SHRIMP U-Pb AND FT PLIOCENE AGES OF NEAR-TRENCH GRANITES IN TAITAO PENINSULA, SOUTHERN CHILE

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INTRODUCTION

The Taitao Peninsula of the continental margin of southern Chile (46° 15' S) is located 40 km south of the present day Chile Triple Junction (CTJ) of the Nazca, Antarctic and South America plates. South of this triple point, the active oceanic ridge has been progressively subducted below South America, starting at the southern tip of the continent at 14 Ma (Cande & Leslie, 1986). The peninsula is characterized by the presence of the Taitao ophiolite (Forsythe & Nelson, 1985; Bourgois et al., 1992), a unique occurrence of this rock association along the Pacific margin of Chile. The ophiolite was emplaced in a segment of the continental margin where fossil accretionary complexes of Late Paleozoic to Early Mesozoic age predominate.

In Taitao Peninsula there are several small (< 10 km^2) granitoid plutons, considered to have adakitic affinities (Lagabrielle et al., 2000; Veloso, 2001) (Fig.1). Some of these have been previously dated as Late Cenozoic by the K-Ar method (Mpodozis et al., 1985; Bourgois et al., 1992, 1993; Guivel et al., 1996).

As the exact geological significance of these ages is unclear, zircons from two samples of the Cabo Raper pluton, which intrudes the Taitao ophiolite, were dated by the SHRIMP U-Pb method on zircon to establish their crystallization ages. The thermochronological history of three of the plutons was further investigated by fission track dating of zircon and apatite. The dating of the crystallization and the cooling history of these intrusive rocks will help to constrain the tectonic evolution of the continental margin in this region.

GEOLOGY

The Taitao Ophiolite has been interpreted as emplaced as part of the collision processes between the Chile Rise and the Andean margin (*e.g.* Forsythe et al., 1986; Nelson et al., 1993; Lagabrielle et al., 1994, 2000; Veloso, 2001). During the last 14 Ma the Chile Triple Junction (CTJ) has migrated northwards from the extreme south of the continent (Cande & Leslie, 1986), and is located at present 40 km north of the Taitao Peninsula at 46º 05' S. Since the Pliocene, this area has experienced successive subduction, with partial overlap, of three short segments of the Chile Rise that are separated by oceanic fracture zones (Cande & Leslie, 1986). The subduction-collision process has exposed the following units in the continental margin:

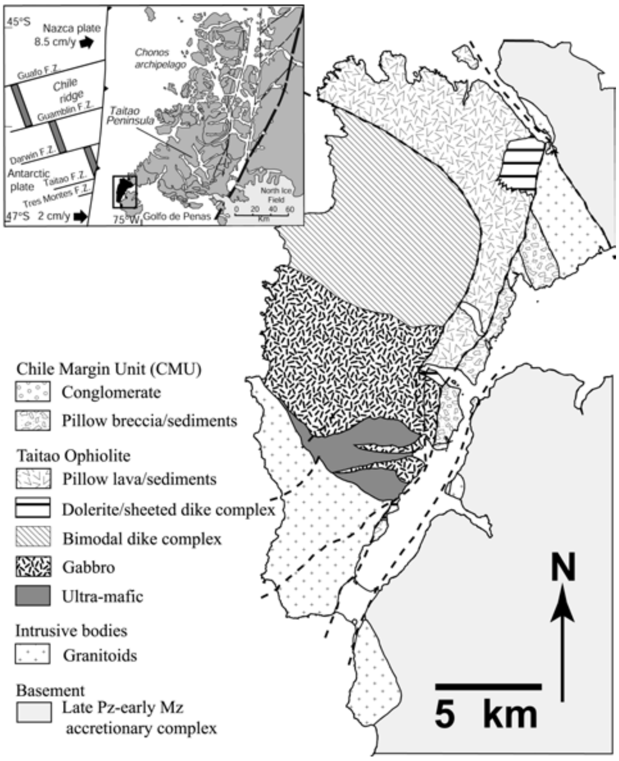

Figure1. Geological map of the Taitao Peninsula.

(1) The Taitao ophiolite: a succession of partly serpentinized peridotites (ultramafic tectonites), gabbros, and bimodal sheeted dyke complex and volcanic products (Main Volcanic Unit (MVU), Bourgois et al., 1993; Lagabrielle et al., 1994) intercalated with marine sediments of Miocene to Pliocene age (Forsythe et al., 1985; Forsythe & Nelson, 1985).

(2) A series of calcalkaline plutons with TTG affinities (Veloso, 2001), the Cabo Raper, Central, Seno Hoppner, Barrientos and Estero Cono plutons, which intrude the ophiolite or its immediate surrounding rocks.

(3) The Chile Margin Unit (CMU) (Bourgois et al., 1993) of Late Pliocene to Pleistocene age, Contrary to

previous interpretations, these authors consider this unit to be unrelated to the effusive products of the ophiolite (MVU), based on outcrop and geochemical differences.

Forsythe & Nelson (1985) showed that the ophiolite is limited to the north by low grade metamorphic rocks belonging to the Chonos Metamorphic Complex, which is of Late Triassic depositional age (Hervé & Fanning, 2000). The ophiolite is intruded by the Cabo Raper granodiorite pluton and by the Central Pluton, while the Estero Cono granodiorite pluton, the Bahia Barrientos and the Seno Hoppner plutons intrude the basement rocks in the immediate vicinity of the ophiolite (Mpodozis et al., 1985), and perhaps the ophiolite itself in inaccessible internal areas of the peninsula.

The generation and emplacement ages of the ophiolite are not well established. A Late Miocene K-Ar age in a coarse amphibole vein cutting the gabbro section of the ophiolite (Bourgois et al., 1992) indicates a Late Miocene minimum age for its generation. The age of the cross-cutting Raper pluton constrains the emplacement of the ophiolite on the continental margin. Emplacement took place either by localized obduction from the otherwise normally subducting oceanic crust or by in situ generation in an extensional environment in the continental margin (Nelson & Forsythe, 1985; Nelson et al., 1993, Bourgois et al., 1993). The ophiolite was affected by brittle deformation after emplacement (Veloso, 2001).

PETROGRAPHY OF THE ANALYSED SAMPLES.

The Cabo Raper Pluton crops out in the southwestern part of the Taitao Peninsula, and covers an area of ca. 30 km^2. It intrudes the peridotite and gabbro facies of the ophiolite (contacts not seen). Grain size varies from 0.5 to 6.0 mm, with granular to porphyritic texture. It corresponds to a granodiorite. It is composed of plagioclase (35%), alkali feldspar (10%), quartz (25%), biotite (20%) and hornblende (10%). Zircon and apatite are accessory minerals. Secondary minerals are white mica, chlorite, smectite and epidote.

The Estero Cono pluton covers approximately 6 km^2 at the northern end of the ophiolite and, where it intrudes the basement rocks. It is a tonalite, with granular and porphyritic texture, similar to the Cabo Raper granodiorite, but poorer in alkali feldspar.

GEOCHRONOLOGY

Previous radiometric datings of rocks of the area, all by the K-Ar method, are presented in Table 1 and Fig. 2.

Results obtained during the present investigation are presented in Table 2 and Figs 3 and 4.

SHRIMP U-Pb zircon ages were obtained at the Australian National University in Canberra, and FT ages by ST at the Ruhr-University in Bochum, Germany. Methodologies at these two centres were the same as presented in Williams (1998) and Thomson et al. (2001), respectively.

The U-Pb SHRIMP zircon ages obtained on clear tips of euhedral crystals are 3.84 ± 0.09 Ma (TPO 127) and 3.97 ± 0.14 Ma (TPO 128b). The first sample has inherited zircon components of ca. 5, 105 and 295 Ma, though other such inheritance was not specifically targeted during the analytical session.

The FT ages are in consistent with the U-Pb ages, with the FT zircon ages being slightly younger, and the apatite ages further so.

DISCUSSION

Subduction processes in the area of the Taitao peninsula have been very complex in the last 6 Ma. The Chile Rise is segmented by fracture zones, which are oblique to the margin. Thus events in which fracture zones are subducted, with the CTJ migrating slowly southwards, alternate with others in which segments of spreading ridge are subducted and the CTJ migrates rapidly northwards. The timing of these events has been established by Cande and Leslie (1986), and we examine below the possible correlation between the crystallization and cooling of the studied plutons with these different subduction events.

The U-Pb SHRIMP age determinations in zircons indicate that the Cabo Raper pluton crystallized at 3.9 Ma during the Early Pliocene, in the Zanclean stage according to the IUGS Time Scale (IUGS, 2000). This age is: (a) younger than two of the previous K-Ar ages on the Cabo Raper pluton (Guivel et al., 1996), (b) within the large errors of four other previous determinations (Mpodozis et al., 1985), and (c) older than the three others, two of which do not have reported errors. Thus, the relationship between the K-Ar and U-Pb ages is not systematic. The Seno Hoppner pluton, not dated in this study, has older K-Ar ages of 6.8 ± 0.2 and 5.2 ± 0.3 Ma, but the geological significance of these are not precisely established. The crystallization ages of the plutons are similar, within error, to five of the eight K-Ar ages of the volcanic rocks of the CMU, suggesting that they represent closely related events and that the emplacement of the CMU continued after the intrusions had crystallized.

One of the zircon FT ages of Cabo Raper is concordant within error with the U-Pb SHRIMP crystallization age, and the other (TPO 128b) is only 0.06 to 0.53 Ma younger than the crystallization age. The data point to a very rapid cooling to below ca. 250°C after crystallization of these plutons. The apatite FT age for both Cabo Raper and Estero Cono are significantly younger than the crystallization ages, but the other apatite FT age is within error of the obtained crystallization ages. These data indicate that cooling of the plutons in the Taitao Peninsula area from crystallization temperatures (ca. 650°C) to below 60°C occurred in an interval no longer than 2 Ma, during which the volcanic rocks of the CMU were emplaced.

Samples TPO 137 (Seno Barrientos pluton) and TPO 173 (Estero Cono pluton) yield similar FT zircon ages, and though no SHRIMP U-Pb ages have been obtained in these samples, they very probably have similar crystallization ages to the Cabo Raper pluton.

Table 1. Previous age determinations of rock units in the Taitao Peninsula. (1) Bourgois et a1., 1992 (2) Munizaga, 1970, (3) Mpodozis et al., 1985 (4) Guivel et al., 1996, (5) Bourgois et al., 1993, (6) Lemoigne, 1994, (*) nannofossil age.

Unit	Age (Ma)	Error (2 σ)
Gabbro (1)	13.8	2.6
C Raper(2)	3.2	–
C Raper(2)	3.0	–
C Raper(3)	4.1	2.4
C Raper(3)	3.6	0.6
C Raper(3)	3.4	0.8
C Raper(3)	3.3	0.3
C Raper(3)	3.2	1.2
C Raper(4)	5.0	1.0
C Raper(4)	4.8	0.3
S.Hoppner(3)	5.5	0.4
S Hoppner(3)	5.2	0.3
S Hoppner(4)	5.9	0.5
S Hoppner(4)	6.8	0.2
CMU(5)	2.3(*)	1.3
CMU(3)	4.6	1.0
CMU(3)	4.4	1.0
CMU(3)	4.4	0.6
CMU(3)	3.7	0.6
CMU(3)	3.0	0.8
CMU(3)	3.0	1.4
CMU(3)	2.9	0.8
CMU(3)	2.5	0.3
CMU(6)	6.0	0.0

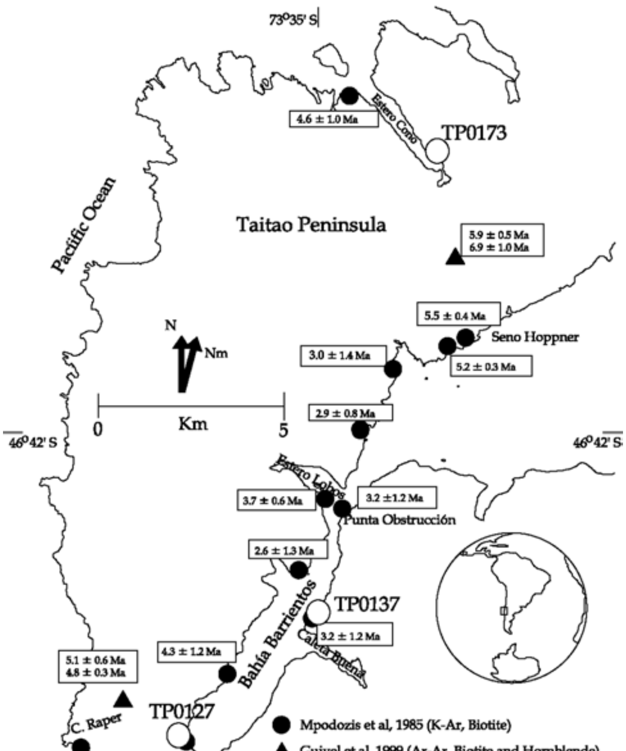

Figure2. Radiometric ages in Taitao Peninsula.

Table 2. New (U-Pb SHRIMP and FT) age determinations on theTaitao Peninsula plutons.

Sample	Unit	U-Pb zircon (Ma ± 2σ)	FT zircon (Ma ± 1σ)	FT apatite (Ma ± 1σ)
TPO 127	Cabo Raper	3.84 ± 0.09	4.05 ± 0.29	1.85 ± 0.56
TPO 128b	Cabo Raper	3.97 ± 0.14	3.51 ± 0.26	2.88 ± 0.76
TPO 137	Seno Barriento	-	3.47 ± 0.22	3.14 ± 1.30
TPO 173	Estero Cono	-	3.49 ± 0.27	-

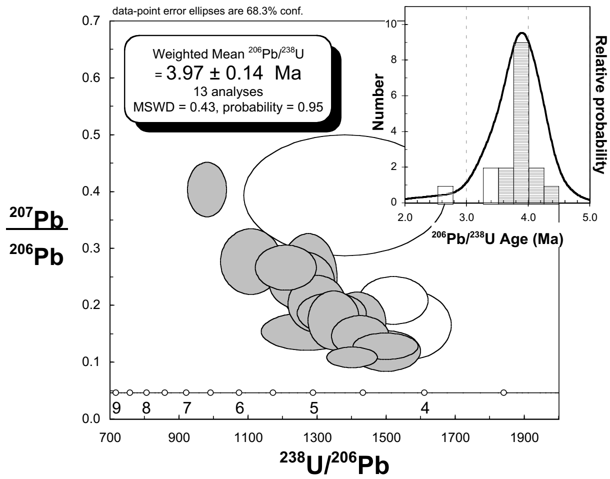

Figure 3. Tera & Wasserburg Concordia plot of SHRIMP U-Pb zircon data for sample TP01-28B (calibrated, total ratios plotted as 1σ error ellipses). Inset is a relative probability plot with stacked histogram.

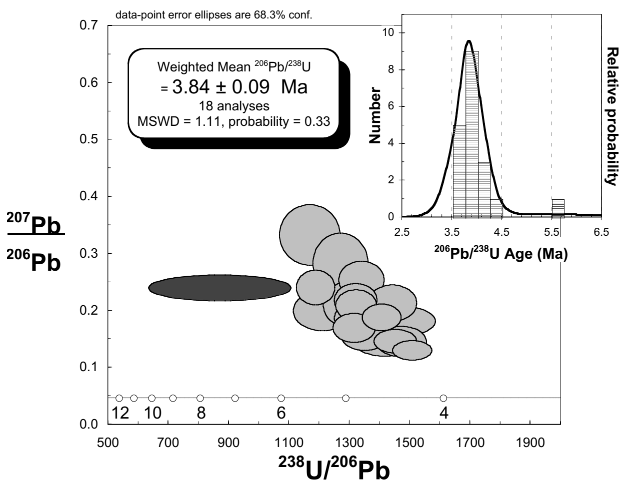

Figure 4. Tera & Wasserburg Concordia plot of SHRIMP U-Pb zircon data for sample TP0127 (calibrated, total ratios plotted as 1σ error ellipses). Inset is a relative probability plot with stacked histogram.

According to Cande & Leslie (1986) the Tres Montes Fracture Zone was being subducted in the interval between 5-6 and 3 Ma, when the Cabo Raper pluton was emplaced, and very probably also the Estero Cono and Seno Barrientos plutons. This apparently triggered the intrusion of the granitoid bodies. The LIL-depleted adakitic characteristics of these granites are probably related to this scenario. Defant & Drummond (1990) advocate genesis of adakite by melting of young subducted oceanic crust, whereas Petford & Atherton (1996) suggest melting of lower crustal underplate beneath a thickened volcanic arc. Either possibility would be compatible with the rise of excess heat or hot fluids along the fracture zone as it was subducted to the partial melting zone. When the later subduction of a short segment of the Chile Rise occurred (3 to 2.8 Ma), the granitoid bodies had already cooled to below 250°C. This cooling was probably induced by associated rapid uplift and erosion of the continental margin, which is known to be produced by subduction of a spreading ridge (Cande & Leslie, 1986).

Similar very young (7 to 2 Ma) FT ages on apatite have been obtained by Thomson (2002) near to the southern termination of the Liquiñe-Ofqui fault zone (shown by dashed lines in Fig.1) which implies that the ridge collision was a major force driving late Cenozoic transpression in the area.

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