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35. *DATA REPORT:* $^{40}Ar/^{39}Ar$ AND ADDITIONAL PALEONTOLOGIC AGE CONSTRAINTS, SITE 862, TAITAO RIDGE[1]

Randall D. Forsythe,[2] Robert Drake,[3] and Richard K. Olsson[4]

ABSTRACT

This paper presents additional chronological data for samples obtained during Leg 141 of the Ocean Drilling Program. The samples were obtained from Hole 862C, located on the Taitao Ridge, an anomalous bathymetric promontory that juts out from the Pacific continental margin of South America near the Chile Margin Triple Junction (latitude ~46–47°S).

Four samples were selected for $^{40}Ar/^{39}Ar$ isotopic dating. Two of these samples were hornblende rhyolite, and the other two were phyric basalt. Hornblende separates from the rhyolitic samples provide ages of 1.54 ± 0.08 Ma and 2.2 ± 0.4 Ma. Low K contents in the basaltic samples and their slight alteration inhibited more precise age determinations.

One sample, Sample 141-862C-6R-1, 36–44 cm (Piece 6), from the Taitao Ridge, is an indurated fragment of sandstone with carbonate and volcanic clasts. Foraminifer tests isolated from this fragment have yielded age diagnostic planktonic species indicative of a very late Paleocene age. The benthic and planktonic species suggest middle shelf depths.

INTRODUCTION

This paper presents additional age constraints for samples recovered from Site 862 during Ocean Drilling Program Leg 141. The site is located on the Taitao Ridge, an anomalous feature located along the Pacific continental margin of South America within the Chile Triple Junction region (Fig. 1). The Taitao Ridge is a bathymetric promontory extending southwestward into the Pacific Basin from the continental margin of South America. To the southeast of this baythmetric ridge, a large ophiolite complex has been mapped on the Taitao Peninsula (Forsythe et al., 1986). This uplifted complex, and some associated "near-trench plutons" (Kaeding et al., 1990), are dated by K/Ar and micropaleontologic findings as late Miocene to Pliocene in age (Mpodozis et al., 1985; Forsythe et al., 1985). The age and location of the onshore magmatic rocks has tied their formation and uplift to the late Cenozoic arrival and subduction of the Chile Rise spreading center along the Peru-Chile Trench. The offshore Taitao Ridge, because of its proximity to the ophiolite and its geophysical characteristics, had been hypothesized to potentially represent an offshore extension of the Taitao ophiolite (Behrmann, Lewis, Musgrave, et al., 1992). If true, then samples recovered from the ridge could provide important information to help constrain the origin and mechanism of ophiolite emplacement. Due to the unknown nature of the boundaries of the Taitao Ridge with the surrounding oceanic floor, it is not known whether the ridge is part of the South American, Nazca, or Antarctic plate. Scientific objectives for drilling at Site 862 included determining the lithologies of the basement and its relation (if any) to the onshore ophiolite.

TECTONOSTRATIGRAPHIC SETTING OF THE SITE 862 SAMPLE SUITE

During Leg 141 three holes (Holes 862A, 862B, and 862C) were drilled at Site 862 on the crest of the Taitao Ridge approximately half way out along its length from the continental margin at a depth of approximately 1200 m. The relative positions and penetration depths of the three holes are illustrated in Figure 2. The core recovered demonstrates that the Taitao Ridge at this location is characterized by a 20 m thick sedimentary cover overlying volcanic rocks. The upper sedimentary section was continuously cored at Hole 862A, but portions of this sedimentary cover were also recovered at Holes 862B and 862C. The underlying volcanic units were penetrated approximately 20 m at Hole 862B and somewhere between 60 and 80 m at Hole 862C.

The overlying sediments and sedimentary rocks are dominantly silty clay to clayey silt and silty fine sand (or their lithified equivalents). The sediments became lithified within 6 m of the seafloor, suggesting potential unroofing may have occurred. Microfossils (foraminifers and nannofossils) recovered from these sediments indicate late Pliocene ages. Two of the holes recovered cores containing samples of sediment in depositional contact with the glassy rinds of phyric basalt flows. Within the sedimentary units found in contact with the volcanic rocks and extending a variable distance above the contact zone are abundant copper sulfides of a hydrothermal origin (Berhmann, Lewis, Musgrave, et al., 1992).

Volcanogenic material within the cores can be broken down into three types from three stratigraphic levels: isolated clasts within the uppermost cores, submarine glass fragments within the sediments, and volcanic rock samples recovered from the underlying volcanic units.

Below the upper 20 m of sedimentary cover, drilling at Holes 862B and 862C recovered 103 volcanic fragments and one fragment of well-indurated sandstone. Within these units, however core recovery was very poor, ranging from 1% to 18%. The poor recovery impedes determining the potential correlation between the holes, the relative abundance of types of units within the holes, or even the absolute order of units within any one core. While the majority of the core fragments were too large to mix within the core barrel, few had clear signs of having actually been cut by the core bit. Thus, the majority of fragments were likely produced by a zone of crushing developed in advance of the core bit. The potential for downward mixing of units from higher stratigraphic levels certainly exists. However, in describing the core fragments, new units were only defined by the appearance of new compositions or textural changes that clearly indicated the start of a new cooling unit. The application of textural and compositional criteria for defining cooling units resulted in a breakdown of the rock samples into seven cooling units within the 20 m of basement penetration at Hole 862B, and 13 units within the 60 to 80 m of penetration at 862C. The fragment of indurated sandstone was recovered in Hole 862C at approximately 60 m below

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[2] Department of Geography and Earth Sciences, University of North Carolina at Charlotte, Charlotte, NC 28223, U.S.A.
[3] P.O. Box 8819, Mammoth Lakes, CA 93546, U.S.A.
[4] Department of Geological Sciences, Rutgers University, New Brunswick, NJ 08903, U.S.A.

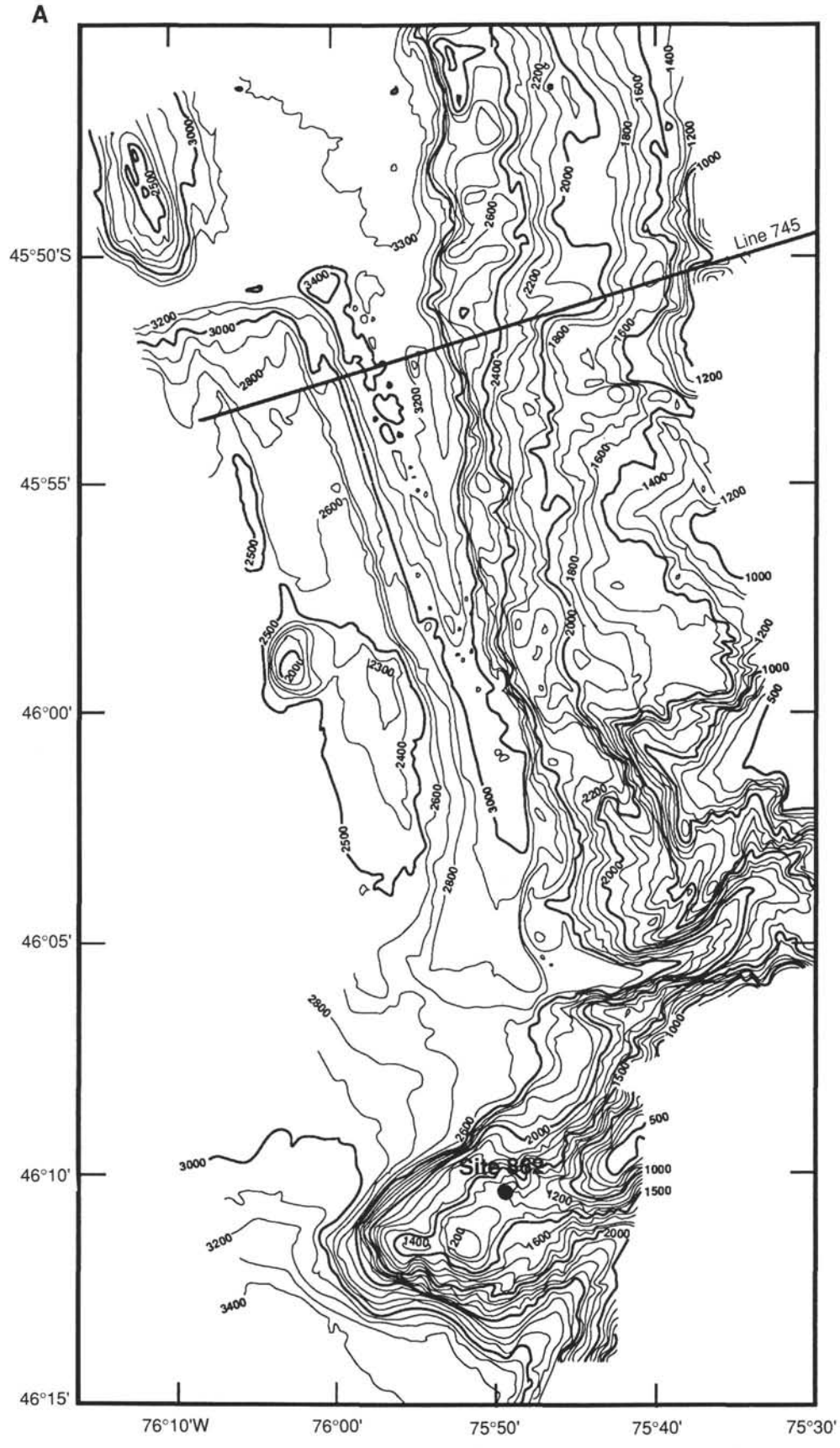

Figure 1. Location of the Taitao Ridge and Site 862. **A.** Bathymetry derived from sonar profiling. **B.** Seismic profile across the Taitao Ridge. Both from Behrmann, Lewis, Musgrave, et al., 1992.

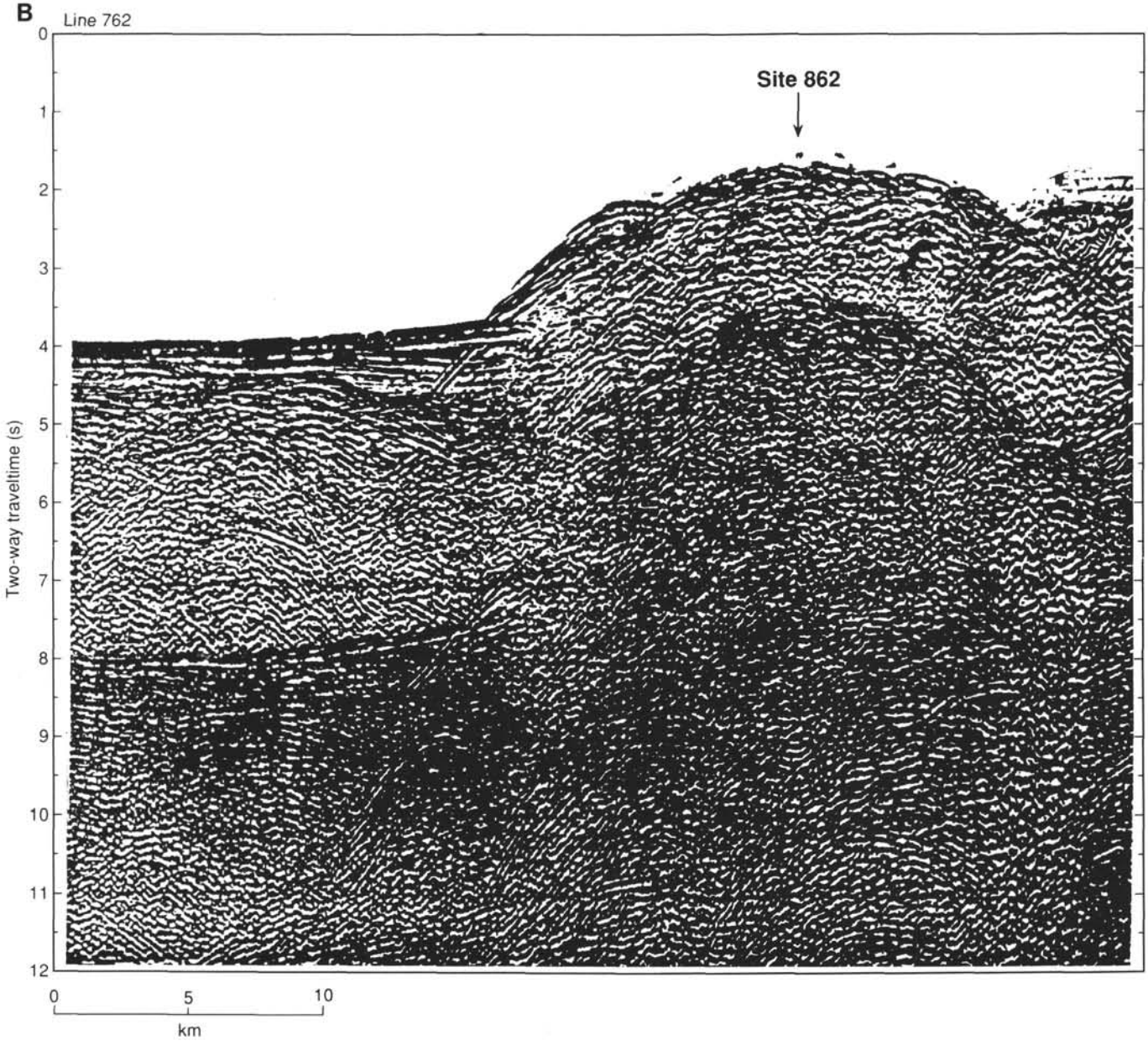

Figure 1 (continued).

the seafloor (mbsf) between fragments of moderately plagioclase phyric basalt.

^{40}AR/^{39}AR DATING PROCEDURES

Four samples from Hole 862C were selected for $^{40}Ar/^{39}Ar$ dating. Two (Samples 141-862C-5R-1, 2–7 cm, Piece 1, and 141-862C-5R-1, 30–33 cm, Piece 3) were hornblende rhyolite. Two samples (141-862C-1W-1, Piece 6, and 141-862C-8R-1, Piece 5) were phyric basalt. The four samples were crushed and sieved. Separates of hornblende (with minor orthopyroxene + groundmass) were obtain from the 28–50 mesh for dating of Sample 141-862C-5R-1 (Piece 1). Hornblende separates were obtained from the 60–100 mesh for dating of Sample 141-862C-5R-1 (Piece 3). Separates composed of plagioclase and groundmass were obtained from the 60–100 mesh for dating of Sample 141-862C-8R-1 (Piece 5) and from Sample 141-862C-1W-1 (Piece 6) a separate composed of hornblende, plagioclase, orthopyroxene and groundmass from the 60–100 mesh was used for dating.

30 to 100 mg samples were placed in Al cups and stacked in a quartz tube for a 1 hr neutron irradiation in the Oregon State University reactor. A known age standard (Taylor Creek Rhyolite 85–G003; age = 27.92 Ma) was placed in bracketing and central positions in the stack to monitor neutron flux gradients. These sanidine monitors were analyzed using laser fusion of single crystals to establish the local *J* value, which represents the fraction of ^{39}K that is converted to ^{39}Ar. Each sample was then packed in Cu foil and loaded in a vacuum sample chamber and baked-out under high vacuum at 250°C in preparation for argon extraction and analysis in a double vacuum resistance furnace. Following bake-out, each sample was analyzed in several increasing temperature steps leading to complete fusion. Because the samples are young and low in K content, only three to four steps were used so that each gas increment had sufficient argon abundance for optimum measurement. Following Ar extraction and purification, isotopic abundance measurements were performed in the static mode using the Mass Analyzer Products Model 216 mass spectrometer at Stanford University. The data acquisition process is monitored on a

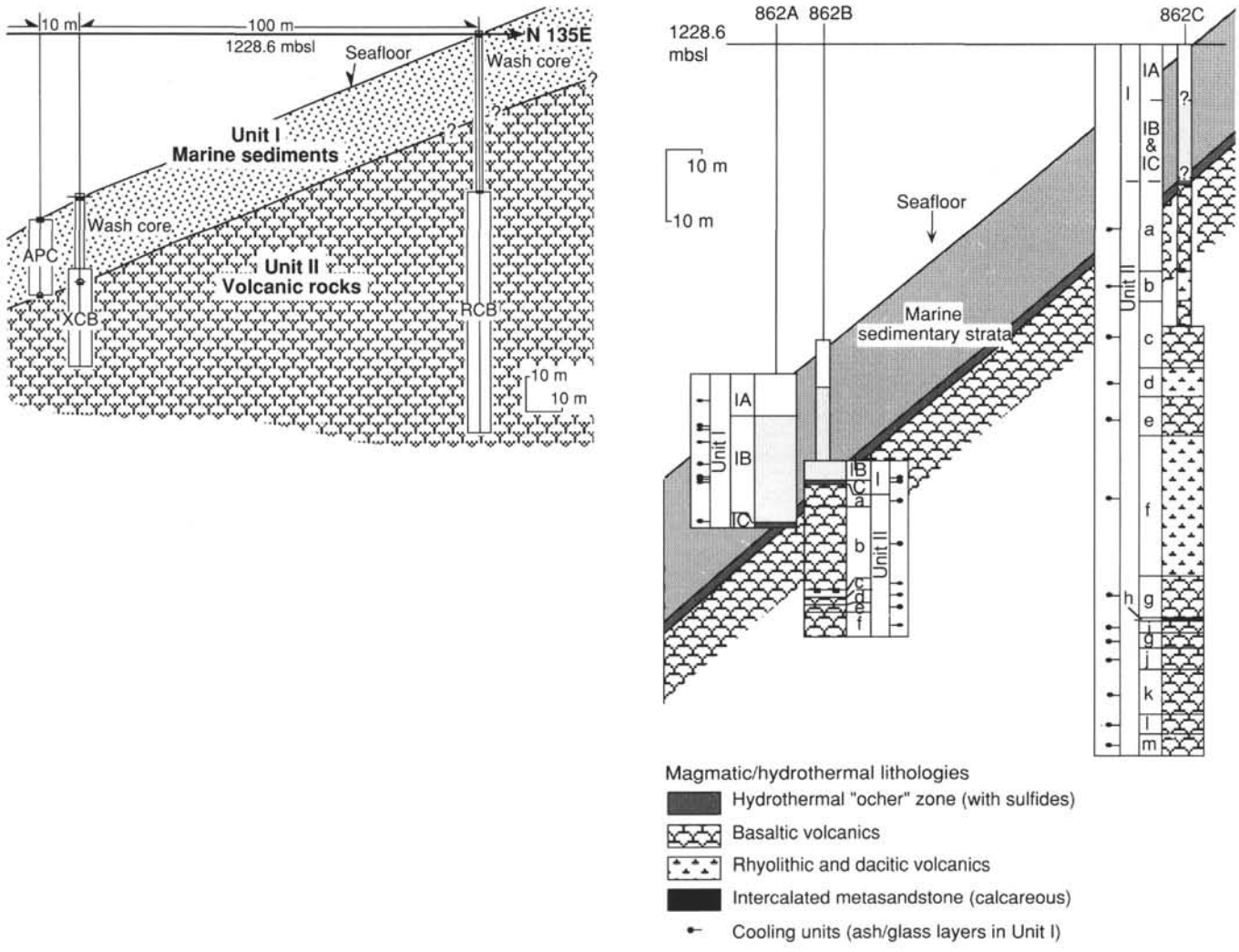

Figure 2. Topographic profile along the line of hole offsets on the Taitao Ridge, illustrating the depth and core recovery intervals, and relative positions of the three holes. From Behrmann, Lewis, Musgrave, et al., 1992.

computer display and each set of isotopic abundance measurements is plotted against time and regressed to determine the initial value at t = 0. These data are then transferred to the age calculation employing previously input sample information and irradiation parameters. Ages are calculated as inverse isochron total fusion ages (TFA) and weighted mean plateau ages (WMPA). Errors are calculated at 2 standard deviations.

^{40}Ar/^{39}Ar DATING RESULTS

The results from three of the samples are shown in Figure 3 and Table 1. WMPA ages give more reliable results because the TFA ages calculated by the inverse isochron method yield anomalous results. This is because only 3 or 4 data points exist and the errors for each point are relatively large. Hence a meaningful line representing an isochron could not be obtained.

Sample 141-862C-5R-1, 2–7 cm (Piece 1), gave a good 4-step WMPA of 1.54 ± 0.08 Ma and a total fusion age of 1.37 ± 0.22 Ma. Sample 141-862C-5R-1 (Piece 3) gave a less coherent WMPA of 2.20 ± 0.41 Ma and a total fusion age of 1.43 ± 1.05 Ma.

The error margins of the WMPA determinations for the hornblende rhyolite samples are non-overlapping. The results from Sample 141-862C-5R-1 (Piece 1) are more coherent, and at this time the 1.54 ± 0.08 Ma is considered the best refinement of the cooling age for the upper volcanism represented by the units penetrated on the Taitao Ridge during Leg 141.

The basalt samples were found to be too low in Ar to be precisely dated by step wise heating techniques. However the results provide some indications of consistency with the data form the rhyolite samples, which is at least a point of confirmation of their comagmatic origin. Basalt sample 141-862C-8R-1 (Piece 5) yielded nearly all atmospheric Ar in both the 600°C and 1200°C steps, which loosely suggests the age to be less than 1.5 Ma. Basalt Sample 141-862C-1W-1 (Piece 6) yielded nearly all atmospheric argon in the first 600°C. However, two fractions of the sample were run separately, and by combining the two separate results from the 1200°C steps we obtained an average (pseudo weighted mean plateau age) of 1.7 ± 0.2 Ma.

MICROPALEONTOLOGIC FINDINGS

Sample 141-862C-6R-1 (Piece 6) is a fragment of light brownish-gray, well indurated, medium- to coarse-grained, calcareous sandstone with a clay and micritic matrix. Low angle cross bedding is visible in the sample. Shipboard paleontologic analysis showed the sample to contain shell and microfossil tests of marine origin but did not reveal age diagnostic forms. Fragments of this sample were subjected to a clay matrix disaggregation treatment using a bath of sodium borate solution. The process successfully dislodged a number

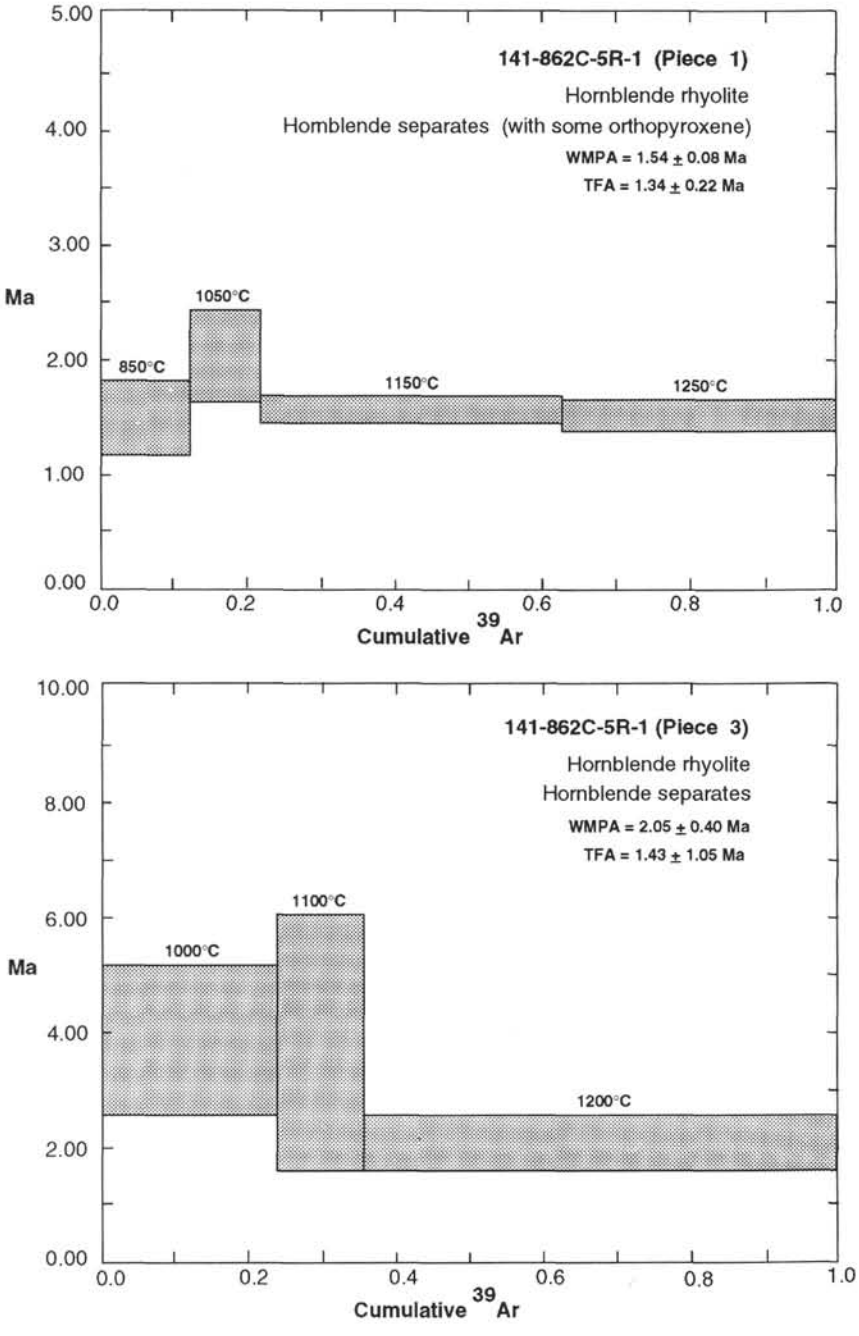

Figure 3. Graphs of Ar/Ar results from stepwise heating.

of planktonic and benthic tests. The recovered planktonic tests were more numerous than the benthics. All planktonic tests were juveniles (i.e., or not fully mature adults; that is to say lacking the terminal reproductive stage). This suggests that paleodepths were shallow shelf (corroborated by the benthics discussed below).

The planktonic foraminiferal species in this sample are indicative of very late Paleocene age. The species include: *Acarinina primitiva, Globanomalina ovalis, Globanomalina* sp., *Morozovella* cf. *gracilis, Morozovella occlusa, Subbotina linaperta, Subbotina triangularis*, and juvenile specimens of a *Morozovella* species.

The benthics include *Cibicides mortoni, Gavelinella* cf. *succedens*, and *Nonionellina* sp. These forms and one example of *Bolivina* noted in thin section are indicative of shelf depths. The combined benthic and planktonic data suggest middle shelf depths.

The late Paleocene age from this sample is in marked contrast to the late Pliocene age indicated by the microfossils from the upper sedimentary cover. It is also in marked contrast with the Ar/Ar ages reported above. This suggests that the indurated sandstone was transported from some yet unknown Late Paleocene source and deposited on the Taitao Ridge during volcanism.

DISCUSSION

The late Pliocene/earliest Pleistocene Ar/Ar dates are consistent with the late Pliocene micropaleontologic findings from the overlying sediments. The age considered most precise and accurately reflective of the age of volcanism at the Taitao Ridge is 1.54 ± 0.08 Ma. This age is substantially younger than the origin of the near trench plutons and the volcanics exposed in the Taitao ophiolite immediately on shore to the southeast. The K/Ar ages from whole rock, biotite, and hornblende analyses from these inshore units ranged from 2.4 ± .5 Ma

Table 1. Ar isotopic data for ODP Site 862, Taitao Ridge, Chile Margin Triple Junction.

Sample	Step (°C)	^{40}Ar	^{39}Ar	^{37}Ar	^{36}Ar	37/39	40*/39	%Rad	Age (Ma)	Error	%Ar	Irrad.	*J*
Run #1: hornblende separate from rhyolite (minor OPX)													
141-862C-5R-1, #1	850	0.2931	0.01091	0.00252	0.09040	0.231	2.44	9.1	1.33	±0.30	12.7	S8-A2	0.0003022
141-862C-5R-1, #1	1050	0.3336	0.00868	0.00028	0.00101	0.033	4.06	10.6	2.21	±0.38	10.1	S8-A2	0.0003022
141-862C-5R-1, #1	1150	0.9059	0.03494	0.01038	0.00284	0.297	2.95	11.3	1.61	±0.11	40.6	S8-A2	0.0003022
141-862C-5R-1, #1	1250	0.5389	0.03158	0.01003	0.00137	0.318	2.80	16.3	1.52	±0.13	36.7	S8-A2	0.0003022
								TFA	1.37	±0.22			
								WMPA	1.54	±0.08			
Run #2: hornblende separate from rhyolite													
141-862C-5R-1, #3	1000	0.5416	0.00399	0.00027	0.00175	0.068	6.18	4.6	3.37	1.29	25.5	S8-A4	0.0002982
141-862C-5R-1, #3	1100	0.2143	0.00178	0.00011	0.00065	0.064	13.40	11.1	7.29	2.31	11.3	S8-A4	0.0002982
141-862C-5R-1, #3	1200	0.5329	0.00990	0.00379	0.00175	0.382	3.06	5.6	1.68	0.44	63.2	S8-A4	0.0002982
								TFA	1.43	±1.05			
								WMPA	2.05	±0.40			

Notes: TFA = total fusion age calculated as inverse isochron. WMPA = weighted mean plateau age. 40* = radiogenic ^{40}Ar. Ar isotopic abundances in volts. Errors are 2. Correction coefficients: 39/37 = 2.74×10^{-4}, 36/37 = 2.4×10^{-3}, 40/39 = 6.75×10^{-11}. Decay constant ($1/\lambda$) 5.543×10^{-10} a^{-1}. *J* value standard: Taylor Creek Rhyolite Sanidine # 85G003 (27.92 Ma)

to 5.5 ± .4 Ma (this excludes a whole rock result of 0.8 ± .5 Ma derived from a pervasively altered porphyry stock; Mpodozis et al., 1985).

There is the remote possibility that the Taitao Ridge represents a lateral time transgressive (i.e., slightly younger) segment of the onshore Taitao Ophiolite. The 1.5 Ma age indicates that the Taitao Ridge is more than 1 Ma older than the oceanic crust to the north, and 0.5 to 1 Ma younger than the oceanic crust to the south, based on the extrapolation of the identified marine magnetic anomaly patterns adjacent to the Taitao Fracture Zone (Cande et al., 1987). This age contrasts requires either tectonic boundaries between the Taitao Ridge and the adjacent ocean floor or off axis magmatism of a leaky transform type.

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* Abbreviations for names of organizations and publications in ODP reference lists follow the style given in *Chemical Abstracts Service Source Index* (published by American Chemical Society).

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