete L deposit (Booth *et al* 1978). Sample from old roadcut cutting through western end of spatter rampart; altitude 670m Candelaria sheet (37°50.22'N, 25°46.29'W). Coll 1982 by RB Moore.

Comment: W-5161 and -5262 agree well and establish age of this young prehistoric eruption at ca 1000 BP.

W-6132. Trachyte maar, Zone 2 **1044 ± 150**

Large charcoal fragments in coarse trachyte maar deposit. Maar, characterized by pyroclastic surge deposits and large (1m) juvenile breadcrust bombs, formed at about same time as trachyte cone (W-6140) that caps Cruz cone ca 800m to northwest. Sample from roadcut on southern side of Coroa da Furna spatter cone, near center of Zone 2; altitude 230m; Ponta Delgada sheet (37°46.92'N, 25°37.37'W). Coll 1988 by RB Moore.

Comment: dates young explosive trachytic eruption only 500m from Caldeirão electrical power plant, largest on São Miguel.

W-6140. Trachyte scoria, Cruz cone, Zone 2 **1100 ± 150**

Charcoal fragments at top of soil beneath aphyric trachyte scoria near top of Cruz, cone near center of Zone 2. Sample from old roadcut on upper southern flank; altitude 360m; Ponta Delgada sheet (37°47.40'N, 25°37.86'W). Coll 1988 by RB Moore.

Comment: date agrees well with W-6132 and establishes young age of this episode of trachytic volcanism in Zone 2.

W-5205. Furnas F trachyte pumice deposit, Furnas volcano (Zone 5) **1100 ± 60**

Charcoal fragments in pyroclastic flow deposit correlated with the Furnas F trachyte pumice deposit of Booth *et al* (1978). Sample from quarry 1.3km east of Pico do Gaspar, trachyte dome that occupies vent for Furnas F deposit; quarry is 100m west of paved road between villages of Furnas and Ribeira Quente; altitude 160m; Povoação sheet (37°45.90'N, 25°18.00'W). Coll 1982 by RB Moore.

Comment: date agrees well with W-5435 and is important in determining average frequency of eruption of Furnas volcano during late Holocene time.

W-5435. Furnas F trachyte pumice deposit, Furnas volcano (Zone 5) **1120 ± 110**

Carbonaceous soil immediately below base of Furnas F pumice deposit of Booth *et al* (1978). Location is same as W-5205. Coll 1983 by RB Moore and M Rubin.

Comment: date agrees well with W-5205.

W-6154. Pico das Mos basanitoid flow, Zone 2 **1250 ± 150**

Charcoal fragments at top of soil beneath extensive basanitoid aa and pahoehoe flow from Pico das Mos, in southeastern part of Zone 2. Flow reached ocean at village of Lagoa. Sample from western side of small canyon on western side of Lamego spatter cone; altitude 140m; Ponta Delgada sheet (37°45.65'N, 25°33.80'W). Coll 1989 by RB Moore.

Comment: dates young mafic eruption in Zone 2.

W-6149. Carvão basanitoid flow, Zone 2 **1280 ± 150**

Charcoal fragments at top of soil beneath pahoehoe flow erupted from Pico do Carvão, in western part of Zone 2. Extensive flow is mostly aa and reached ocean at village of Capelas. Sample from roadcut in pasture; altitude 395m; Candelaria sheet (37°49.08'N, 25°43.11'W). Coll 1988 by RB Moore.

Comment: Pico do Carvão and its flow are overlain only by 500-year-old Sete L trachyte pumice deposit of Booth *et al* (1978), indicating that Sete K erupted between 1860 BP (Sete J; W-5406) and 1280 BP (Carvão).

W-6137. Caldeirão basanitoid flow, Zone 2 **1350 ± 120**

Charcoal fragments at top of soil beneath extensive basanitoid aa flow erupted from unnamed cone only 20m west of the Caldeirão electrical power plant, near center of Zone 2. Flow reached ocean at Praia do Populo. Sample from large quarry on western side of main road between Ponta Delgada and Ribeira Grande; altitude 180m; Ponta Delgada sheet (37°46.60'N, 25°36.78'W). Coll 1988 by RB Moore.

Comment: dates young mafic eruption in Zone 2.

W-5433. Hawaiiite flow, Zone 2 **1790 ± 150**

Charcoal fragments at top of soil under hawaiiite pahoehoe flow. Flow underlies western part of city of Ribeira Grande and formed lava delta where it entered ocean. Sample from edge of flow in small canyon 800m west of Pico Vermelho, in northeastern part of Zone 2; altitude 130m; Ribeira Grande sheet (37°48.00'N, 25°31.03'W). Coll 1983 by RB Moore and AMR da Silva.

Comment: dates extensive, relatively young flow and provides information on late Holocene average frequency of eruption in Zone 2.

W-5406. Sete J trachyte pumice deposit, Sete Cidades volcano (Zone 1) **1860 ± 120**

Charcoal fragments in pyroclastic flow deposit associated with Sete J pumice deposit of Booth *et al* (1978). Sample from new roadcut at Vista do Rei on southern rim of Sete Cidades caldera; altitude 580m; Candelaria sheet (37°50.30'N, 25°47.72'W). Coll 1983 by RB Moore.

Comment: dates third youngest explosive eruption of trachyte from Sete Cidades volcano and provides data for estimating the volcano's average frequency of eruption during late Holocene time.

W-6145. Pico da Furna basanitoid bombs, Zone 2 **2460 ± 220**

Charcoal fragments at top of soil under large (0.7m) basanitoid bombs from Pico da Furna, near center of Zone 2. Extensive flow from cone reached ocean between villages of Capelas and

Fenais da Luz on northern coast of Zone 2. Sample from old roadcut on western flank of Pico Grande; altitude 260m; Ribeira Grande sheet (37°48.15'N, 25°39.45'W). Coll 1988 by RB Moore.

Comment: dates relatively young eruption and provides data bearing on average frequency of eruption in Zone 2.

W-5265. Eguas ankaramite bombs, Zone 2 **2700 ± 250**

Charcoal fragments at top of soil beneath large (1m) ankaramite bombs from Eguas cone, in western part of Zone 2. Sample from roadcut 1.6km southeast of Sete Cidades caldera; altitude 720m; Candelaria sheet (37°49.85'N, 25°45.30'W). Coll 1982 by RB Moore.

Comment: Eguas cone erupted an extensive ankaramite flow that covers much of western part of Zone 2 and reached ocean near village of Feteiras. Date is important for stratigraphy and determination of average frequency of eruption in this area.

W-6143. Basanitoid cone, Zone 2 **2800 ± 120**

Charcoal fragments at top of soil beneath basanitoid bombs from prominent cone between Picos de Lima and Pico Grande, near center of Zone 2. Thick, extensive flow was erupted from this vent. Sample from old roadcut in pasture where large (0.5m) bombs fell on northwestern flank of Picos de Lima; altitude 320m; Ponta Delgada sheet (37°47.75'N, 25°38.88'W). Coll 1988 by RB Moore.

Comment: date is important for stratigraphy and determination of average frequency of eruption in this area.

W-5414. Lagoa do Congro trachyte maar, Zone 4 **3800 ± 400**

Charcoal fragments at top of soil underlying coarse (0.3m) trachyte pumice in basal pyroclastic flow deposit from Lagoa do Congro, near center of Zone 4. Sample from canyon 300m west of Lagoa do Congro; altitude 500m; Vila Franca do Campo sheet (37°45.65'N, 25°24.83'W). Coll 1983 by RB Moore.

Comment: date is in accordance with age inferred by Booth *et al* (1978) on basis of soil development and stratigraphy of trachyte pumice deposits from Agua de Pau volcano. Lagoa do Congro is second youngest volcanic vent in Zone 4.

W-6174. East Congro trachyte maar, Zone 4 **4160 ± 160**

Large charcoal fragments in trachyte pyroclastic flow deposit associated with small maar 0.7km east of Lagoa do Congro, near center of Zone 4. Sample from northeastern wall of shallow maar crater; altitude 490m; Vila Franca do Campo sheet (37°45.60'N, 25°23.85'W). Coll 1989 by RB Moore.

Comment: date is similar to W-5414, indicating that this deposit was emplaced at about same time that Lagoa do Congro erupted.

W-5424. Fogo A trachyte pumice deposit, Agua de Pau volcano (Zone 3) **4480 ± 180**

Large charcoal fragments in trachyte pyroclastic flow deposit associated with Fogo A Plinian deposit from Agua de Pau volcano (Walker & Croasdale 1970). Sample from quarry in ankaramite spatter cone that underlies Fogo A on northwestern side of main road 2.5km northeast of village

of Remedios, on western flank of Agua de Pau volcano; altitude 550m; Ponta Delgada sheet (37°45.88'N, 25°31.08'W). Coll 1983 by RB Moore.

Comment: date is one of nine new determinations, reported here, of age of charcoal from separate locations within Fogo A deposit. Shotton *et al* (1968, 1969) reported ages of 4435 ± 99 and 4672 ± 100 BP for Fogo A; nine new dates average 4936 BP, nearly 400 years more than average of determinations by Shotton *et al*. Range in mean ages (900 years) suggests that Fogo A may be product of more than one eruption.

W-5436. Fogo A trachyte pumice deposit, Agua de Pau volcano (Zone 3) 4700 ± 200

Charcoal fragments in trachyte pyroclastic flow deposit associated with Fogo A Plinian deposit. Sample from old roadcut in Ribeira Grande canyon 1.8km southeast of village of Caldeiras, on northern flank of Agua de Pau volcano; altitude 550m; Vila Franca do Campo sheet (37°47.42'N, 25°28.47'W). Coll 1983 by RB Moore.

Comment: dates pyroclastic flow deposit within Fogo A sequence.

W-5438. Fogo A trachyte pumice deposit, Agua de Pau volcano (Zone 3) 4700 ± 180

Charcoal fragments in trachyte pyroclastic surge deposit associated with Fogo A Plinian deposit. Sample from roadcut 0.9km northwest of village of Agua de Alto, on southern flank of Agua de Pau volcano; altitude 210m; Vila Franca do Campo sheet (37°43.95'N, 25°27.79'W). Coll 1983 by RB Moore.

Comment: dates pyroclastic surge deposit within Fogo A sequence.

W-5434. Fogo A trachyte pumice deposit, Agua de Pau volcano (Zone 3) 4890 ± 150

Charcoal fragments at base of basal trachyte Plinian deposit of Fogo A. Sample from roadcut 1.4km northeast of village of Ribeira Chã, on southern flank of Agua de Pau volcano; altitude 310m Vila Franca do Campo sheet (37°44.29'N, 25°28.70'W). Coll 1983 by RB Moore.

Comment: dates basal Plinian deposit of Fogo A eruption.

W-5426. Fogo A trachyte pumice deposit, Agua de Pau volcano (Zone 3) 4960 ± 180

Large charcoal fragments in trachyte pyroclastic surge deposit associated with Fogo A Plinian deposit. Sample from trail in Ribeira Grande canyon on northern flank of Agua de Pau volcano; altitude 470m; Vila Franca do Campo sheet (37°47.39'N, 25°28.73'W). Coll 1983 by RB Moore.

Comment: dates pyroclastic surge deposit within Fogo A sequence.

**W-5251. Monte Gordo-Ribeirinha hybrid basalt flow, 4990 ± 100
Agua de Pau volcano (Zone 3)**

Charcoal fragments at top of thin soil underlying extensive flow of hybrid basalt. Flow appears to be underlain and overlain by pumice-fall deposits associated with the Fogo A eruption. Flow came from spatter cone at Monte Gordo on northern flank of Agua de Pau volcano. Sample from top of sea cliff 1.9km northeast of city of Ribeira Grande; altitude 50m; Ribeira Grande sheet (37°50.47'N, 25°30.30'W). Coll 1981 by RB Moore and AMR da Silva.

Comment: dates important stratigraphic unit interbedded with Fogo A trachyte pumice deposit. Rise of mafic magma may have initiated Fogo A eruption; mafic magma may have mixed with

trachytic magma at margins of trachytic magma reservoir, leading to hybrid composition of this flow.

W-5437. Fogo A trachyte pumice deposit, Agua de Pau volcano (Zone 3) 5020 ± 200

Charcoal fragments in trachyte pyroclastic surge deposit associated with Fogo A Plinian deposit. Sample from roadcut 0.9km north-northwest of village of Agua de Alto, on southern flank of Agua de Pau volcano; altitude 280m; Vila Franca do Campo sheet (37°44.12'N, 25°27.60'W). Coll 1983 by RB Moore.

Comment: dates pyroclastic surge deposit within Fogo A sequence; underlies W-5438.

W-5411. Fogo A trachyte pumice deposit, Agua de Pau volcano (Zone 3) 5140 ± 180

Charcoal fragments in trachyte pyroclastic flow deposit associated with Fogo A Plinian deposit. Sample from roadcut 4km southwest of village of Porto Formoso, on northern flank of Agua de Pau volcano; altitude 480m; Maia sheet (37°47.90'N, 25°27.78'W). Coll 1983 by RB Moore.

Comment: dates pyroclastic flow deposit within Fogo A sequence.

W-5257. Fogo A trachyte pumice deposit, Agua de Pau volcano (Zone 3) 5150 ± 120

Charcoal fragments in trachyte pyroclastic flow deposit associated with Fogo A Plinian deposit. Sample from roadcut 200m east of village of Ribeira Chã, on southern flank of Agua de Pau volcano; altitude 150m; Vila Franca do Campo sheet (37°43.60'N, 25°29.05'W). Coll 1981 by RB Moore.

Comment: dates pyroclastic flow deposit within Fogo A sequence.

W-5431. Fogo A trachyte pumice deposit, Agua de Pau volcano (Zone 3) 5380 ± 210

Charcoal fragments in trachyte pyroclastic flow deposit associated with Fogo A Plinian deposit. Sample from small quarry on northeastern side of main road 4.5km north of village of Vila Franca do Campo; altitude 520m; Vila Franca do Campo sheet (37°45.68'N, 25°26.00'W). Coll 1983 by RB Moore.

Comment: date is oldest for Fogo A deposit.

W-5190. Lake sediments, Furnas volcano (Zone 5) 6520 ± 100

Black carbonaceous lake sediments associated with mudflow deposit on floor of caldera of Furnas volcano. Sample from small excavation 0.7km east of main fumaroles in village of Furnas; altitude 186m; Povoação sheet (37°46.70'N, 25°17.82'W). Coll 1982 by RB Moore.

Comment: date indicates time of deposition of sediments in small pond that may have formed when pyroclastic flows and associated mudflows dammed ancestral Ribeira Quente (Hot River). Source of pyroclastic deposits may have been Pico do Canario, post-caldera tristanite cone on eastern caldera rim 1.3km east of sample location.

W-5420. Pico do João Fernandes ankaramite cone, Zone 2 8700 ± 200

Charcoal fragments at top of soil underlying ankaramite scoria of Pico do João Fernandes, cone in southeastern part of Zone 2. Sample from small excavation 1.6km north of village of

Comment: dates largest in a group of ankaramite cones and provides data bearing on average frequency of eruption in Zone 2.

Charcoal fragments at top of soil underlying aphyric hawaiiite scoria of relatively old cone at Cerrado dos Bezerros, in southeastern part of Zone 4. Sample from roadcut; altitude 540m; Vila Franca do Campo sheet (37°45.20'N, 25°22.00'W). Coll 1982 by RB Moore.

W-5160. Trachyte dome, Pico do Ferro, Furnas volcano (Zone 5) 11,230 ± 100

Comment: dates group of post-caldera domes and provides approximate age of 12,000 years for formation of the caldera of Furnas volcano.

Charcoal fragments at top of soil beneath canyon-filling, locally welded, trachyte pyroclastic flow deposit on southern flank of Agua de Pau volcano. Sample from roadcut 300m south of village of Ribeira Chã; altitude 20m; Vila Franca do Campo sheet (37°43.23'N, 25°29.39'W). Coll 1982 by RB Moore.

Comment: dates formation of inner caldera of Agua de Pau volcano and agrees with W-5416.

Charcoal fragments at top of soil beneath coarse basal trachyte pumice of younger caldera-outflow deposit from Agua de Pau volcano. Sample from small canyon 400m west of village of Ribeira Chã on southern flank of Agua de Pau volcano; altitude 100m; Vila Franca do Campo sheet (37°43.34'N, 25°29.73'W). Coll 1983 by RB Moore.

Comment: dates formation of inner caldera of Agua de Pau volcano and agrees with W-5172.

Charcoal fragments in pyroclastic flow deposit associated with trachyte domes and flows on northern side of village of Ginetes, on western flank of Sete Cidades volcano. Sample from top of sea cliff beneath overlook 500m west of Escalvado cone; altitude 210m; Candelaria sheet (37°52.30'N, 25°50.72'W). Coll 1982 by RB Moore.

Comment: dates major post-caldera flank eruption of Sete Cidades volcano.

W-5409. Coroa da Mata trachyte pumice ring, 18,600 ± 300
Agua de Pau volcano (Zone 3)

Large charcoal fragments in pyroclastic flow deposit in pumice ring surrounding Coroa da Mata trachyte dome, on northern flank of Agua de Pau volcano. Ring overlies older caldera-outflow deposit from Agua de Pau. Sample from roadcut 2.2km east of village of Ribeirinha; altitude 210m; Maia sheet (37°49.54'N, 25°28.42'W). Coll 1983 by RB Moore.

Comment: dates major flank eruption and provides minimum age for formation of outer caldera of Agua de Pau volcano.

W-5189. Mugearite flow, Zone 2 20,890 ± 240

Charcoal fragments at top of soil beneath aphyric mugearite aa flow. Sample from roadcut on northwestern side of village of Feteiras, in western part of Zone 2; altitude 140m; Candelaria sheet (37°48.30'N, 25°47.55'W). Coll 1981 by RB Moore and AMR da Silva.

Comment: date combined with stratigraphy provides information about average frequency of eruption in Zone 2.

W-5170. Tristanite scoria, Sete Cidades volcano (Zone 1) 21,160 ± 180

Charcoal fragments at top of soil beneath coarse tristanite scoria on northwestern wall of caldera of Sete Cidades volcano. Soil with charcoal is developed on similar deposit of tristanite scoria which, in turn, rests on Sete Cidades caldera-outflow deposit. Sample from roadcut 1.7km northwest of village of Sete Cidades; altitude 420m; Candelaria sheet (37°52.39'N, 25°48.82'W). Coll 1982 by RB Moore.

Comment: date provides approximate age of 22,000 BP for formation of caldera of Sete Cidades volcano, based on thicknesses of soils separating W-5170 from caldera-outflow deposit and comparison with soils developed on historic (AD 1563 Agua de Pau and AD 1630 Furnas) trachyte pumice deposits on São Miguel.

W-5188. Trachyte mudflow deposit, Furnas volcano (Zone 5) 22,060 ± 250

Charcoal and carbonaceous material in trachyte mudflow deposit, interpreted as hot during emplacement. Overlies W-5168 and -5249. Sample from base of sea cliff on southern flank of Furnas volcano; altitude 8m; Povoação sheet (37°43.88'N, 25°19.18'W). Coll 1981 by RB Moore.

Comment: dates thick (40m) deposit near base of stratigraphic section on southern coast and illustrates young age of Furnas volcano, which has been constructed entirely within past 100,000 years.

W-5259. Carbonaceous lake sediments, Furnas volcano (Zone 5) 23,000 ± 1000

Fossiliferous, carbonaceous, thinly-bedded lacustrine sediments, mainly consisting of trachyte ash, on western wall of Furnas caldera. Lake probably occupied pre-caldera volcanic crater. Fossils include five species of shallow freshwater diatoms (J Platt Bradbury, written commun 1984). Three separate lacustrine deposits, separated by lava flows, were dated (W-5259, -5192, -5253, and -5441) and yielded ages from 23,000-27,000 BP. Sample from small canyon at base of caldera wall 500m northwest of Lagoa das Furnas; altitude 360m; Vila Franca do Campo sheet (37°46.45'N, 25°20.30'W). Coll 1981 by RB Moore.

Comment: W-5259 is in middle of three dated carbonaceous beds. Date establishes age of interbedded lava flows. Lake sediments underlie W-5160 (Pico do Ferro) and ca 12,000-year-old caldera-outflow deposit, and overlie trachyte flow dated by K-Ar at $48,000 \pm 4000$ BP (EH McKee, written commun 1983).

W-5192. Carbonaceous lake sediments, Furnas volcano (Zone 5) 24,000 \pm 500

Lowest of three dated carbonaceous beds. Sample location and collector are same as W-5259 and -5253.

Comment: date agrees well with others from this site.

W-5441. Carbonaceous lake sediments, Furnas volcano (Zone 5) 25,500 \pm 500

Highest of three dated carbonaceous beds. Sample location is same as W-5259, -5192 and -5253. Coll 1983 by RB Moore and M Rubin.

Comment: sample is recollection of W-5253; dates are in accordance.

W-5427. Basanitoid flow, Zone 4 26,500 \pm 500

Basanitoid aa flow in northwestern part of Zone 4. Sample from roadcut 500m southeast of village of Porto Formoso; altitude 160m; Maia sheet ($37^{\circ}49.25'N$, $25^{\circ}25.60'W$). Coll 1983 by RB Moore.

Comment: dates relatively old flow in Zone 4.

W-5253. Carbonaceous lake sediments, Furnas volcano (Zone 5) 27,000 \pm 1000

Highest of three dated carbonaceous beds. Sample location is same as W-5259, -5192 and -5441. Coll 1981 by RB Moore.

Comment: date agrees with W-5441.

W-5175. Trachyte pumice deposit, Sete Cidades volcano (Zone 1) >29,000

Charcoal fragments in trachyte pyroclastic flow deposit. Sampled unit is third from bottom in section of interbedded lava flows and pyroclastic deposits. Sample from sea cliff near Ponta da Ferraria on western end of São Miguel; altitude 10m; Candelaria sheet ($37^{\circ}51.46'N$, $25^{\circ}51.28'W$). Coll 1981 by RB Moore and AMR da Silva.

Comment: most charcoal samples within pyroclastic flow deposits and under lava flows in Ponta da Ferraria section are too old to date by radiocarbon; they overlie tristanite flow dated by K-Ar at $74,000 \pm 6000$ BP (EH McKee, written commun 1983).

W-6151. Basanitoid cone, Zone 2 >30,000

Large soft charcoal fragments at top of soil underlying welded basanitoid spatter. Sample from new excavation 1.5km west of Serra Gorda, in west-central part of Zone 2; altitude 320m; Arrifes sheet ($37^{\circ}47.49'N$, $25^{\circ}42.47'W$). Coll 1988 by RB Moore.

Comment: dates one of oldest cones in Zone 2. Sampled unit underlies caldera-outflow deposit from Sete Cidades volcano, four trachyte pumice deposits and two basaltic cinder deposits.

W-5176. Trachyte pumice deposit, Sete Cidades volcano (Zone 1) >33,000

Charcoal fragments in pyroclastic flow deposit near middle of section near Ponta da Ferrara. Sampled unit is higher in section than W-5175. Sample from trail on sea cliff; altitude 90m; Candelaria sheet (37°51.70'N, 25°51.18'W). Coll 1981 by RB Moore.

Comment: this date and others in Ponta da Ferrara section indicate relatively old age of this part of Sete Cidades volcano.

W-5168. Trachyte pumice deposit, Furnas volcano (Zone 5) >33,000

Large soft charcoal fragments in trachyte pyroclastic flow deposit near base of section on southern flank of Furnas volcano. Sample from sea cliff 1.3km west of village of Ribeira Quente; altitude 5m; Povoação sheet (37°44.15'N, 25°18.90'W). Coll 1981 by RB Moore.

Comment: this deposit, W-5249 and -5188 overlie tristanite flow, dated by K-Ar at 93,000 ± 9000 BP (EH McKee, written commun 1983), at base of section west of Ribeira Quente.

W-5249. Trachyte pumice deposit, Furnas volcano (Zone 5) >34,000

Charcoal fragments in trachyte pyroclastic surge deposit overlying W-5168. Sample location and collector are same as W-5168.

Comment: unit underlies W-5188, dated at 22,060 ± 250 BP.

W-5428. Calcite, PV-1 geothermal well, Zone 2 >36,000

Calcite precipitate at geothermal wellhead. Sample from PV-1 well, drilled in 1980-1981, 2.5km southeast of city of Ribeira Grande, in northeastern part of Zone 2; altitude 152m; Ribeira Grande sheet (37°48.24'N, 25°30.53'W). Coll 1983 by AMR da Silva.

Comment: date indicates old age of carbon dioxide that has been produced from geothermal reservoir beneath Agua de Pau volcano.

W-5201. Tristanite flow, Agua de Pau volcano (Zone 3) >40,000

Charcoal fragments at top of soil beneath tristanite flow. Sampled unit is lowest flow in thick, mainly pyroclastic, sequence on southern flank of Agua de Pau volcano; sequence overlies trachyte dome dated by K-Ar at 181,000 ± 15,000 BP (Gandino *et al* 1985). Sample from sea cliff 400m southeast of village of Ribeira Chã, on southern flank of Agua de Pau volcano; altitude 30m; Vila Franca do Campo sheet (37°43.35'N, 25°29.00'W). Coll 1981 by RB Moore.

Comment: dates flow between Units 4 and 5 of Booth, Croasdale and Walker (1978) and agrees with age of >34,200 years reported by Shotton and Williams (1973) for Unit 14 of Booth, Croasdale and Walker (1978).

W-5243. Trachyte pumice, Agua de Pau volcano (Zone 3) >40,000

Charcoal fragments in trachyte pyroclastic flow deposit. Sample from roadcut 1.3km west of village of Porto Formoso, on northern flank of Agua de Pau volcano; altitude 50m; Maia sheet (37°49.63'N, 25°27.04'W). Coll 1982 by RB Moore and AMR da Silva.

Comment: dates old pyroclastic flow deposit from Agua de Pau volcano. Sampled unit overlies welded tuffs dated by K-Ar at 103,000 ± 7000 BP (Gandino *et al* 1985).

W-5173. Hawaiite flow, Sete Cidades volcano (Zone 1) >40,000

Charcoal fragments at top of soil beneath thick (23m) hawaiite aa flow. Sample from sea cliff 500m southwest of village of Candelaria on southwestern flank of Sete Cidades volcano; altitude 15m; Candelaria sheet (37°49.20'N, 25°49.72'W). Coll 1982 by RB Moore.

Comment: dates flow that underlies caldera-outflow deposit from Sete Cidades volcano.

W-5179. Trachyte pumice deposit, Sete Cidades volcano (Zone 1) >40,000

Charcoal fragments in trachyte pyroclastic flow deposit near Ponta da Ferraria on western end of São Miguel. Unit overlies W-5175. Sample from sea cliff; altitude 15m; Candelaria sheet (37°51.46'N, 25°51.28'W). Coll 1981 by RB Moore and AMR da Silva.

Comment: dates old pyroclastic flow deposit on western flank of Sete Cidades volcano.

W-5183. Trachyte mudflow deposit, Sete Cidades volcano (Zone 1) >40,000

Charcoal fragments in trachyte mudflow deposit. Unit overlies W-5175 and underlies -5179. Sample location and collectors are same as W-5175 and -5179. Altitude 11m.

Comment: mudflow deposit presumably was hot when emplaced.

W-5193. Mugearite flow, Sete Cidades volcano (Zone 1) >40,000

Charcoal fragments in soil 15 cm below base of mugearite flow. Unit underlies W-5176. Sample from sea cliff near Ponta da Ferraria on western end of São Miguel; altitude 55m; Candelaria sheet (37°51.70'N, 25°51.18'W). Coll 1981 by RB Moore.

Comment: mugearite flows are common in Ponta da Ferraria section and apparently were erupted between 74,000 and ca 40,000 years.

W-5194. Trachyte pumice deposit, Sete Cidades volcano (Zone 1) >40,000

Charcoal fragments in trachyte pyroclastic flow deposit. Sample from sea cliff 1.3km west-northwest of village of Feteiras on southern flank of Sete Cidades volcano; altitude 30m; Candelaria sheet (37°48.50'N, 25°48.76'W). Coll 1982 by WA Duffield and RB Moore.

Comment: dates old pyroclastic flow deposit from Sete Cidades volcano.

W-5199. Trachyte pumice deposit, Sete Cidades volcano (Zone 1) >40,000

Charcoal fragments in pyroclastic flow deposit. Sample from southwestern wall of caldera of Sete Cidades volcano, 700m northwest of Vista do Rei; altitude 420m; Candelaria sheet (37°50.60'N, 25°48.21'W). Coll 1982 by RB Moore.

Comment: dates old pre-caldera pyroclastic flow deposit from Sete Cidades volcano.

W-5206. Mugearite flow, Sete Cidades volcano (Zone 1) >40,000

Charcoal fragments at top of soil under mugearite flow. Sample from small canyon 1.3km southwest of village of Mosteiros on northwestern flank of Sete Cidades volcano; altitude 80m; Candelaria sheet (37°52.78'N, 25°49.95'W). Coll 1981 by RB Moore.

Comment: date agrees well with other old ages of mugearite and associated hawaiite flows (W-5173, -5193) on western flank of Sete Cidades volcano.

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