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Jurassic to Miocene K–Ar dates from eastern central Patagonian Cordillera plutons, Chile (45°–48° S)

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Abstract – Thirty-nine K–Ar and one Ar–Ar radiometric dates from the eastern central Meso-Cenozoic Patagonian Batholith and eastern satellite plutons of the Aysén Region, of southern Chile between latitudes 45° and 48° S, combined with previous dating of seven plutons, have yielded six age groups: (1) Middle to Late Jurassic, (2) Early Cretaceous, (3) mid-Cretaceous, (4) Late Cretaceous, (5) Oligocene and (6) Miocene. In general, the Cretaceous and younger ages correspond to previous reported ages for other parts of the main batholith, but for the satellite plutons to the east show a wider age spectrum than the previously accepted Late Miocene dates. These results indicate a relatively continuous Late Jurassic to mid-Cretaceous plutonism, known to have been coeval with volcanic activity, followed by intermittent magmatism. Biotite K–Ar dates of *c.* 143–151 and 106–109 Ma, from cataclastic granitoids, may be marking the time of deformation. A review of all radiometric data on magmatic rocks from the region between 45° and 48° S in Chile shows a gap in Palaeocene ages that may correlate with a period of low-angle (flat slab) subduction between 65–50 Ma.

1. Introduction

Plutonic rocks form a substantial proportion of the Patagonian Cordillera of southern Chile. They form a continuous belt between latitudes 40° and 56° S known as the Patagonian Batholith which extends for about 1700 km in length and up to 200 km in width. Radiometric dating has yielded Late Jurassic to Miocene dates, whilst chemical analyses indicate a calc-alkaline affinity for most of these rocks (Halpern, 1973; Halpern & Rex, 1972; Suárez, 1977; Halpern & Fuenzalida, 1978; Hervé, Suárez & Puig, 1984; Mpodozis *et al*. 1985; Suárez, Hervé & Puig, 1985; Suárez, Puig & Hervé, 1986; Pankhurst *et al*. 1992, 1999, 2000; Weaver *et al*. 1990; Bruce *et al.* 1991; Vargas & Hervé, 1994, 1995; Hervé *et al.* 1996; Suárez & De La Cruz, 1997*a* and this work). Satellite plutons exposed to the east of the batholith are known to be mainly of Miocene age (Halpern, 1973; Nullo, Proserpio & Ramos, 1978; Petford & Turner, 1996; Pankhurst *et al.* 1999).

In this article we present 39 K–Ar and 1 Ar–Ar new mineral dates from granitoids of the eastern part of the Aysén Region (Fig. 1), in the eastern central Patagonian Cordillera of Chile (between 45° and 48° S), which complement earlier radiometric dates reported from this area (Halpern & Fuenzalida, 1978; Petford & Turner, 1996; B. Townley, unpub. Ph.D. thesis, Queen's Univ., 1996; Parada, Palacios & Lahsen, 1997; Pankhurst *et al.* 1999, 2000; D. Welkner, unpub. Thesis, Univ. Chile, 1999). It also complements a recent work of Pankhurst *et al.* (1999), that covers a wider area to the west and north of the region of the present study.

2. Regional geology

The oldest stratified units exposed in the region correspond to metamorphic rocks, mainly metasedimentary, of the Eastern Andean Metamorphic Complex, assigned to the Palaeozoic and interpreted either as an accretionary complex or as originating in the crystalline core of an orogenic belt, probably resulting from microplate collision, rather than fore-arc accretion (Hervé, 1993; Hervé *et al.* 1981, 1988, 1998; Bell & Suárez, 2000). The Mesozoic history of the region started during Middle?–Late Jurassic to Berriasian times with calc-alkaline volcanism of the Ibáñez Group (Niemeyer *et al.* 1984; Baker *et al.* 1981; Suárez, Demant & De La Cruz, 1999) and I-type plutonism (Suárez & De La Cruz, 1997*a*; Pankhurst *et al.* 1999). To the south, along the cordilleran belt, the Ibáñez Group is correlated with the mainly silicic volcanic rocks of El Quemado Formation and even further south, with the Tobífera Formation, that have given U–Pb ages of 154.5 ± 1.4 Ma (Estancia la Union) and 171.8 ± 1.2 Ma (Morla Vicuña), respectively (Pankhurst *et al.* 2000). The geochemistry of these volcanic rocks is more characteristic of destructive plate margins, but the presence of inherited zircon points to a crustal source (Pankhurst *et al.* 2000). Further east, in Argentina, rifting associated with silicic volcanism derived from crustal anatexis took place during Early and Middle Jurassic times (Bruhn, Stern & De Wit, 1978; Pankhurst *et al.* 1998, 2000).

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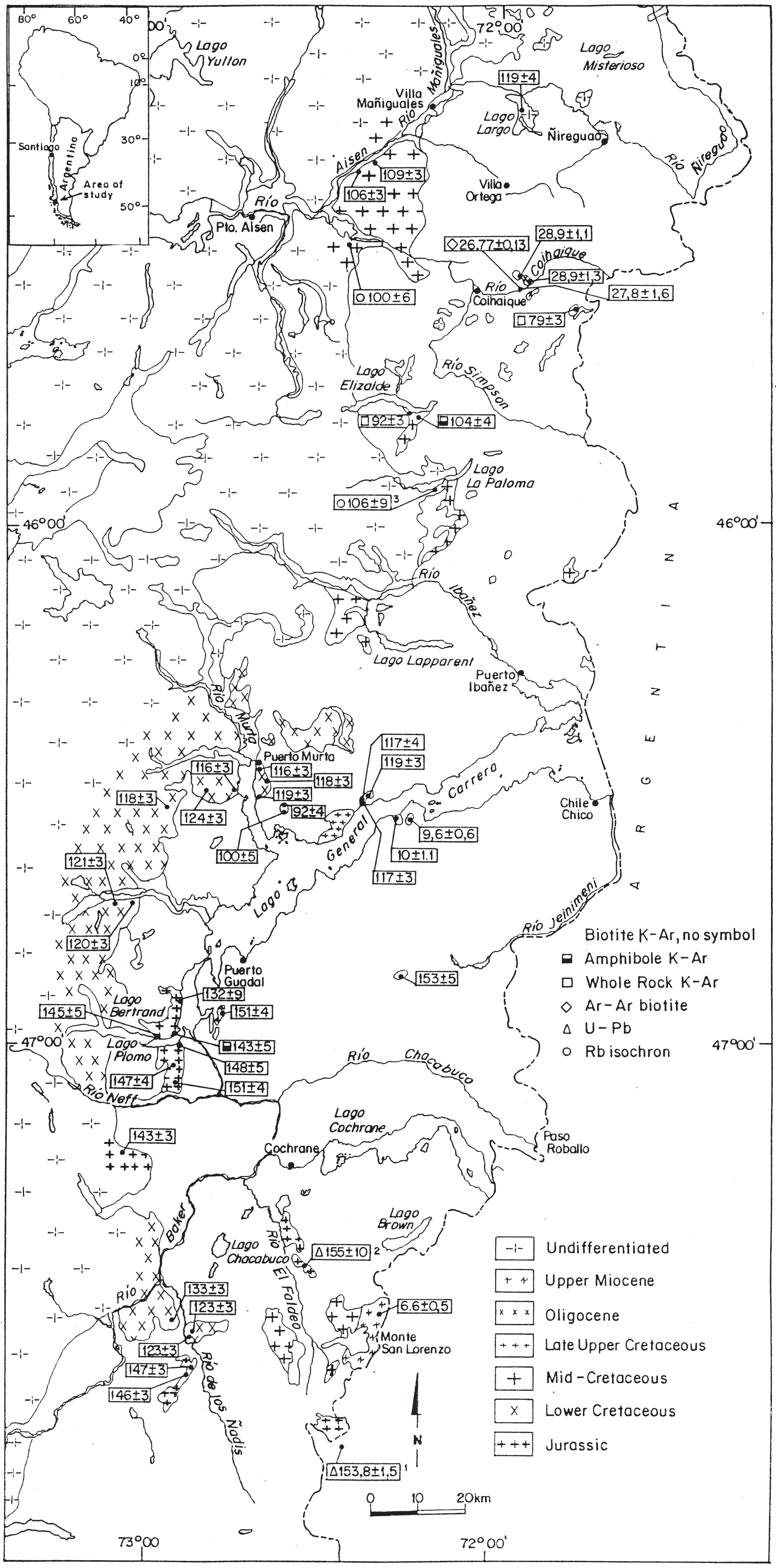

Figure 1. Geological sketch map of area between 45° and 48° S, Aysén Region, showing the distribution of plutonic rocks mainly dated by the authors. Dates with no numbers: this work. 1 – Pankhurst *et al.* (2000). 2 – Parada, Palacios & Lahsen (1997). 3 – Halpern & Fuenzalida (1978). 4 – B. Townley (unpub. Ph.D. thesis, Queen's University, 1996).

Diachronously during the Late Jurassic and Berriasian, a marine transgression, representing the initial stages of the Austral Basin (Biddle *et al.* 1986; Riccardi, 1988) coeval with volcanism, took place in the area of the present day eastern central Patagonian Cordillera (Toqui Formation: De La Cruz *et al.* 1996; Suárez, De La Cruz & Bell, 1996). During the Early Cretaceous period, post-rift thermal subsidence continued in the region of this study until early Aptian times, allowing the widespread accumulation on a shelf of black shales (Katterfeld Formation and equivalent units) and shallow marine, mainly tidal sandstones (Apeleg Formation: González-Bonorino & Suárez, 1995; Bell & Suárez, 1997).

These marine sedimentary rocks were covered by subaerial volcanic rocks that have yielded K–Ar dates of 118–100 Ma (Divisadero Group), locally reaching up to *c.* 128 Ma south of Lago General Carrera (Los Flamencos Tuffs: Suárez, De La Cruz & Troncoso, 2000). Eroded remnants of Upper Cretaceous calc-alkaline andesites, basalts and dacites, crop out east of Coihaique (latitude 44°–46° S; Laguna del Toro and Casa de Piedra complexes, Morro Negro Basalts: Suárez, De La Cruz & Bell, 1996), indicating continuation of subaerial volcanic activity in the region.

Remnants of Tertiary sedimentary deposits occur mainly in the southern part of the region. The more than 1000 m thick succession includes Late Palaeocene–Early Eocene fluvial deposits (Ligorio Márquez Formation: Suárez, De La Cruz & Troncoso, 2000), fluvial deposits (San José Formation of Flint *et al.* 1994) of Middle Eocene–Late Oligocene (?) age, Late Oligocene–Early Miocene shallow marine beds (Guadal Formation: Frassinetti & Covacevich, 1999), fluvial deposits (Galera Formation), correlated with the late Early to early Middle Miocene Santa Cruz Formation of Argentina (Marshall *et al.* 1986; Marshall & Salinas, 1990), Pliocene (–Pleistocene) fluvial gravel deposits and Pleistocene–Recent glacial deposits. Locally, Eocene to Pliocene flood basalts are intercalated in the Tertiary sedimentary succession (Charrier *et al.* 1979; Niemeyer *et al.* 1984). The Eocene and Miocene to Recent basalts have been interpreted as having formed under the influence of a migrating slab window associated with a migrating subducting oceanic ridge related to the Aluk-Farallon and Chile Ridge triple junctions, respectively (Cande & Leslie, 1986; Ramos & Kay, 1992; Kay, Ramos & Márquez, 1993; Gorring *et al.* 1997; Demant *et al.* 1998).

The plutonic rocks of the area have few published radiometric dates that indicate mainly Cretaceous values, with local Jurassic and Miocene ages (Halpern & Fuenzalida, 1978; Petford & Turner, 1996; Pankhurst *et al.* 1999, 2000; Parada, Palacios & Lahsen, 1997; Welkner & Suárez, 1999). However, to the west and north, between latitudes 43°30′ and 47°30′ S, a recent study based on Rb–Sr geochronological data revealed an age zonation that from west to east has plutons of Late Cretaceous, Early Cretaceous, Eocene and Early Miocene, and mid-Cretaceous age (Pankhurst *et al.* 1999). In this work, however, Jurassic plutons have been identified along an eastern segment of the Patagonian Batholith and as satellite plutons exposed to the east of it. Also, a series of new Cretaceous values obtained from the eastern part of the batholith and in eastern satellite plutons is reported, thus extending the known occurence of Cretaceous plutonism in central Patagonia, and an Oligocene pluton is reported for the first time, east of Coihaique.

3. Analytical procedure

The K–Ar dating was carried out at the Geochronology Laboratory of the Servicio Nacional de Geología y Minería in Santiago, Chile. The Ar was purified in Pyrex extraction lines and the radiogenic ^{40}Ar volumes were determined using standard isotopic dilution techniques in a MS10S Mass Spectrometer, with a total accuracy of 1–2%. The potassium analyses were done in triplicate by atomic absorption techniques with an accuracy of 0.7–1.3%, depending on the K content. The errors are quoted at the 2 sigma level and the decay constants are those suggested by Steiger & Jäger (1977). The mineral concentrate was obtained by heavy liquid and magnetic methods, usually in a size ranging from 60 to 80 mesh.

The Ar–Ar analysis was done at Stanford University, USA (Michael McWilliams, pers. comm., 1999). The sample was wrapped in pure Cu foil and irradiated at the TRIGA reactor at the University of Oregon. Gas was extracted in 15 minute intervals with a double-vacuum (Staudacher-type) resistance furnace with a Ta crucible and replaceable Mo liner. Extracted gas was equilibrated with SAES Zr–Al getters and analysed in static mode with a MAP 216 mass spectrometer. Dynamic and 1200 °C static blanks of ^{40}Ar were typically 1×10^{-17} and 2×10^{-15} mol, respectively. Isotopic abundances were calculated by linear extrapolation to time zero of peak heights above background during 6–12 serial scans of ^{40}Ar to ^{36}Ar. These data were corrected for neutron flux gradients (using sanidine standard 85G003 with an assumed age of 27.92 Ma), decay since irradiation, mass discrimination, and interference of Cl-, Ca- and K-produced Ar isotopes. Reported uncertainties are one sigma, determined using uncertainties in monitor age, decay rates of ^{37}Ar, ^{39}Ar and ^{40}K, rates of reactor-produced Ar isotopes, duration of irradiation, time between irradiation and analysis, peak heights, blank values and irradiation parameter J.

4. Field relations, petrography and geochronology

Rigorous interpretation of K–Ar ages can not be considered definitive, since they could represent reset ages rather than crystallization ages or older dates if excess Ar occurred. In the area of this study and its neighbourhood, six cases of rocks, dated by K–Ar and U–Pb, Ar–Ar or Rb–Sr methods by different authors, indicate, as shown below, that in five cases the K–Ar dates are concordant and in one case, originally interpreted as a minimum age, it is 10 Ma younger. Concordant K–Ar and Ar–Ar dates of 27.8 ± 1.6 and 26.77 ± 0.13 Ma were obtained from a pluton east of Coihaique (this work); concordant Ar–Ar (Petford & Turner, 1996), Rb–Sr isochron (Pankhurst *et al.* 1999) and biotite K–Ar dates (this work) of 9.6 ± 0.5 and 9.6 ± 0.4, 10.3 ± 0.4 and 10 ± 1 Ma, repectively, from the Paso las Llaves Pluton; concordant U–Pb and biotite K–Ar dates of 153.0 ± 1.0 and 150 ± 4 Ma, respectively, were obtained from an ignimbrite in Puerto Levicán (Pankhurst *et al.* 2000; Suárez & De La Cruz, 1997*b*); concordant U–Pb and biotite K–Ar dates of 154.1 ± 1.5 and 150 ± 4 Ma, repectively, were obtained in ignimbrites from Sierra Colorada (Pankhurst *et al.* 2000; Suárez, Márquez & de La Cruz, 1997); from the Cerro Barrancoso Monzogranite two similar biotite K–Ar ages of 123 ± 3 Ma (this work) and a Rb–Sr isochron age of 117 ± 1 Ma (Pankhurst *et al.* 1999) were obtained; from the Sobral Tonalite an U–Pb age of 153.8 ± 1.5 Ma (Pankhurst *et al.* 2000) and a biotite K–Ar date of 143 ± 5 Ma, interpreted as a minimum age considering the alteration of the biotite (Welkner & Suárez, 1999), were obtained. Therefore, if the above is representative of the behaviour of the Ar system in the rocks of the area, it can be expected that, in the absence of an independent date from another more reliable method, the K–Ar data presented here may represent, in most cases, a minimum or even a near-crystallization age. Fundamental in the interpretation of the K–Ar dates is the petrographic study of the samples. Excess argon, although always a probability, if it occurs, would do so locally, as it has not been identified in the 'tested' cases.

Six age groups can be distinguished in the plutons exposed in the area of study (Fig. 1). The following rock descriptions of the plutonic rocks of the study area are organized in order of decreasing age, according to radiometric data.

4.a. Middle–Late Jurassic

Plutons with Late Jurassic and earliest Cretaceous K–Ar dates occur along the eastern side of the Patagonian Batholith and as satellite plutons east of the batholith between latitudes 46°30′ and 47°40′S (Fig. 1; Table 1).

4.a.1. Eastern segment of the Patagonian Batholith (Berriasian data; Middle–Late Jurassic crystallization)

A cataclastic granodiorite of biotite and amphibole exposed on the eastern part of the Patagonian Batholith, south of Rio Nef, has given a biotite K–Ar date of 143 ± 3 Ma (CH-2093; Fig. 1, Table 1). The cataclastic nature of the analysed specimen with deformed primary biotite and the presence of recrystallized biotite (Fig. 2), suggests that the K–Ar date represents a minimum age, probably related to tectonism.

4.a.2. Eastern satellite plutons

Six isolated plutons east of the Patagonian Batholith have given Late Jurassic radiometric dates, of which four are reported here for the first time (Table 1). From north to south they are (Fig. 1):

Lago Plomo Pluton. This pluton crops out from the northern coast of Lago Bertrand (46°50' S) to the Rio Nef, west and southwest of Lago General Carrera (Fig. 1), emplaced in Palaeozoic metamorphic rocks forming a N–S elongated body. South of Lago Plomo it is separated from the Patagonian Batholith to the west by metamorphic rocks, however, to the west of Lago Bertrand a similar situation is inferred but has not been proven. This pluton, at least locally, presents a wide contact aureole (1–3 km) crossed by numerous granitic dykes and apophyses. The pluton is composed of a variety of petrographic types, including medium- to coarse-grained granodiorites, quartz monzodiorites and tonalites. The rocks exposed along the northern and southern coasts of Lago Plomo exhibit moderate and strong alteration and a cataclastic fabric (Fig. 3). The mafic minerals of these rocks include amphibole, biotite and pyroxene, although the latter is not always present. Biotite occurs in crystals approximately 1 mm in size, which in most of the dated samples is strongly deformed, partially altered to chlorite and with prehnite along the cleavage planes.

Granodiorites along the southwest coast of Lago Bertrand exhibit a moderate alteration to kaolinite, illite, chlorite and actinolite and include magnetite, apatite and sphene as accessories. Amphibole and

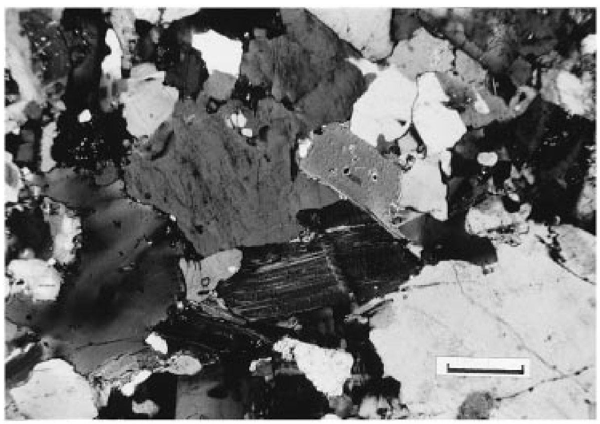

Figure 2. Thin section photomicrograph (crossed nicols) of kinked biotite and recrystallized quartz and feldspar (5 × 10; scale bar 0.25 mm; sample CH-2093).

Table 1. Late Jurassic K–Ar mineral dates

Sample number	Laboratory number	Location UTM	Rock type	Material dated	% K	^{40}Ar Rad (nl/g)	Atm Ar	Age and Error (Ma)
Eastern Segment								
CH-2093	H520.CH	650018; 4768652	Granodiorite	Biotite	7.182	41.624	8	143 ± 3
Lago Plomo Pluton								
CH-1391	P62.CH	661291; 4779091	Granodiorite	Biotite	5.999	36.641	11	151 ± 4
CH-806-1	H 193.CH	657420; 4791299	Quartz/Monzodiorite	Biotite	3.353	20.042	19	148 ± 5
CH-2089	P104.CH	658569; 4787237	Granodiorite	Biotite	7.025	41.751	15	147 ± 4
CH-801	P2144.CH	655992; 4792785	Granodiorite	Biotite	4.755	27.841	33	145 ± 5
CH-800	H188.CH	659022; 4792700	Granodiorite	Amphibole	0.469	2.712	15	143 ± 5
CH-745	P2150.CH	661275; 4798418	Granodiorite	Amphibole (chlor.)	0.482	2.574	76	132 ± 9
Rio Blanco Monzogranite								
CH-2103	H351.CH	707030; 4812986	Monzogranite	Biotite (chlor.)	4.586	28.485	10	153 ± 5
Pampa Seguel Quartz Microdiorite								
CH-1295	H153.CH	668438; 4793964	Quartz microdiorite	Biotite	5.821	35.550	39	151 ± 4
Estero Ventisquero Pluton								
CH-2065	P380.CH	660024; 4718676	Granodiorite	Biotite (chlor.)	6.9333	41.212	4	147 ± 35
CH-2081	P378.CH	657648; 4716406	Granodiorite	Biotite	6.866	40.564	6	146 ± 3

UTM – Universal Transversal Mercator Projection; Ar Rad – Radiogenic Argon; Atm Ar – Atmospheric argon

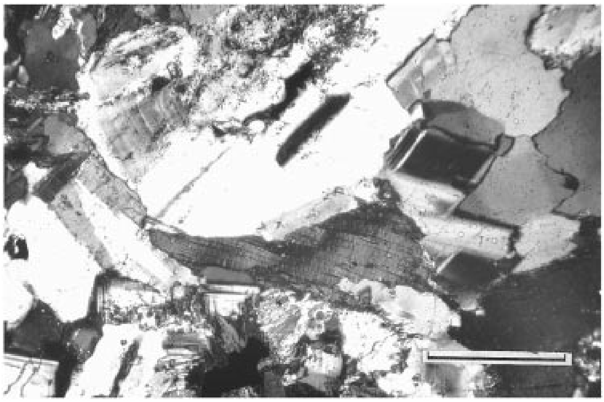

Figure 3. Thin section photomicrograph (crossed nicols) showing deformed biotite and plagioclase and polygonization (10 × 10; scale bar 0.25 mm; sample CH-1391).

biotite tonalites, moderately altered, exposed along the northern shore of Lago Plomo are locally cataclastic, with strongly deformed zones; the biotites are strongly deformed and exhibit prehnite along the cleavage planes and partial alteration to chlorite (CH-801). Amphibole and biotite granodiorites (CH-800) exposed along the northern shore of Lago Plomo and east of the above tonalites are medium- to coarse-grained rocks, with incipient cataclasis and moderate alteration to kaolinite, sericite, illite, epidote and actinolite. Amphibole is recrystallized and slightly altered to actinolite and epidote. Biotite exhibits prehnite along the cleavage planes and is intensely altered to chlorite and epidote. On the southern coast of Lago Plomo a cataclastic medium-grained quartz monzodiorite has amphibole (18 %, partially altered to actinolite), strongly deformed biotite, slightly altered to chlorite and with prehnite along the cleavage planes, and subordinate pyroxene (CH-806-1). A granodiorite of biotite and hornblende, with a weak foliation, crops out in the hills south of Lago Bertrand (CH-2089).

Four biotite separates from rocks of the Lago Plomo Pluton (Table 1) gave concordant K–Ar dates of 151 ± 4 (CH-1391), 148 ± 5 (CH-806-1), 147 ± 4 (CH-2089) and 145 ± 5 (CH-801), and a K–Ar hornblende analysis gave an age of 143 ± 5 Ma (CH-800), equivalent to a Kimmeridgian–Berriasian age (Time Scale of Gradstein & Ogg, 1996). These dates are interpreted as minimum ages as the rocks are cataclastic and the biotites are deformed, present prehnite along the cleavage planes and are partially altered to chlorite. A K–Ar hornblende date of 132 ± 9 Ma (CH-745) most probably is a reset age due to the chloritized character of the hornblende. The concordant K–Ar biotite dates, within the range of 151 ± 4 and 145 ± 5 Ma, may represent the timing of the tectonism that affected these rocks.

The *Rio Blanco Monzogranite* is emplaced in the Ibáñez Group and exposed along the valley of Rio Blanco or Pedregoso, 8 km east of the confluence with Rio Los Maitenes, in an area of approximately 5 km^2 (CH-2103). It is a medium- to coarse-grained monzogranite of biotite and amphibole. Some biotites are chloritized and with prehnite along the cleavage planes. The Rio Blanco Monzogranite gave a K–Ar (biotite) age of 153 ± 5 Ma (Table 1), that may represent a minimum or even a near-crystallization age considering the undeformed nature of the rocks and the weak alteration of the biotite to chlorite (Fig. 4).

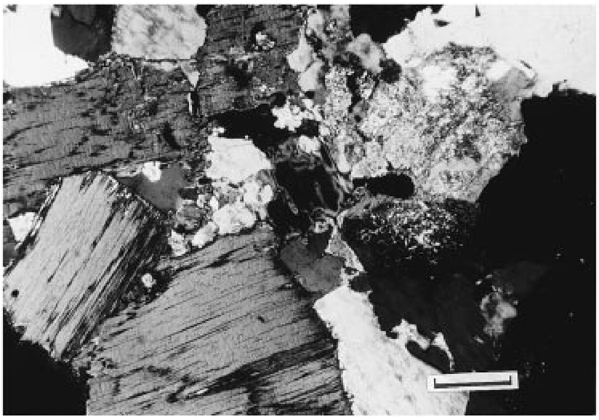

Figure 4. Thin section photomicrograph (crossed nicols) showing undeformed and weakly chloritized biotite (5 × 10; scale bar 0.25 mm; sample 2103).

Pampa Seguel Quartz Microdiorite. This pluton is exposed as a minor body 4.5 km east of the outlet of Rio Baker from Lago Bertrand (CH-1295), emplaced in Palaeozoic metamorphic rocks. It gave a biotite K–Ar date of 151 ± 4 Ma (Table 1), probably representing a minimum age considering the biotite alteration to chlorite.

The *Estero Ventisquero Pluton* is exposed as a NNE–SSW pluton, southwest of Cochrane and emplaced in Palaeozoic metamorphic rocks. It is composed of biotite and amphibole granodiorites, with slightly deformed biotites and locally weakly altered to chlorite. It gave two concordant biotite K–Ar dates of 146 ± 3 (CH-2081) and 147 ± 3 (CH-2065) Ma, interpreted as minimum ages, due to the weak deformation and alteration (Table 1).

Sobral and Cerro Esmeralda plutons. These two plutons have yielded U–Pb Late Jurassic ages (Pankhurst *et al.* 2000; Parada, Palacios & Lahsen, 1997). A U–Pb zircon age of 153.8 ± 1.5 Ma was obtained from the Argentinean part of the Sobral Pluton (Pankhurst *et al.* 2000), in the San Lorenzo Plutonic Complex (47°45′ S, 72°30′ W) exposed in the boundary between Chile and Argentina. K–Ar ages of 143 ± 5 and 138 ± 8 Ma, done in biotite and hornblende from a sample from the same pluton, have been interpreted as representing a minimum age due to the moderate to strong alteration of the analysed minerals to chlorite, epidote and actinolite (D. Welkner, unpub. Thesis, Univ. Chile, 1999; Welkner & Suárez, 1999). The Cerro Esmeralda Tonalite, exposed approximately 20 km south of Cochrane, is associated with polymetallic mineralization developed in cover rocks of the Ibáñez Group (Parada, Palacios & Lahsen, 1997). It has been dated by different radiometric methods that yielded a U–Pb age of 155 ± 10 Ma, and Ar–Ar dates from two different samples of 157.7 ± 1.5 and 158.9 ± 1.5 Ma (Parada, Palacios & Lahsen, 1997), equivalent to an Oxfordian age. These authors obtained pooled fission track ages of the same samples dated by Ar–Ar methods of 7 ± 4 and 14 ± 4 Ma. Parada, Palacios & Lahsen (1997) interpreted these data as indicating that the pluton was exhumed after *c.* 140 Ma and as recently as the Late Miocene.

South and west of the area of this study, Weaver *et al.* (1990) reported concordant U–Pb zircon and Ar–Ar biotite ages of 149.3 ± 0.8 and 146.9 ± 5.4 Ma, respectively, for an isolated pluton from the extreme east of Canal Baker (48°20′ S; 73°40′ W, according to Bruce *et al.* 1991), and immediately east of the main batholith.

4.b. Early Cretaceous

Lower Cretaceous plutons are an important component of the Patagonian Batholith (Hervé, Suárez & Puig, 1984; Weaver *et al.* 1990; Pankhurst *et al.* 1999), and in the area of this study they form part of a segment of the batholith and of the eastern satellite plutons. These plutons are emplaced in Upper Jurassic volcanic rocks of the Ibáñez Group and in Palaeozoic metamorphic rocks.

4.b.1. Eastern segment of the Patagonian Batholith (Valanginian–Aptian data)

Granitoids with Early Cretaceous radiometric dates (Table 2; Fig. 1) crop out along an eastern segment of the Patagonian Batholith between Lago Bertrand and Cerro Castillo, emplaced in Palaeozoic metamorphic rocks of the Eastern Andean Metamorphic Complex. The dated rocks are mainly composed of medium- to coarse-grained biotite and amphibole tonalites and of biotite monzogranites, slightly altered and, locally, weakly deformed.

These rocks have yielded five biotite K–Ar dates of 116 ± 3 (CH-881), 118 ± 3 (CH-856), 120 ± 3 (CH-995), 121 ± 3 (CH-758) and 124 ± 3 (CH-992) Ma, all of Early Cretaceous age (Table 2). Some of the analysed biotites are slightly altered to chlorite (CH-995; CH-856) and the others are relatively fresh (CH-992; Fig. 5), suggesting that the former dates may represent a minimum age and the latter a near-crystallization age. Pankhurst *et al.* (1999) obtained a whole rock Rb–Sr age of 132 ± 7 Ma for a granodiorite at Rio Murta, north of Lago General Carrera, and within this plutonic belt, which, although an older age, supports an Early Cretaceous age for these plutons. Further south, and west of Rio de los Ñadis, a biotite K–Ar date of 133 ± 3 Ma was obtained from a biotite granodiorite (CH-2079; Table 2), slightly deformed, exposed along the eastern part of the batholith. This date may represent a minimum age, however, it is not clear whether the pluton forms part of the Lower Cretaceous magmatism or is associated with the Jurassic Estero Ventisquero Pluton, exposed 12 km to the south.

Table 2. Early Cretaceous K–Ar dates

Sample number	Laboratory number	Location UTM	Rock type	Material dated	% K	^{40}Ar Rad (nl/g)	Atm Ar	Age and Error (Ma)
Eastern Segment								
CH-992	H202.CH	669541; 4844083	Monzogranite	Biotite	6.965	34.873	31	124 ± 3
CH-758	H180.CH	653073; 4823666	Tonalite	Biotite	6.85	33.333	8	121 ± 3
CH-995	H176.CH	654326; 4824130	Tonalite	Biotite	7.162	34.395	8	120 ± 3
CH-856	H178.CH	660350; 4842810	Monzogranite	Biotite	6.827	32.277	7	118 ± 3
CH-881	P2138.CH	674555; 4844140	Monzogranite	Biotite	6.582	30.539	12	116 ± 3
CH-2079	H524.CH	657680; 4731437	Granodiorite	Biotite	7.074	38.031	11	133 ± 3
Cerro Barrancoso Monzogranite								
CH-2072	H525.CH	664222; 4728120	Granodiorite	Biotite	6.145	30.361	10	123 ± 3
CH-2146		660329; 4728845	Monzogranite	Biotite	6.623	32.84	7	123 ± 3
Estero Villarroel Pluton								
CC-418	P2098.CC	703293; 4843169	Quartz Monzodiorite	Biotite	6.078	29.014	11	119 ± 3
CC-380	P2068.CC	701557; 4841562	Quartz Monzodiorite	Biotite	7.425	34.763	10	117 ± 3
CH-896	P2140.CH	701180; 4841797	Quartz Monzodiorite	Biotite	6.962	32.776	49	117 ± 4
Bahia Murta Pluton								
CC-425	H1135.CC	678890; 4843956	Granodiorite	Biotite	7.118	35.228	6	119 ± 3
CH-931	P2139.CH	680893; 4846454	Monzogranite	Biotite	5.908	27.966	29	118 ± 3
CH-991	H201.CH	678794; 4851745	Syenogranite	Biotite	6.254	29.161	9	116 ± 3
Lago Largo Pluton								
NG-140	P421.NG	265891; 4988475	Quartz Monzodiorite	Biotite (chlor.)	3.628	17.341	10	119 ± 4

Abbreviations as in Table 1.

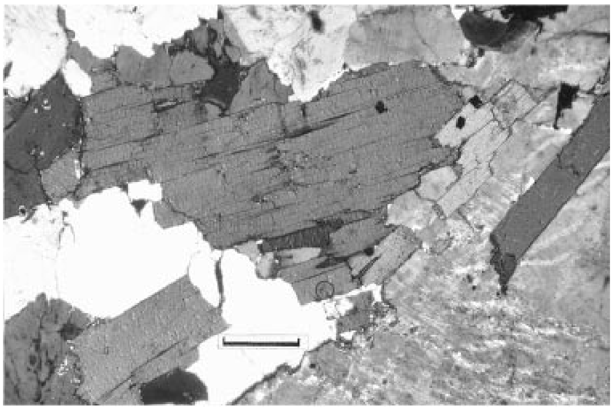

Figure 5. Thin section photomicrograph (crossed nicols) showing undeformed and weakly altered biotite (to chlorite; 5 × 10; scale bar 0.25 mm; sample CH-992).

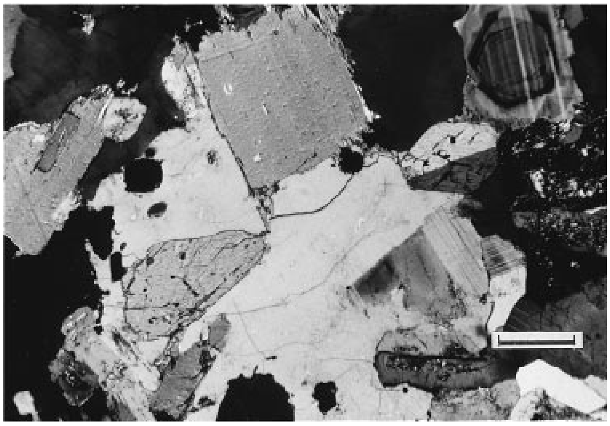

Figure 6. Thin section photomicrograph (crossed nicols) showing fresh biotite (5 × 10; scale bar 0.25 mm; CH-2146).

4.b.2. *Eastern satellite plutons (Barremian–Aptian)*

Three isolated plutons to the east of the batholith gave nine Early Cretaceous dates (Table 2). South to north these are (Fig. 1):

The *Cerro Barrancoso Monzogranite* is exposed near the locality of Los Ñadis, 40 km southwest of Cochrane, forming part of the eastern segment of the batholith. It contains hornblende and relatively fresh biotite. Two K–Ar dates of 123 ± 3 Ma (Table 2; CH-2146; CH-2072) were obtained from analyses carried out on fresh biotites (Fig. 6). A Rb–Sr isochron of 117 ± 1 Ma was obtained from samples of apparently the same pluton by Pankhurst *et al.* (1999). The near concordance of both values suggests a Barremian–Aptian crystallization age.

Estero Villarroel Pluton. Exposed east of Puerto Cristal, on the northern shore of Lago General Carrera, this pluton includes medium-grained quartz monzodiorites (CC-380, CC-418), quartz monzodiorites (CH-896) and quartz diorites (CC-391, CC-399-1). It is emplaced in the Ibáñez Group and the rocks include diffuse basic inclusions, 1–3 cm in diameter and aplitic dykes. Locally it shows weak cataclasis. The rocks include amphibole, biotite altered to chlorite, pyroxene altered to amphibole and, locally, perthite and graphic texture. They are moderately altered and locally are intensely argillized with completely chloritized amphibole. Amphibole diorite, with relicts of pyroxene, may also belong to this pluton. The Estero Villarroel Pluton gave K–Ar (chloritized biotite) dates of 117 ± 3 (CC-380), 117 ± 4 (CH-896) and 119 ± 3 Ma (CC-418) (Table 2), interpreted as Aptian minimum ages.

Bahia Murta Pluton. This pluton is composed of coarse-grained biotite granodiorites and monzogranites, and exposed along the eastern coast of Bahia Murta, along NW Lago General Carrera (CH-931, CH-991, CC-425). Feldspars, partially perthitic, are weakly altered to illite, kaolinite and sericite. The Bahia Murta Pluton yielded three concordant K–Ar (biotite) dates of 116 ± 3 (CH-991), 118 ± 3 (CH-931) and 119 ± 3 (CC-425) Ma (Table 2), obtained from different samples.

Lago Largo Pluton. This is a hydrothermally altered pluton, exposed on the northern shore of Lago Largo and to the north, that gave a biotite K–Ar date of 119 ± 4 Ma (NG-140)(Aptian), which represents a minimum age considering the alteration and the low percentage of K of the biotite (Table 2). This pluton is emplaced in volcanic rocks assigned to the El Cerrito Volcanic Complex, that overlie ignimbrites in turn overlying marine deposits with Berriasian ammonites (Covacevich, De La Cruz & Suárez, 1994; Suárez, De La Cruz & Bell, 1996). Therefore, the age of the Lago Largo Pluton and of the hydrothermal alteration is Early Cretaceous, constrained between the Berriasian and Aptian.

4.c. Mid-Cretaceous

Plutons with mid-Cretaceous radiometric dates (late Early and early Late Cretaceous) are represented by rocks from the eastern segment of the Patagonian Batholith and by isolated plutons to the east (Fig. 1; Table 3).

4.c.1. Eastern segment of the Patagonian Batholith (Albian data)

Two concordant biotite K–Ar dates of 106 ± 3 (NG-105) and 109 ± 3 (NG-107) Ma were obtained from a pink syenogranite and a grey monzogranite, respectively, exposed east of Rio Mañiguales, along the road between Puerto Aysen and Villa Mañiguales, forming part of the eastern segment of the Patagonian Batholith (Fig. 1; Table 3). These rocks are strongly cataclastic and altered, but the analysed samples had slight to moderate alteration. The sample that yielded an age of 109 ± 3 Ma corresponds to a cataclastic rock with primary and secondary biotite (Fig. 7). These dates represent a minimum age and probably reflect the age of tectonism. The above dates are concordant with two Rb–Sr isochron ages of 106 ± 9 Ma and

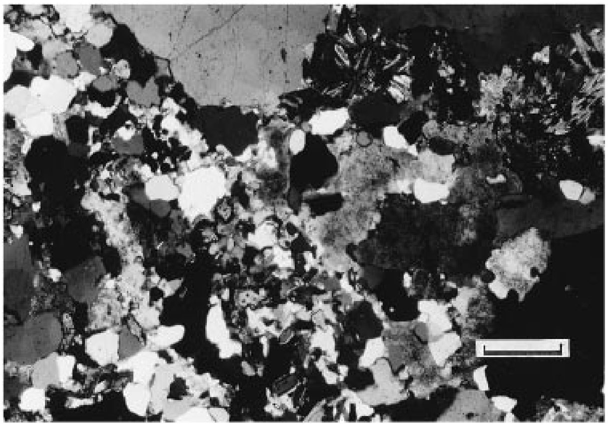

Figure 7. Thin section photomicrograph (crossed nicols) showing deformed and recrystallized feldspar, quartz and biotite. Note biotite aggregate in upper centre part (10 × 10; scale bar 0.25 mm; NG-107).

100 ± 6 Ma obtained from granodiorites exposed south of Lago La Paloma and in the valley of Rio Aysén, respectively (Fig. 1; Halpern & Fuenzalida, 1978), and emplaced in rocks assigned to the Ibañez and Divisadero groups. If Halpern & Fuenzalida's dates represent near-crystallization ages and the Rio Mañiguales dates represent the timing of tectonism in the analysed rocks, a syntectonic emplacement for these granitoids may be inferred if they belong to the same plutonic event.

4.c.2. Eastern satellite plutons (Albian–Cenomanian data)

In the studied area three isolated plutons gave mid-Cretaceous radiometric dates (Table 3), and a fourth was reported by Welkner (D. Welkner, unpub. Thesis, Univ. Chile, 1999; Welkner & Suárez, 1999), from south of Cochrane. The latter gave two biotite K–Ar dates of 90 ± 2 and 89 ± 3 Ma, and an amphibole K–Ar age of 84 ± 4 Ma that may represent near-crystallization ages.

Lago Elizalde Plutonic Complex. Exposed on the north- and southeastern part of the lake, the pluton covers approximately 20 km^2, and is emplaced in rocks assigned to the Ibañez and Divisadero groups. These rocks form part of a plutonic complex composed of diorites, quartz monzonites, syeno- and monzogranites, monzodiorites and gabbros. Two K–Ar dates were obtained from diorites exposed on the eastern coast of Laguna Azul (CH-2430), a small lake south of Lago Elizalde, and on the southern coast of the latter (CA-54), that yielded an age of 104 ± 4 (amphibole) and 92 ± 3 Ma (whole-rock), respectively (Table 3). The *c.* 104 Ma age is concordant with the isochron ages of Halpern & Fuenzalida (1978) and with the K–Ar dates reported here from the Rio Mañiguales area, indicating an important thermal event during Albian times, probably associated with syntectonic plutonic emplacement.

Table 3. Mid-Cretaceous–Late Cretaceous K–Ar dates

Sample number	Laboratory number	Location UTM	Rock type	Material dated	% K	^{40}Ar Rad (nl/g)	Atm Ar	Age and Error (Ma)
Eastern Segment								
NG-107	P419.NG	709503; 4980842	Monzogranite	Biotite	6.852	30.000	11	109 ± 3
NG-105	P420.NG	706178; 4979506	Syenogranite	Biotite (chlor.)	4.025	17.020	8	106 ± 3
Lago Elizalde Plutonic Complex								
CH-2430	H477.CH	715796; 4924665	Diorite	Amphibole	0.474	1.970	20	104 ± 4
CA-54	H497.CA	713647; 4926491	Diorite	Whole rock	0.996	3.669	13	92 ± 3
Estero Montenegro Stock								
CH-940	H187.CH	683254; 4841424	Granite	Biotite	1.483	5.899	29	100 ± 5
CH-943	H181.CH	683711; 4842191	Syenogranite	Biotite	3.840	14.022	47	92 ± 4
Lago Castor Diorite								
CH-2448	H392.CH	282178; 4947673	Diorite/Porph	Whole rock	0.886	2780.000	17	79 ± 3

Porph – porphyritic; other abbreviations as in Table 1.

The *Estero Montenegro Stock* is a small body elongated in a NW–SE direction, exposed north of Puerto Sánchez, on the northern shore of Lago General Carrera. It is composed of moderately altered medium- and coarse-grained biotite and amphibole monzogranites and granodiorites (CH-943 and CH-940, respectively). It gave two mid-Cretaceous K–Ar dates of 100 ± 5 (in oxidized biotite; CH-940) and 92 ± 4 Ma (biotite; CH-943) (Table 3). The low K content of these two biotite concentrates prevents any further consideration of the dates. These rocks are petrographically comparable to the nearby Murta Pluton, with Aptian ages, therefore, this stock may well represent an apophysis of the Bahía Murta Pluton.

4.d. Latest Cretaceous (Campanian–Maastrichtian)

Three plutons with latest Cretaceous radiometric dates, belonging to the eastern satellite plutons, have been identified in the area (Fig. 1).

Lago Cástor Diorite Porphyry. This pluton is exposed on the shores of Lago Cástor, east of Coihaique, and comprises a series of intrusive porphyries of diorite, microdiorite, granodiorite and quartz monzodiorite. Their mineralogy includes amphibole and pyroxene, and biotite in the granodiorite. The granodiorite and quartz monzodiorite are locally silicified and cataclastic. These rocks are emplaced in the Hauterivian?–Aptian–Albian Divisadero Group. The Lago Cástor Diorite Porphyry (CH-2448) gave a K–Ar (whole-rock) date of 79 ± 3 Ma (Table 3), equivalent to a Campanian age. This date may represent a minimum age, therefore, the pluton was emplaced sometime between the Albian and the Campanian. Widespread epithermal mineralization in the nearby Divisadero Group has been dated at *c.* 75 Ma (AUR Resources, unpub. report; pers. comm.). The concordance of these dates and the geographical vicinity suggest a genetic relationship.

The *Puerto Cristal Pluton* is exposed immediately west of Puerto Cristal, on the northern shore of Lago General Carrera, and is emplaced in Palaeozoic metamorphic rocks. The plutonic rocks are mainly coarse-grained miarolitic amphibole and biotite monzogranites, with moderate to intense illite, kaolinite, smectite and chlorite alteration of the mafic minerals (CC-385, CC-386, CC-405). Sphene, apatite, zircon and allanite are accessory minerals. Near the south-eastern contact, a grey graphic biotite and muscovite monzogranite (syenogranite), with miaroles and intense alteration to sericite, kaolinite and chlorite and with veinlets of silica and limonite, crops out. It is intruded by a pink granitoid (CC-381) and by an aplite. The monzogranite has finer-grained zones and exhibits assimilated basic inclusions. In Cerro Blanco, on the western side of the pluton, graphic monzogranites with heterogeneous grain size include coarse and fine-grained facies, with biotite altered to chlorite and epidote. Approximately 1 km east of the outlet of the Rio Miller into Lago General Carrera, a grey medium-grained amphibole tonalite (actinolite and chlorite) with chloritized biotite (CC-404) crops out. It shows moderate to intense argillization, occasional feldspar megacrystals (3 mm), schist xenoliths and 1–3 cm wide zones with concentrated biotite (assimilation of schists) and occasional shear zones. This tonalite may be another facies of this pluton or an independent pluton. The alteration of these rocks prevented any K–Ar dating and the only reliable radiometric reference for this pluton is an Ar–Ar age of 69 ± 4 Ma (K-feldspar) (B. Townley, unpub. Ph.D. thesis, Queen's Univ., 1996).

4.e. Oligocene

The Bandurrias Gabbro, exposed 10 km east of the city of Coihaique (Fig. 1), comprises gabbros, microgabbros and diorites, and has yielded Oligocene K–Ar and Ar–Ar dates. Three isolated small exposures of comparable petrography crop out 3 km to the west–southwest, north and south of Rio Coihaique (Fig. 1). The gabbros and microgabbros include pyroxene (20–30 %), olivine (4–10 %), and biotite (1–4 %). Locally they are moderately to intensely altered. The exposures of these rocks, particularly the small outcrops, exhibit a NE–SW orientation, parallel to a fault system. Two K–Ar ages of 28.9 ± 1.3 (CH-1112) and 28.9 ± 1.0 (CH-1113) Ma (Table 4) were obtained from biotite concentrates of different samples of the Bandurrias Gabbro. A concordant biotite K–Ar age of 27.8 ± 1.6 (CH-1139; Table 4) was yielded by samples from a small gabbro stock exposed 3 km to the southwest of the pluton. The biotite concentrate of the latter gave a concordant Ar–Ar weighted mean plateau age of 26.77 ± 0.13 Ma (including J), an inverse isochron age of 26.88 ± 0.16 Ma and a total fusion age of 26.67 ± 0.13 Ma (including J) (Fig. 8) (M. McWilliams, pers. comm., 1999). The concordant results suggest that these are near-crystallization ages (Late Oligocene).

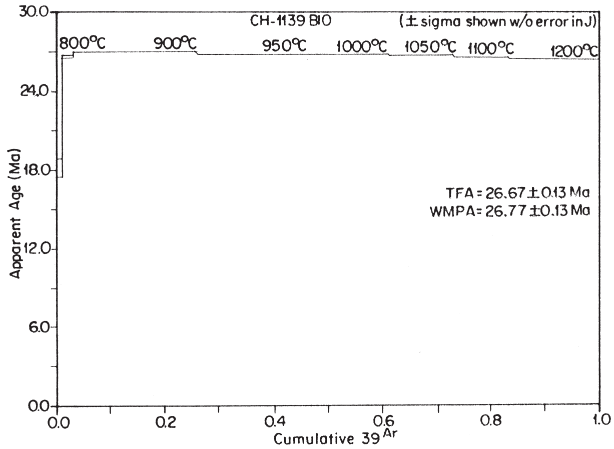

Figure 8. Ar–Ar age spectra of a sample of an Oligocene eastern satellite gabbro.

4.f. Late Miocene

Late Miocene plutonic rocks have been identified in isolated plutons east of the Patagonian Batholith. They occur in the Paso Las Llaves and in the Rio Avilés, south of Lago General Carrera, where they are emplaced in the Ibáñez Group, and in the Monte San Lorenzo, emplaced in Palaeozoic metamorphic rocks (Fig. 1). It is not known whether the two adjacent exposures of Paso Las Llaves and Rio Avilés form one pluton or correspond to two plutons separated by a thin envelope of volcanic rocks.

Paso Las Llaves Pluton. This pluton has an area of exposure of less than 5 km^2 and it is characterized by a variety of petrographic facies, from gabbro to granodiorite and granitic pegmatites with miaroles (Vargas & Hervé, 1994, 1995). Fine-grained darker facies intermingle with coarser and lighter facies. A cataclastic syenogranite (CH-763), with potassic alteration, has abundant secondary biotite in veinlets and primary chloritized biotite, with chlorite, sericite, kaolinite and quartz. In the contact aureole of the Ibáñez Group, a granitic dyke has abundant xenoliths of rounded diorite and angular schist. Geobarometry on hornblendes of this pluton indicate 3 km emplacement (Vargas & Hervé, 1995). Fluid inclusion studies on minerals from the miaroles indicate a formation depth of 2 km (Vargas & Hervé, 1995). The Paso Las Llaves pluton gave Ar–Ar (biotite) ages of 9.6 ± 0.5 and 9.6 ± 0.4 Ma (Petford & Turner, 1996), a Rb–Sr isochron of 10.3 ± 0.4 Ma (Pankhurst *et al.* 1999) and a K–Ar (biotite) date of 10 ± 1.1 (CH-763) Ma (this work; Table 4). The latter was done on secondary biotite generated by potassium alteration of the rocks, and of tardimagmatic origin as the concordance of the radiometric dates suggests. The concordant dates obtained from all these samples and methods support a late Miocene near-crystallization age.

The *Avilés Pluton* has an an area of 25 km^2 and is composed of a medium-grained quartzmonzonite (CH-226) with biotite (7 %), slightly altered to chlorite, pyroxene (3 %), weakly altered to actinolite and epidote and amphibole (1 %), altered to chlorite and with rims of pyroxene. The feldspars are weakly altered. It gave a K–Ar (biotite) date of 9.6 ± 0.6 Ma (Table 4).

San Lorenzo Granite. This is a pluton of 75 km^2 forming the second highest mountain in Patagonia and emplaced in Palaeozoic metamorphic rocks. The main rock type is a biotite syenogranite, with monzogranitic facies, and with occasional miaroles up to 14 cm in diameter (D. Welkner, unpub. Thesis, Univ. Chile, 1999). The San Lorenzo Pluton is the youngest in the area of the Monte San Lorenzo and gave a biotite K–Ar age of 6.6 ± 0.5 Ma (Table 4; Q-379), concordant with a biotite K–Ar date of 6.4 ± 0.4 Ma reported by Welkner (D. Welkner, unpub. Thesis, Univ. Chile, 1999). Previous K–Ar dates from a sample in Argentina gave 8 ± 1 Ma (Ramos & Palma, 1981) and from Chile 8.8 ± 6.1 Ma (M. Pino, unpub. Thesis, Univ. Chile, 1976).

5. Discussion and conclusions

The Patagonian Batholith in the Aysén area of the central Patagonian Cordillera has been reported to have Cretaceous margins and a Cenozoic centre, and Neogene satellite plutons to the east and west (Pankhurst *et al.* 1999). This symmetrical pattern has also been encountered south of Canal Beagle (Hervé, Suárez & Puig, 1984; Suárez, Puig & Hervé, 1986; Suárez, Hervé & Puig, 1985) and in the area of Canal Baker (Weaver *et al.* 1990). The work done on the eastern segment of the Patagonian Batholith and in the eastern satellite plutons, and reported here, shows a

Table 4. Oligocene and Miocene K–Ar dates

Sample number	Laboratory number	Location UTM	Rock type	Material dated	% K	^{40}Ar Rad (nl/g)	Atm Ar	Age and Error (Ma)
Bandurrias Gabbro								
CH-1112	H526.CH112	271964; 4952806	Microgabbro	Biotite	6.516	7.378	47	28.9 ± 1.3
CH-1113	H488.CH-1113	272269; 4953385	Microgabbro	Biotite	6.888	7.802	35	28.9 ± 1.0
CH-1139	P157.CH-1139	268482; 4950934	Microgabbro	Biotite	6.877	7.487	72	27.8 ± 1.6
Paso las Llaves Pluton								
CH-763	P2161.CH	702240; 4832828	Granite	Biotite (chlor.)	5.678	2.217	84	10.0 ± 1.1
Avilés Pluton								
CH-226	H870.CH	709405; 4831131	Quartz monzonite	Biotite	7.216	2.689	66	9.6 ± 0.6
San Lorenzo Granite								
Q-379		700049; 4732923	Monzogranite	Biotite	6.707	1.718	53	6.6 ± 0.5

Abbreviations as in Table 1.

more complex magmatic evolution. It identifies the presence of an important phase of Middle–Upper Jurassic plutonism along the eastern belt of the Patagonian Batholith. This supports the idea that older plutons occur along the margins of the main batholith. However, no Jurassic plutons have been identified along the western side of the batholith, and, it is not certain if the symmetry of the age-belts includes the Jurassic rocks. It is recognized here that between latitudes 45°30' and 47°30' S, the eastern belt of the batholith includes a southern segment of Middle–Upper Jurassic plutons, with a Lower Cretaceous pluton in the far south of the region, a central segment of Lower Cretaceous plutons and a northern segment with mid-Cretaceous radiometric dates.

The satellite plutons to the east of the Patagonian Batholith, and south of latitude 46° S, known to include Miocene intrusives (Paine, Fitz Roy and San Lorenzo plutons: Halpern, 1973; Nullo, Proserpio & Ramos, 1978; Ramos & Palma, 1981; Welkner & Suárez, 1999), have a wider age range, with plutons of Upper Jurassic, Lower and Upper Cretaceous, and Miocene ages. They represent off-axis intermittent plutonism continuing more than 160 Ma, and locally maintaining the same magma conduit.

Most of the K–Ar Late Jurassic–earliest Cretaceous dates reported here are interpreted as minimum ages, and those analyses done in cataclastic rocks of the eastern segment of the batholith and of the Lago Plomo Pluton, and ranging between 143 ± 5 and 151 ± 4 Ma, may represent the time of deformation. The oldest K–Ar dates, of 153 ± 5 (Rio Blanco Monzogranite) and 151 ± 4 Ma (Pampa Seguel Microdiorite), are concordant with the U–Pb ages of 155 ± 10 and 153.8 ± 1.5 Ma, recently reported from two satellite plutons in the area (Parada, Palacios & Lahsen, 1997; Pankhurst *et al.* 2000). Therefore, and although these last K–Ar analyses were carried out on partially chloritized biotites, they may represent near-crystallization ages.

Early Cretaceous K–Ar ages obtained from the eastern segment of the Patagonian Batholith range between 116 ± 3 and 124 ± 3 Ma. The youngest dates were obtained from biotites slightly altered to chlorite, and represent minimum ages. The oldest age, from analyses done in fresh biotites, is concordant with a whole rock Rb–Sr age of 132 ± 7 Ma obtained from this segment (Pankhurst *et al.* 1999), thus supporting a near-crystallization age interpretation. The Cerro Barrancoso Monzogranite yielded two K–Ar dates of 123 ± 3 Ma, from analyses done in fresh biotites, nearly concordant with a Rb–Sr isochron of 117 ± 1 Ma (Pankhurst *et al.* 1999), and are interpreted as near-crystallization ages. The Lago Largo Pluton, emplaced in rocks assigned to the Early Cretaceous period, yielded a K–Ar age of 119 ± 4 Ma, interpreted as a minimum age considering the hydrothermal alteration of the pluton. Therefore, both the emplacement and hydrothermal alteration of the pluton would have taken place during Early Cretaceous times. The Estero Villarroel and Murta plutons yielded six K–Ar dates ranging between 116 ± 3 and 119 ± 3 Ma, which have no other independent age corroboration. However, the concordance of these dates may reflect a main cooling event related either to plutonism or uplift during Aptian times.

An amphibole concordant age of 104 ± 4 Ma obtained in the Lago Elizalde Plutonic Complex may represent a near-crystallization age, considering the freshness of the analysed sample and the concordance with a Rb–Sr isochron of 106 ± 9 Ma (Halpern & Fuenzalida, 1978) obtained in the Lago La Paloma, 17 km to the south. Two concordant biotite K–Ar ages of 106 ± 3 and 109 ± 3 Ma, obtained from cataclastic granites from the eastern segment of the batholith along Rio Mañiguales, may represent the timing of deformation.

The identification of Middle–Upper Jurassic to Tertiary I-type plutons in the studied area, indicates that subduction processes were operative during this period (Suárez & De La Cruz, 1997*a*). Upper Jurassic subduction processes have been inferred independently by the calc-alkaline trend of the Ibáñez Group exposed in the region (Suárez, Demant & De La Cruz, 1999), as formerly suggested by Baker *et al.* (1981). However, recently Pankhurst *et al.* (2000) have demonstrated the presence of inherited zircons in equivalent Jurassic volcanic rocks exposed to the south, indicating crustal participation in the source. Therefore, the Middle–Upper Jurassic plutons may represent the roots of the calc-alkaline arc represented by the Ibáñez Group, as suggested previously (Suárez & De La Cruz, 1997*a*; Pankhurst *et al.* 2000). The Cretaceous plutons may have been related to coeval calc-alkaline volcanic rocks represented by the late Early Cretaceous Divisadero Group, and the Late Cretaceous Laguna del Toro Volcanic Complex, the Casa de Piedra Domes and Morro Negro Basalts (Suárez, De la Cruz & Bell, 1996). The apparent northern boundary of the Middle–Upper Jurassic plutons along the vicinities of Lago General Carrera appears to be due to absence of data, as the Ibáñez Group, interpreted as the volcanic envelope of the coeval Jurassic plutons, covers a much wider area of exposure to the north and south of Lago General Carrera, implying that related Jurassic plutonism may also have existed in those areas.

The new data also have implications that relate to the age of the Ibáñez Group. A pre-153 Ma age can be inferred for the volcanic rocks of this group that were intruded by the Rio Blanco Monzogranite, which yielded that date. This is in accordance with the radiometric dating done in rocks of the Ibáñez Group that have yielded Late Jurassic values (Suárez & De La Cruz, 1997*b*; Suárez, Márquez & De La Cruz, 1997; Pankhurst *et al.* 2000).

A new Cenozoic pluton was identified within the satellite plutonic belt east of the Patagonian Batholith. It corresponds to an Oligocene pluton (Bandurrias Gabbro), east of Coihaique, that rendered *c.* 27–29 Ma K–Ar and Ar–Ar dates. No Oligocene volcanic unit crops out in the area and the only evidence of coeval Oligocene volcanism is given by the pyroclastic detritus in the clastic sedimentary beds of the Middle Eocene–Oligocene (?) San José Formation and in the Upper Oligocene–Lower Miocene Guadal Formation exposed south of Lago General Carrera. The Upper Miocene plutons were coeval with a *c.* 12 Ma tuff interbedded in the Miocene sedimentary beds in adjacent Argentina (Dal Molin & Franchi, 1996).

Some of the K–Ar dates from cataclastic rocks, locally with secondary biotites, may represent the age of tectonism. If this is correct, tectonic deformation of plutonic rocks occurred during *c.* 148 Ma and 105 Ma, equivalent to the Tithonian and Albian, repectively. The latter timing is coeval with emplacement of plutonic rocks in the area, as *c.* 106 Ma Rb–Sr isochron ages (Halpern & Fuenzalida, 1978), probably representing near-crystallization ages, were obtained from rocks exposed in the area (Rio Aysen and Lago La Paloma), implying syntectonic or forceful emplacement.

Magmatic processes were active in the region, at least since Middle to Late Jurassic times. However, a search on the published radiometric data on granitoids from the segment of the Patagonian Cordillera between 45°–48° S showed the absence of any Palaeocene date between *c.* 69 (B. Townley, unpub. Ph.D. thesis, Queen's Univ., 1996) and 48 Ma (Weaver *et al.* 1990). The recent work of Pankhurst *et al.* (1999, 2000) and the data presented here, also failed to yield Palaeocene ages. Gaps in arc magmatism have been explained as related to flat subduction, which could be generated by subduction of oceanic ridges, aseismic plateaus or ridges (De Long & Fox, 1977; Pilger, 1981; McGeary, Nur & Ben-Avraham, 1985; Thorkelson & Taylor, 1989). In southern South America, it has been proposed that the Aluk-Farallon oceanic ridge migrated across Patagonia, from north to south, during the Eocene (Cande & Leslie, 1986), representing the only known information about a probable ridge collision during the Palaeogene. However, the inferred Palaeocene arc magmatic gap would have occurred before the assumed ridge collision. Flat-slab subduction, however, could have started before the ridge–trench collision if the young crust adjacent to the ridge maintained its positive buoyancy for some time, by some mechanism delaying the basalt to amphibolite and eclogite transition (*c.* 10 Ma; see Cloos, 1993). We thus speculate that the Palaeocene inferred plutonic hiatus may relate to a period of low-angle subduction sometime between 65 and 50 Ma, that stopped magmatic activity during this time. Further detailed age dating is required to test this model.

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